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Persistent Organic Pollutants in the Environment

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EXECUTIVE SUMMARY

In accordance with the EMEP Work-plan for 2008, 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.

Monitoring of POP concentrations in 2006 was performed at 15 monitoring sites among which only 6 sites made parallel measurements of POPs in air and precipitation. Even though the spatial distribution of measurement sites has improved due to a new site in the Mediterranean region, there is still a need in additional sites in Southern and Eastern parts of Europe. A passive air sampling campaign for POPs was carried out across the Europe during the summer of 2006. The campaign was organised by the CCC in collaboration with the Lancaster University (the UK) and the Global Atmospheric Passive Sampling (GAPS) initiative.

The official data on POP emissions (PAHs, PCDD/Fs, HCB, PCBs and HCHs) for at least one year within the period from 1990 to 2006 were submitted by 36 European countries and Canada. It should be pointed out that in recent years the number of countries that have submitted official information on emissions is increasing. In particular, Georgia and Portugal have begun reporting their emission data on PAHs and PCDD/Fs, and Italy – on HCB. Furthermore, PAH and PCDD/F gridded emission data were reported this year by 24 countries compared with 23 in the previous year. According to official and unofficial data, emissions of considered POPs tend to decrease from 1990 to 2006. 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 20 - 27%, and emissions of PCDD/Fs have halved.

MSC-E continued the work on further development of POP models. This year the following modifications and improvements of MCSE-POP model were carried out:

- preparation of data on aerosol content in the atmosphere for the MSCE-POP model;
- refinement of model description of gas-particle partitioning;
- investigation of possible approaches to model description of wet deposition of POPs in gaseous form;
- further analysis of the parameterization of POP re-suspension with aerosol particles to the atmosphere;
- appropriate modifications of the MSCE-POP regional and hemispheric models due to the extension of the EMEP domain.

Model evaluation of environmental pollution levels was performed for the four indicator PAHs (B[a]P, B[b]F, B[k]F and I_P), PCDD/Fs (the mixture of all 17 toxic congeners), PCB-153, γ-HCH and HCB for 2006. Pollution levels and source-receptor relationships for PAHs were evaluated at the regional scale since these pollutants are mainly particle-bound. For the rest of selected POPs 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 modelling approach. In particular, the hemispheric MSCE-POP model was used to implement the nesting to the regional modelling. This approach allowed to take into account the contributions of non-EMEP emission sources and of re-emission of POPs from the environmental media within the Northern Hemisphere.

Annual mean B[a]P concentrations in surface atmospheric layer in 2006 within the European region varied from 0.01 to 1 ng/m^3. Average level of B[a]P air concentrations for the European countries was about 0.4 ng/m^3. Elevated B[a]P air concentrations (0.5 ng/m^3 and above) were obtained for the countries in Central and Eastern Europe. Moderate and low values of air concentrations (0.01 – 0.1 ng/m^3) can be noted for some countries of the Western and Northern Europe, as well as for Russia, and the Central Asian countries.

Levels of B[a]P deposition fluxes in 2006 within the European region differed from 1 g/km^2/y to about 150 g/km^2/y. High values of deposition fluxes (20 – 150 g/km^2/y) were characteristic of the Central, Southern, and Eastern Europe. Deposition fluxes in other regions, namely, Scandinavian Peninsula, France, Spain, Portugal, and the UK, were typically below 20 g/km^2/y.

Spatial distribution of pollution levels for the rest three indicator PAHs (B[b]F, B[k]F, and I_P) in 2006 was similar to that of B[a]P. The levels of B[k]F air concentrations were somewhat lower comparing to the air concentrations of the rest three indicator PAHs. Evaluation of transboundary fluxes for B[a]P between the European countries in 2006 was performed using the regional MSCE-POP model. The contribution of transboundary transport to B[a]P air concentrations and depositions in particular countries was essential and varied typically from 20 to 70%.

The comparison of calculated air concentrations and deposition fluxes of B[a]P for 2006 with data of EMEP monitoring sites showed reasonable agreement between model results and measurements. For the majority of sites calculated air concentrations agree with measurements within a factor of two. For three stations (SE12, FI96 and CZ3) differences between calculations and measurements do not exceed 25%. For wet deposition fluxes measured and calculated values agree within a factor of two for most of measurement sites.

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. Average level of PCDD/F annual mean air concentrations over the European countries in 2006 was about 1 fg TEQ/m^3. Elevated levels of PCDD/F air concentrations (more than three times exceeding EMEP average) were obtained for the Central, Southern, and Eastern Europe, namely, for Macedonia, Bulgaria, Hungary, Serbia and Montenegro, the Ukraine, the Czech Republic, Slovakia, Croatia, Albania, Poland, Romania and Greece. Low values of air concentrations (below 1 fg TEQ/m^3) were characteristic of the Western and Northern Europe.

Calculated PCDD/F deposition fluxes ranged from 0.1 – 1 ng TEQ/m^2/y in Western and Northern Europe to more than 3 ng TEQ/m^2/y in some regions of the Central, Southern and Eastern Europe. In comparison with modelling results for 2005 contamination levels in most of the European countries in 2006 did not change significantly.

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. The contribution of transboundary transport to the pollution of the EMEP countries in 2006 ranged from 3% to 60%. Non-EMEP sources contributed to the pollution levels up to 33%, and re-emission − from 30% to 70%. Thus it can be noted that the contribution of re-emission is essential and should be taken into account in the assessment of pollution levels in the European countries.

Model estimates of the hemispheric transport and pollution levels within the European region for 2006 were carried out for PCB-153, HCB, and γ-HCH. Using available emission data the distribution of pollution from the emission sources within the Northern Hemisphere was evaluated. Modelling results were compared with available measurements of EMEP monitoring sites for 2006.

The extension of EMEP modelling domain made it possible to obtain detailed information on pollution levels and transboundary transport for the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) and Asian part of the Russian Federation. This information includes the spatial distribution of depositions within the EMEP region originated from national emission sources, spatial distribution of depositions to the country including the contributions of transboundary transport, export and import diagrams characterizing the transboundary depositions for individual countries. This information in English and in Russian languages can be found on MSC-E web-site [http://www.msceast.org/].

The work on the assessment of POP pollution levels within the European region for 2006 was performed in close co-operation with the subsidiary bodies to the Convention (TFMM, TFHTAP), international organizations (EU, ECHA, HELCOM, OSPAR, Stockholm Convention, UNEP Chemicals), as well as with national experts.

CONTENTS

INTRODUCTION

This status report describes the progress in activities of EMEP Centres − Meteorological Synthesizing Centre-East (MSC-E) and Chemical Coordinating Centre (CCC) − in evaluation of contamination of the extended EMEP region by persistent organic pollutants (POPs). During 2008 investigations 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 2008 [*ECE/EB.AIR/GE.1/2007/10*] were performed for the following POPs: polycyclic aromatic hydrocarbons (PAHs), polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs), polychlorinated biphenyls (PCBs), lindane (γ-HCH), and hexachlorobenzene (HCB).

Measurements of POP concentrations in air, in precipitation and wet deposition fluxes are carried out at the EMEP monitoring network. The spatial coverage of the European region by the monitoring stations measuring POPs is still limited. The information on observed levels of concentrations and depositions of POPs in 2006 is available from 15 stations located, in northern, western, and central parts of Europe. In response to this, a passive air sampling campaign was carried out across Europe during the summer 2006. The campaign was organized by EMEP/CCC in close collaboration with the Lancaster University (the UK) and the Global Atmospheric Passive Sampling (GAPS) initiative (which carries out passive air sampling of POPs on a global scale in support of the Stockholm Convention on POPs). The key objectives of the campaign were to gain new insight into the spatial patterns of POPs in European background air, using a consistent sampling and analytical methodology across all stations, and also to evaluate limitations of the current EMEP measurement network with respect to spatial coverage. Additionally, there was an intention to evaluate the use of passive air samplers as a complementary and cost efficient tool regarding possible future monitoring strategies within EMEP. Results of this campaign may also help to support further evaluation of EMEP POP models in order to better understand and predict the source-receptor relationships on the European scale.

For model assessment of pollution levels and transboundary transport of POPs the MSCE-POP model was applied. The model was thoroughly reviewed at the workshop held in 2005 under supervision of the EMEP Task Force of Measurements and Modelling (TFMM). One of the main conclusions of the TFMM Workshop on the Review of the EMEP Models on Heavy Metals and Persistent Organic Pollutants was that “the MSCE-POP model represents the state-of-the-science and fits to the purpose of evaluating the contributions of long-range transport to the environment impacts caused by POPs” [*ECE/EB.AIR/GE.1/2006/4*]. Along with that, further improvement of the model was recommended.

In the current year the work on the implementation of the TFMM recommendations on further development of MSCE-POP models was continued. This work included investigation of different approaches to model description of gas-particle partitioning (adsorption, absorption and combined approach) and of wet deposition of POPs in gaseous form, and further evaluation of the contribution of re-suspension process to POP re-emissions. Along with that appropriate modifications of the regional and hemispheric MSCE-POP models were performed as a result of the extension of the EMEP modelling domain. The summary of the results of model development in these directions is presented in this report.

Input information on emissions of the above-mentioned POPs for modelling was prepared on the basis of officially submitted emission totals and gridded emissions and available unofficial data. The most recent emission data were used to prepare spatial distribution of emissions within the EMEP grid. For the evaluation of contribution of non-EMEP sources to the pollution of the EMEP domain and of re-emissions due to historical accumulation, available emission data for PCDD/Fs, PCBs, γ-HCH and HCB within the Northern Hemisphere were compiled.

To assess the contributions of non-EMEP emission sources and historical accumulation, model simulations for PCDD/Fs, PCBs, γ-HCH and HCB were carried out using developed nested hemispheric/regional modelling approach (see [*Gusev et al.*, 2007]). On the basis of this approach the evaluation of pollution levels and source-receptor relationships for the European and the Central Asia countries was fulfilled taking into account contributions of re-emissions and non-EMEP sources. Since the selected PAHs are mainly particle-bound, modelling for these pollutants for 2006 was performed by the regional MSCE-POP model only. The evaluation of source-receptor relationships for PAHs is exemplified by B[a]P. In order to verify the results obtained by the modified MSCE-POP model the comparison of computed concentrations with available measurement data of the EMEP monitoring network for 2006 was carried out.

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.

Detailed information on the work fulfilled during this year are presented in the Technical Reports of the EMEP Centres [*Aas and Breivik*, 2008; *Gusev et al*., 2008] as well as on the Internet www.emep.int and www.msceast.org.

Below the content of the report is briefly outlined.

Chapter 1 is devoted to the progress in the field of monitoring of POP concentration levels within the European region. The description of the EMEP monitoring network for POPs is presented and the analysis of POP concentrations measured at the EMEP monitoring sites in 2006 is performed. Passive air sampling campaign carried out across the European region during the summer of 2006 and its preliminary results are discussed.

In Chapter 2 an overview of officially submitted information on POP emissions by Parties to the Convention is given. The chapter describes the changes in POP emissions in the period 1990-2006. Sector distribution of POP emissions is summarized on the basis of available official emission data. The set of emission data used in modelling both on hemispheric scale and within the extended EMEP grid is presented.

Chapter 3 is devoted to the progress in further development of the EMEP multicompartment POP transport model (MSCE-POP) during 2008. In particular, the possibility of using of CMAQ model for preparation of data on aerosol content in the atmosphere was considered. Investigations of possible modelling approaches to the description of POP gas-particle partitioning and removal of POPs in gaseous phase with precipitation were continued and evaluation of the contribution of POP re-suspension with aerosol particles to total re-emission from underlying surface was carried out. The modifications of regional and hemispheric MSCE-POP models due to the extension of the EMEP modelling domain are briefly described.

Chapter 4 presents the results of evaluation of pollution levels and transboundary fluxes for 2006 within the extended EMEP domain for PAHs and PCDD/Fs. Evaluation of pollution levels for PCB-153, γ-HCH and HCB for 2006 was performed on hemispheric and regional scales using the nesting of hemispheric and regional MSCE-POP models. The spatial distribution of pollution levels was analyzed and verification of model results against measurements was carried out.

The co-operation with the EMEP Task Forces (TFMM, TF HTAP), international organizations and programmes (ECHA, HELCOM, OSPAR, UNEP) is highlighted in Chapter 5.

Chapter 6 contains a brief description of future activities related to POPs proposed by MSC-E for 2009.

The main results of the EMEP Centres activities in the field of the evaluation of pollution levels and transboundary transport of POPs are summarized in Conclusions.

The report is complemented by two Annexes. Annex A contains the requirements of the EMEP work plan for 2008 concerning the evaluation of pollution levels of POPs in European region. Annex B presents detailed matrices of transboundary fluxes for 2006 calculated using MSCE-POP model for PCDD/Fs and B[a]P.

Acknowledgements

The authors of the report are grateful to Prof. I Holoubek for providing measurement data on POPs performed at the monitoring site Košetice (CZ3) and co-operation 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 OSPAR. 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 2006, are shown in Fig. 1.1 and 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*, 2008]. In 2006 it was 6 sites measuring POPs in both compartments, and altogether it was 15 measurement sites, one more than in 2005. Even though the spatial distribution has improved due to a site now also in the Mediterranean area it is still need for more sites in south - southeast. Hopefully, the new EU directive on heavy metals and PAH will have a positive effect on the number of EMEP measurement stations as well.

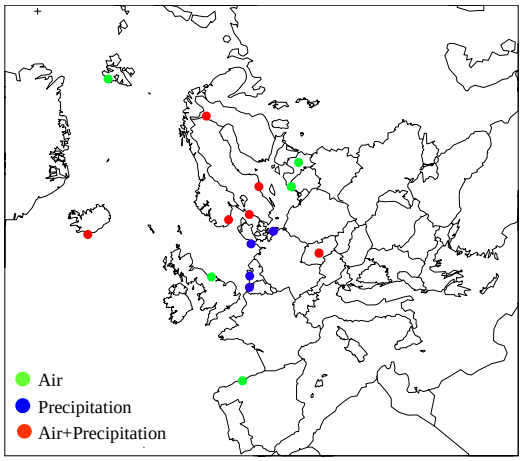


Fig. 1.1. *Measurement network of POPs in EMEP, 2006*

Table 1.1. *Measurements sites and programs for POPs in 2006*

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
ES08	PAHs	
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 2006

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 Tables 1.2 and 1.3 a summery of the results of the most common POP measurements in air. 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 5 times higher at LV10 compared to LV16. The differences are mainly seen during the winter period. Maybe this is due to influence from local sources or contamination problems. 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]. A new intercomparison is scheduled for 2009.

Table 1.2. *Annual average concentrations of selected POPs in 2006, (pg/m^3; ng/m^3 for benzo-a-pyrene (B[a]P and pyrene))*

Stations	HCHs		PAHs		PCBs			Pesticides	
	α-HCH	γ-HCH	B[a]P	Pyrene	PCB-180	PCB-28	ratio 28/180	pp_DDE	pp_DDT
CZ3R	21.2	29.9	0.235	1.340	1.71	6.26	4	20.7	2.6
ES8R			0.037	0.018					
FI96G	8.4	2.3	0.017	0.094	0.10	3.15	31	0.59	0.20
GB14R			0.035	0.410	0.16	5.98	37		
IS91R	3.9	2.8			0.12	3.30	27	0.13	0.10
LV10R			0.487						
LV16R			0.099						
NO1R	10.5	7.7			0.30	1.69	6		
NO42G	10.8	1.9	0.003	0.019	0.13	2.95	24	1.31	0.12
SE12R	3.5	2.3	0.075	0.405	0.15	1.01	7	1.89	
SE14R	6.8	5.7	0.069	0.360	0.66	2.34	4	2.73	1.13

The concentration in the Czech Republic for POPs in general is much higher than those observed in the Nordic countries. For PCB it is explained by the high historical usage 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. 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 γ-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 level in precipitation is 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 Island.

1.3. Passive air sampling of POPs

The EMEP network of monitoring stations measuring POPs in air and deposition is still limited in terms of spatial coverage. In response, a passive air sampling campaign was carried out across Europe during the summer of 2006. The campaign was organized by EMEP/CCC in close collaboration with the Lancaster University (the UK) and the GAPS initiative (which carries out passive air sampling of POPs on a global scale in support of the Stockholm Convention on POPs). The key objectives of the EMEP campaign have been to gain new insight into the spatial patterns of POPs in European background air, using a consistent sampling and analytical methodology across all stations, and also to evaluate limitations of the current EMEP measurement network with respect to spatial coverage. Additionally, we wanted to evaluate the use of passive air samplers as a complementary and cost efficient tool regarding possible future monitoring strategies within EMEP. Hopefully, the results may also help support further model evaluation at EMEP/MSC-E in order to better understand and predict the source-receptor relationships on a European scale. Here we present some initial preliminary results from this campaign. Further work is ongoing at CCC to interpret and discuss these data in more detail.

In order to increase the quantitative understanding of atmospheric sources, occurrence and transport of selected POPs across Europe, passive air samplers (PAS) using polyurethane foam disks (PUF) [*Shoeib and Harner*, 2002] were deployed for 3 months in various European countries during late summer of 2006. The study regions included 33 countries and 85 background sites, located from Spitsbergen (78°N) in the north to Cyprus (33°N) in the south and from Greenland (38° W) in the west to Kazakhstan (75°E) in the east. Of these 85 background sites, 72 were EMEP sites. Duplicate samples were furthermore deployed at 6 EMEP sites where POPs in air are measured on a regular basis. The PAS results from these sites will be compared with measured air concentrations, corresponding to the actual PAS deployment period.

Figure 1.2 and figure 1.3 show the measured distribution of pp-DDT and pp-DDE respectively, from the background sites in Europe. This insecticide was banned in most European countries several decades ago [*Pacyna et al.*, 2003].

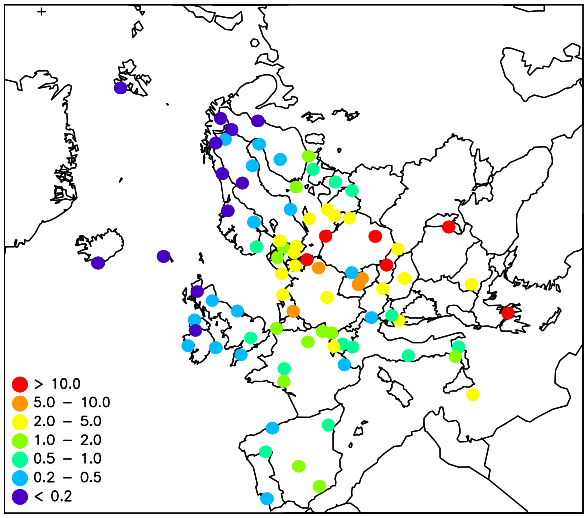


Fig. 1.2. *pp-DDT in air, ng/sample*

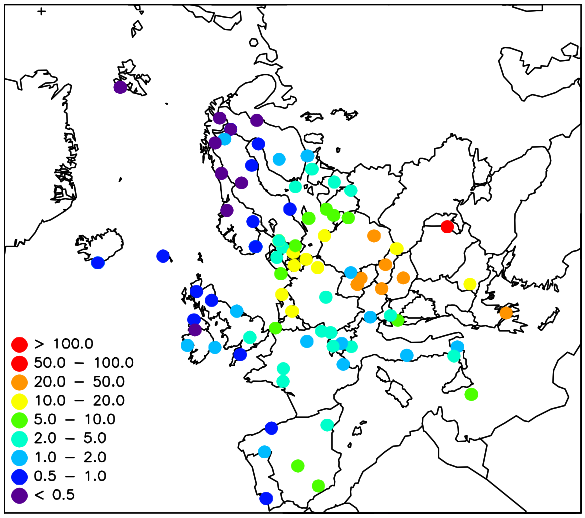


Fig. 1.3. *pp-DDE in air, ng/sample*

pp-DDE is an important breakdown product of pp-DDT [e.g. *Harner et al.*, 2004]. The amount of pp-DDE in the passive air samplers were typically higher than of pp-DDT and the spatial distribution of both isomers across Europe show a consistent pattern with low levels in the northwestern part.

In addition to DDT, this campaign also included polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), hexachlorobenzene (HCB), hexachlorocyclohexanes (HCHs), various other organochlorine pesticides, as well as polybrominated diphenyl ethers (PBDEs).

2. EMISSIONS

In this Chapter the information on POP emission data officially submitted by Parties to the LRTAP Convention by May 2008 is presented. Trends in emissions of PAHs, PCDD/Fs, HCB, PCBs and HCHs in the period 1990-2006 are characterized along with information on emission changes in individual countries. Detailed information on POP emissions, in particular, the distribution by source category, is presented. Emission changes caused by backward recalculations of emission data are analyzed. In order to include the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) and Asian part of the Russian Federation into routine calculations of POP transboundary transport gridded emissions data were prepared. The description of emission datasets, used for model simulations, is provided for the following pollutants: PAHs (4 indicator compounds − B[a]P, B[b]F, B[k]F and I_P), PCDD/Fs (the mixture of 17 toxic congeners), PCBs (indicator congener PCB-153), lindane (γ-HCH) and HCB. The spatial distribution of these POPs within the EMEP grid is presented together with the distribution of emissions within the Northern Hemisphere for PCB-153, γ-HCH, and HCB.

Detailed information on POP emissions in the period 1990-2006 can be found in Internet on the MSC-E web site [http://www.msceast.org/] and at the web site of EMEP Centre on Emission Inventories and Projections (CEIP) [http://www.emep-emissions.at/ceip/].

2.1. Polycyclic Aromatic Hydrocarbons (PAHs)

Officially submitted emissions. Official data on the emission totals of polycyclic aromatic hydrocarbons (PAHs) were submitted by 36 countries for 1990-2006 (for at least one year). In comparison with the previous year additional two countries – Georgia and Portugal – reported their emission data.

According to the CLRTAP Protocol on POPs four PAH indicator compounds should be used. These 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*]. Emission totals of each from four indicator PAHs for the considered period (for at least one year) were submitted by 20 countries, namely, Belarus, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Iceland, Ireland, Latvia, Lithuania, Poland, Republic of Moldova, Romania, Slovakia, Slovenia, Switzerland and the United Kingdom.

Official emissions of Cyprus for 2004 and 2005 were changed in comparison with previously reported data. The recalculation has led to 3.6 times increase of Cyprus emissions for 2004 and 5.6 times increase of emissions for 2005.

Information on PAH emission spatial distributions was provided by 24 countries (Austria, Belarus, Belgium, Bulgaria, Croatia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Monaco, the Netherlands, Norway, Poland, Slovakia, Spain, Sweden, the United Kingdom). Among them 16 countries (underlined) submitted gridded sector data. In comparison with the previous year one more country – Croatia – reported gridded emission data.

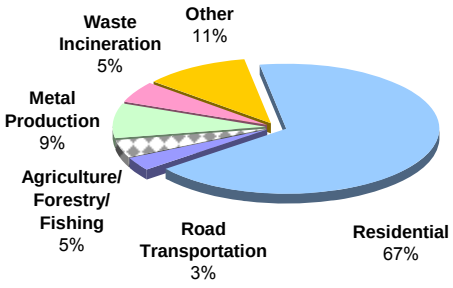


Fig. 2.1. *Sector split for PAHs emissions in 2006 (23 countries), %*

Official information on emissions of four indicator PAHs by sectors in 2006 is available for 23 countries. The sector split for PAH emissions for these countries is presented in Fig. 2.1. The Residential sector is the major contributor to the total annual emission accounting for on average 67%. The predominant source in the Residential sector is combustion of wood. The second most important sector is the Metal Production. This sector is a significant source of PAHs for Italy and Sweden.

Considerable contribution of the Residential sector to the total PAH emissions determines its pronounced seasonal variation. However, at present no official information on emission seasonal variations is available. In model calculations it is supposed that the level of B[a]P emissions in winter is 10% higher than in summer [*Baart et al.*, 1995]. However, measurements at some EMEP monitoring sites show much more pronounced variations of air concentrations and depositions within the year (see [*Gusev et al.*, 2007]). Thus, the refinement of information on emission seasonal variations from Parties to the Convention is highly appreciated.

Emission data used for modelling. For the evaluation of pollution levels within the EMEP region officially submitted PAH emissions were complemented by unofficial emission data. In particular, for European countries, which did not report their emissions, unofficial data of TNO emission inventory [*Denier van der Gon et al.*, 2005] were used. The PAH emissions in the Asian part of Russia were estimated using official emission data for the European part of the country and the ratio between the population [*Li*, 1996] of European and Asian parts of the country. The PAH emission values for Tajikistan, Turkmenistan and Uzbekistan for 2004 were taken from the global atmospheric emission inventory of PAHs prepared by *Zhang* [2008] and used for modelling of pollution levels in 2006. For Kazakhstan and Kyrgyzstan unofficial emission data from TNO inventory [*Denier van der Gon et al.*, 2005] were applied. The spatial distribution of PAH emissions in the Central Asian countries and the Asian part of Russia was determined on the basis of data on population density [*Li*, 1996] obtained from the web site of Canadian Global Emissions Interpretation Centre [http://www.ortech.ca/cgeic].

The spatial distribution of PAH emissions for 2006 is illustrated in Fig. 2.2 by the example of B[a]P. It can be seen that elevated levels of B[a]P emissions (20 – 200 g/km^2/y) are characteristic of the Central, Southern and Eastern parts of Europe. For the most parts of Northern and Western Europe, Russia, and the Central Asian countries emission fluxes do not exceed 20 g/km^2/y.

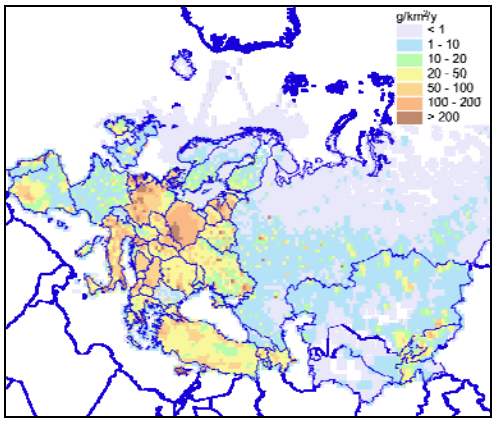


Fig. 2.2. *Spatial distribution of B[a]P emissions in 2006 over extended EMEP grid with resolution 50x50 km^2, g/km^2/y*

Emission trends. According to the official and unofficial information, emissions of four indicator PAHs within the EMEP domain decreased by 20% - 27% in period from 1990 to 2006. Temporal variations of total emissions of four indicator PAHs within the EMEP region are displayed in Fig. 2.3.

Among the countries submitted official data on PAH emissions for 2006, maximum emission reduction within the considered period took place in the UK (95%) and Republic of Moldova (68%). At the same time in Denmark, Italy, Latvia, Poland, Portugal, and Sweden PAH emissions were increased in comparison with the level of emission in 1990.

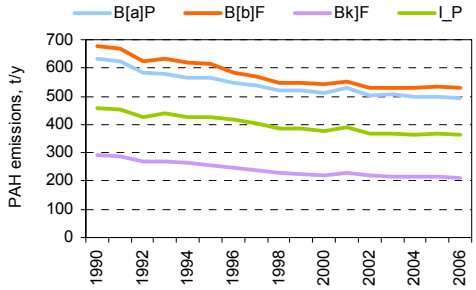


Fig. 2.3. *Temporal variations of B[a]P emissions within the EMEP grid in 1990-2006, t/y*

The total emissions of B[a]P within the extended EMEP grid in 2006 used for model calculation amounted to 494 tonnes. Considering the B[a]P annual emissions of individual countries it can be noted that maximum contributions to total emission within the EMEP region were made by the Ukraine (20%), Poland (10%) and Turkey (8%).

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

Officially submitted emissions. Data on total emissions of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) (sum of toxicities of 17 toxic PCDD/F congeners) were officially reported by 35 European countries and Canada for the period from 1990 to 2006 (for at least one year). In comparison with the previous reporting year additional two countries – Georgia and Portugal – reported their emission data.

19 Parties recalculated their official emissions for at least one year within the period from 1990 to 2005. Maximum recalculation took place for the emission of Romania for 2005. For this country emission reported for 2005 in current reporting year (297 g I-TEQ) is almost three times higher than emission reported in the previous year (99 g I-TEQ).

Information on the spatial distribution of PCDD/F emissions was reported by 24 countries (Austria, Belarus, Belgium, Bulgaria, Croatia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Monaco, Netherlands, Norway, Poland, Slovakia, Spain, Sweden, and the United Kingdom). Among them 17 countries (underlined) submitted gridded sector data. In comparison with the previous year additional country – Croatia – reported gridded emission data.

Official information on PCDD/F emissions by sectors for 2006 is available for 28 countries. The sector split for PCDD/F emissions for these countries is presented in Fig. 2.4. It can be seen that maximum contribution to the total PCDD/F emission is made by the Residential sector (26%). This sector is the largest source of PCDD/Fs for Austria, Belgium, Croatia, Denmark, Estonia, Lithuania, Portugal, Poland, Romania and Slovenia. The second

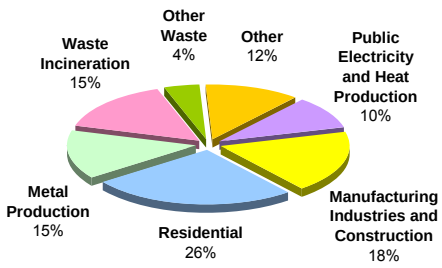


Fig. 2.4. *Sector split for PCDD/F emissions in 2006 (among 28 countries), %*

most important sector is the Manufacturing Industries and Construction (18%). This sector is the dominating source of PCDD/Fs for the Czech Republic, Italy, Latvia, Slovakia and Spain. The next essential sectors are the Metal Production (15%) and the Waste Incineration (15%). Thus these for sectors are responsible for almost 75% of total emission of 28 countries.

Emission data used for modelling. Model evaluation of PCDD/F pollution levels within the EMEP region was carried out on the basis of officially submitted emissions complemented by unofficial emission data. In absence of officially reported information unofficial data of emission inventories [*Denier van der Gon et al*., 2005; *Pulles et al.,* 2006] were applied.

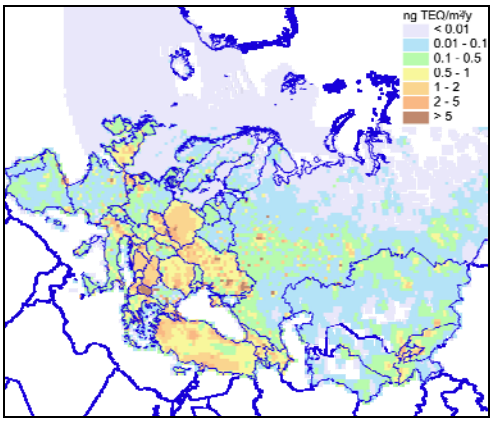


Fig. 2.5. *Spatial distribution of PCDD/F emissions in 2006 over extended EMEP grid with resolution 50x50 km^2, ng TEQ/m^2/y*

The PCDD/F emission for the Asian part of Russia was estimated using official emission data for the European part of the country and data on population density similar to PAHs. The PCDD/F emission values in Tajikistan, Turkmenistan and Uzbekistan for 2006 were taken from the unofficial inventory of PCDD/F emissions in the Central Asian countries made in the framework of the global International POPs Elimination Project (IPEP) [*Hodjamberdiev,* 2006]. The latest available information on PCDD/F emission in the USA was taken from the dioxin and furan inventories prepared by [*UNEP*, 1999] for 1995. The spatial distribution of PCDD/F emissions in the Central Asian countries and the Asian part of Russia was determined on the basis of data on population density [*Li*, 1996] obtained from the web site of the Canadian Global Emissions Interpretation Centre [http://www.ortech.ca/cgeic].

The spatial distribution of PCDD/F emissions in the EMEP domain for 2006 is shown in Fig. 2.5. It can be noticed that significant levels of PCDD/F emissions (1-5 ng TEQ/m^2/y) are characteristic of Central, Southern and Eastern parts of Europe. For the most parts of Northern and Western Europe emission fluxes do not exceed 0.5 ng TEQ/m^2/y.

Emission trends. According to the official and unofficial emission data, total emission of PCDD/Fs within the extended EMEP domain decreased by 48% in the period 1990- 2006. PCDD/F emission within the Northern Hemisphere, including Europe, the USA and Canada, decreased by 41% during the same period (Fig. 2.6). The total emissions of PCDD/Fs in 2006 used for model calculation within the Northern Hemisphere amounted to 9.9 kg TEQ, including 7.1 kg TEQ/y within the EMEP grid and 2.8 kg TEQ/y in North America. The maximum decrease of PCDD/F emissions was reported by the Netherlands (almost 20 times), and the maximum increase - by Latvia (about 2 times). Considering the PCDD/F annual emissions of individual countries for 2006 it can be noted that maximum contributions to total annual emission within the EMEP region were made by Turkey (15%), the Ukraine (15%), the Russian Federation (11%), and Poland (6%).

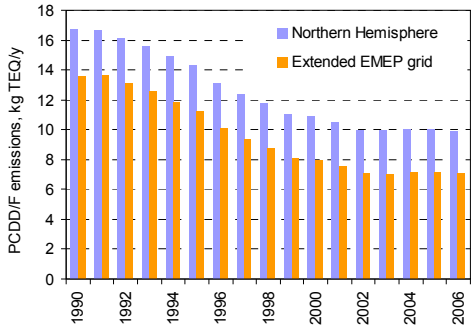


Fig. 2.6. *Temporal trends of PCDD/F emissions in the EMEP domain and the Northern Hemisphere in 1990-2006, kg TEQ/y*

2.3. Hexachlorobenzene (HCB)

Officially submitted emissions. Official data on the emission totals of HCB were submitted by 25 European countries and Canada for the period from 1990 to 2006 (for at least one year). In comparison with number of countries in previous reporting year, one more country – Italy – reported its emission data.

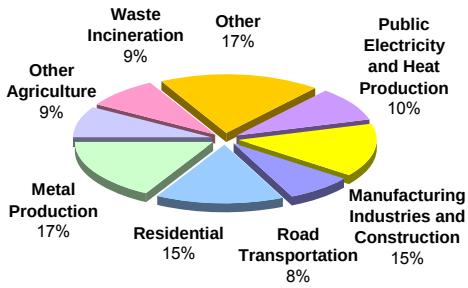


Fig. 2.7*. Sector split for HCB emissions in 2006 (among 22 countries), %*

10 Parties (Austria, Belgium, Cyprus, Finland, France, Germany, Latvia, Romania, Slovenia and the UK) recalculated their official emissions for at least one year within the period from 1990 to 2005. In particular, official HCB emissions of Belgium for 2005 were increased from 36 to 47 kg/y, and British HCB emissions were decreased from 851 to 838 kg/y for the same year.

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.

Official information on emissions of HCB by sectors in 2006 is available for 22 countries (Fig. 2.7). The maximum contribution to the total HCB emissions is made by the Metal Production sector (17%). The next most important sectors are the Residential and the Manufacturing Industries and Construction. These sectors are the dominating source of HCB for Austria, Estonia, Germany, Latvia, Hungary, Poland, Romania, and Slovakia.

Emission data used for modelling. For modelling purposes officially submitted data were complemented by unofficial emission estimates of [*Pacyna et al.*, 1999] in cases when there were no officially reported emissions. The HCB emission values for Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan were estimated on the basis of the gross domestic product of these countries. Relationship between the gross domestic product and unofficial HCB emissions for these countries was obtained on the basis of the data for Azerbaijan taken from [*Pacyna et al.*, 1999].

To compile the distribution of HCB emission within the Northern Hemisphere unofficial information of *Bailey* [2001] was used. The HCB emission for Japan for 2002 was taken from the emission inventory of *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 2006 taken for countries with similar economic indexes. The HCB emission value in India was taken from the previous studies of HCB pollution levels presented in EMEP Technical Report 7/2005 [*Shatalov et al.*, 2005].

The distribution of HCB emissions over the EMEP grid was prepared on the basis of officially submitted gridded emission data of 12 European countries. For other European countries, the spatial distribution of HCB emissions from TNO inventory [*Denier van der Gon et al*., 2005] was used. For the evaluation of the HCB emission spatial distribution in the Asian part of Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan within the EMEP grid as well as in the Northern Hemisphere the data on the population density for 1990 [*Li*, 1996] were implemented.

The spatial distributions of HCB emissions for 2006 within the EMEP domain and the Northern Hemisphere are shown in Figs. 2.8 and 2.9, respectively. It can be seen that there is a significant difference between the national emission levels of individual countries. In particular, the highest HCB

emission fluxes can be noted for Spain (over 9 g/km^2/y). Moderate values of emission fluxes (3-9 g/km^2/y) are characteristic of the Russian Federation, the Ukraine, and the UK. Levels of emissions in other European countries are considerably lower.

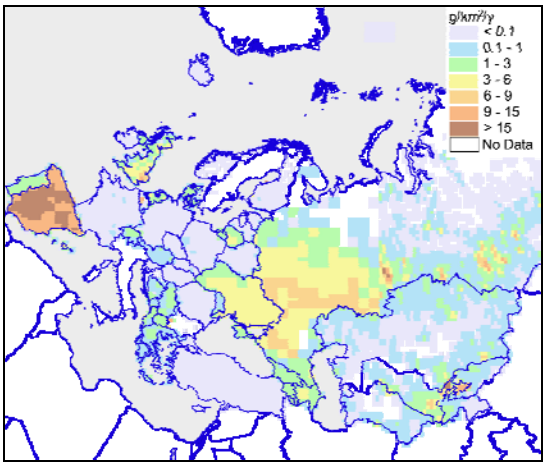


Fig. 2.8. *Spatial distribution of HCB emissions over the extended EMEP grid in 2006 with resolution 50x50 km^2, g/km^2/y*

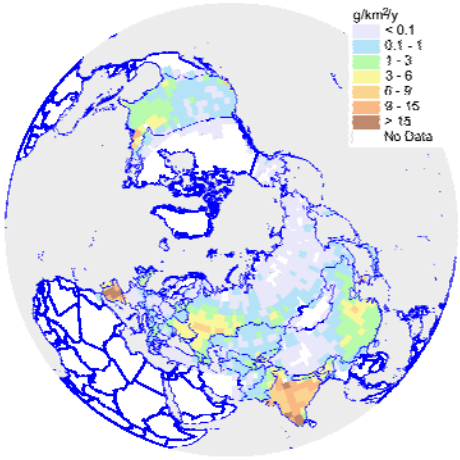


Fig. 2.9. *Spatial distribution of HCB emissions within the Northern Hemisphere in 2006 with resolution 2.5°x2.5°, g/km^2/y*

Emission trends. The total emissions of HCB in the Northern Hemisphere amounted to 90 tonnes in 2006, including 27 tonnes within the EMEP region and 63 tonnes in other regions. On the basis of official and unofficial emission data, the total HCB emission within the EMEP domain decreased by 13% between 1990 and 2006 (Fig. 2.10). Lack on information on temporal variations of HCB emission within the Northern Hemisphere complicates the analysis of HCB emission changes at hemispheric scale.

Among the countries submitted data for both years 1990 and 2006 the most significant emission decrease was reported by Slovenia (from 47 to 0.3 kg) and France (from 1199 to 13 kg). HCB emission of Republic of Moldova was increased almost 8 times. Maximum contributions to the total annual HCB emission within the EMEP grid in 2006 were made by the Russian Federation (47%), Spain (28%), and the Ukraine (8%).

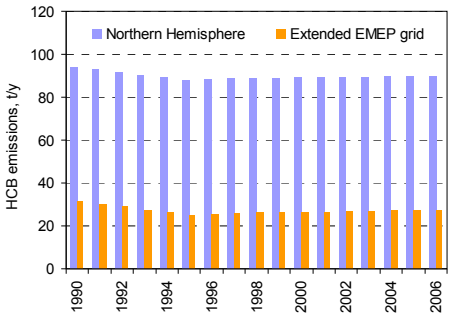


Fig. 2.10. *Temporal trends of HCB emissions in the EMEP domain and the Northern Hemisphere in 1990-2006, t/y*

2.4. Polychlorinated biphenyls (PCBs)

Officially submitted emissions. Information on total emissions of polychlorinated biphenyls (PCBs) was officially submitted by 23 countries for the period from 1990 to 2006 (for at least one year). During this reporting year additional three countries, namely, Cyprus, Italy, and Portugal, reported emission data on PCBs.

Data on spatial distribution of PCB emissions were submitted by Belarus, Bulgaria, Finland, France, Germany, Latvia, Lithuania, Monaco and Poland. Among them 7 countries (underlined) reported gridded sector data.

Official information on PCB emissions by sectors for 2006 is available for 20 countries (Fig. 2.11). The maximum contributions to the total PCB emissions among the aggregated sectors are made by the Industrial Processes sector (46%) and Waste sector (26%). The Industrial Processes sector provides the largest contribution to the total PCB emission for Belarus, the Czech Republic, Germany, Italy, Poland, Romania, and the UK. The Waste sector is the most important for Cyprus, Finland, and Portugal.

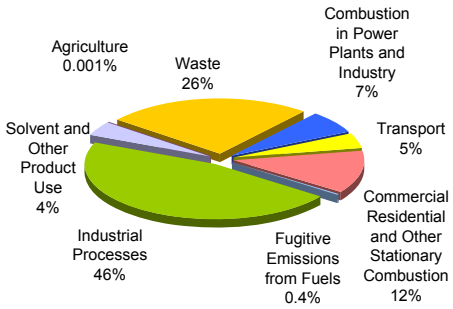


Fig. 2.11. *Sector split for official submitted PCB emissions for 2006 (among 20 countries), %*

Emission data used for modelling. Since the official information on PCB emissions within the European region is currently available for a limited number of countries and it does not provide the information on PCB congener composition, the evaluation of PCB long-range transport is currently based on unofficial global inventory of PCB usage and emission [*Breivik et al*., 2007]. The inventory provides consistent set of historical emissions of PCBs to the atmosphere obtained on the basis of available data on production and consumption of PCB mixtures and projection of future levels of emissions up to 2100. Along with temporal variations of PCB emissions of individual countries the spatial distribution of annual emissions of 22 individual PCB congeners on global scale with resolution 1°x1° was prepared. Three different scenarios of global PCB emissions, namely, minimum scenario, default scenario, and maximum scenario, describe the range of emission variations estimated to an order of magnitude [*Breivik et al*., 2002 a,b].

Preliminary computations with the hemispheric MSCE-POP model using these three emission scenarios allowed to evaluate what emission data could be used as input information for modelling to get reasonable description of pollution levels within the EMEP region. Using the results of these computations, the emission values between the maximum and default emission scenario were selected for the investigation of PCB long-range transport and depositions. The indicator congener PCB-153 was selected for the evaluation of pollution levels for 2006 on regional and hemispheric scales. On the basis of this information the spatial distribution of PCB-153 emission for the European region with resolution 50x50 km^2 (Fig. 2.12) and within the Northern Hemisphere with resolution 2.5°x2.5° (Fig. 2.13) was prepared for MSCE-POP model simulations. It can be seen that the most significant levels of PCB-153 emission fluxes are the characteristic of the European region. Other regions are characterised by comparatively lower annual emissions. Since there was no information on seasonal variation of PCB emissions to the atmosphere it was assumed that it was uniformly distributed over a year.

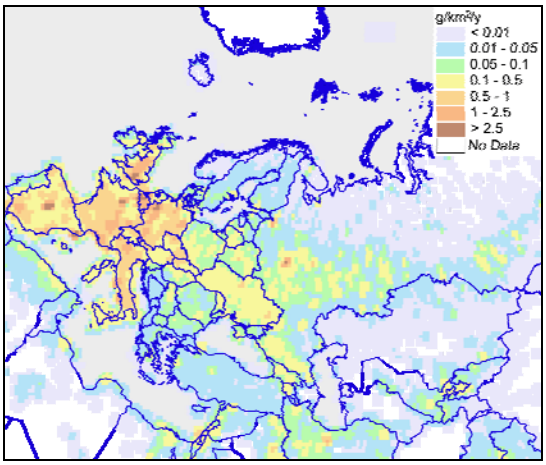


***Fig. 2.12**. Spatial distribution of PCB-153 emissions over the extended EMEP grid in 2006 with resolution 50x50 km^2, g/km^2/y*

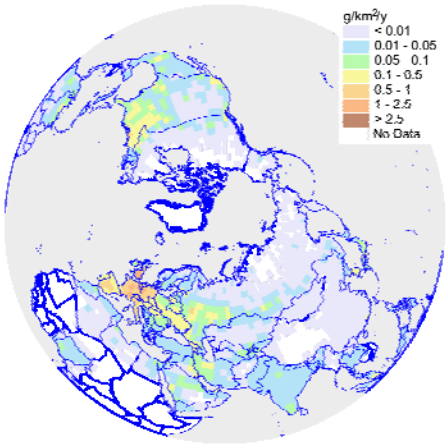


***Fig. 2.13**. Spatial distribution of PCB-153 emissions within the Northern Hemisphere in 2006 with resolution 2.5°x2.5°, g/km^2/y*

Emission trends. Following the official data, the total PCB emissions in 17 countries submitted data for both years 1990 and 2006 have decreased by about 50%. The most significant decrease of emission was reported by the Czech Republic (89%), Slovenia (88%), and the UK (85%). For some countries the increase of PCB emission from 1990 to 2006 can be noted, in particular, for Portugal from 63 to 1064 kg/y, Bulgaria (9%), and Cyprus (5%). According to unofficial estimates of PCB-153 annual emissions used for modelling within the EMEP domain decreased in period 1990-2006 by 75%.

2.5. Hexachlorocyclohexanes (HCHs)

Official submitted emissions. Official information on HCH emission was reported by 11 European countries for the period 1990-2006 (for at least one year). At the same time data on HCH emissions for 2006 were officially submitted by the UK, Spain, Belgium, and Romania only. Most of other European countries reported no application or emission of HCHs.

The information on spatial distribution of HCH emissions and gridded sector data were submitted by Belgium, Germany and Spain for at least one year from the period 1990-2006.

Official data on HCH emissions by sectors is available for Belgium, Croatia, Germany, Romania, Spain and the United Kingdom for the period from 1990 to 2006 (for at least one year). In Belgium and the United Kingdom the maximum contribution to the total HCH emissions is made by the Solvent and Other Product Use (Other sector). In Croatia, Germany, Romania and Spain HCH emissions from the Agriculture (Other sector) contributed most to the total HCH emissions.

Emission data used for modelling. Model evaluation of pollution levels of lindane (γ-HCH) within the EMEP region was based on the official emission data and unofficial information on emission. Data on emissions or usage of γ-HCH for hemispheric modelling for the period 1990-2006 were compiled from several sources and covered only part of the Northern Hemisphere being thus subject of significant uncertainties. Three groups of emission sources were considered, namely, European, North

American, and Chinese emission sources. For European region official information on emissions was complemented by unofficial estimates on γ-HCH usage in period 1990-1996 [*Pacyna et al.*, 1999] and expert estimates of γ-HCH emission for 2000 [*Denier van der Gon et al.*, 2005]. The γ-HCH emission values in North America and China were estimated on the basis of information from [*Shatalov et al.*, 2003 [*Li et al.*, 1996; *Macdonald et al.*, 2000], [*Gusev et al.*, 2005 [*Li et al.*, 2001]], and [*Li,* 2004].

The spatial distribution of γ-HCH emissions within the European region was obtained from the officially submitted data (Belgium, Germany, and Spain) and from expert estimates [*Pacyna et al.*, 1999; *Denier van der Gon et al.*, 2005]. The gridded γ-HCH emissions for North America was prepared by *Li* [2004]. For the evaluation of the γ-HCH emission spatial distribution in China over the 2.5°x2.5° calculation grid, data on using cropland area available in the Canadian Global Emissions Interpretation Centre [http://www.ortech.ca/cgeic] were used.

The spatial distribution of γ-HCH emissions within the Northern Hemisphere and over the EMEP grid for 2006 used for model simulations is presented in Fig. 2.14 and Fig. 2.15, respectively. Taking into account that the usage of lindane (γ-HCH) is severely restricted in Europe and that most of countries reported no application of lindane, no emission of γ-HCH in 2006 was assumed for these countries in model simulations.

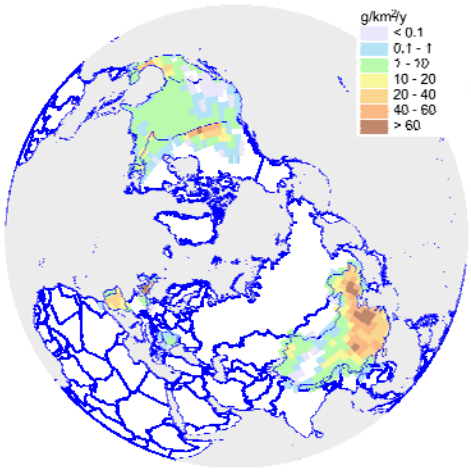


***Fig. 2.14**. Spatial distribution of γ-HCH emissions within the Northern Hemisphere in 2006 with resolution 2.5°x2.5°, g/km²/y*

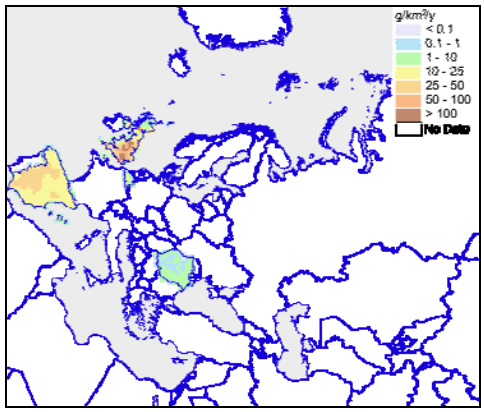


***Fig. 2.15**. Spatial distribution of γ-HCH emissions over the extended EMEP grid in 2006 with resolution 50x50 km², g/km²/y*

Emission trends. According to the official and unofficial emission data, the total emissions of γ-HCH in the European region decreased in period 1990-2006 by 98%. Temporal variations of γ-HCH emission in individual countries in period 1990-2006 can be characterized on the example of official emissions of the UK, Spain, and Germany. Thus, γ-HCH emission in the UK during this period decreased by 87%. At the same time in Spain it increased by 26%. In Germany annual emissions of γ-HCH have been ceased in 1990-1998 (from 60 tonnes in 1990 down to 14.5 tonnes in 1997).

3. MODEL DEVELOPMENT

This chapter is devoted to the description of the progress in further development of the EMEP multicompartment POP transport model (MSCE-POP). The work in this field included investigation of possible approaches to the description of POP gas-particle partitioning and removal of POPs in gaseous phase from the atmosphere with precipitation. Additionally the evaluation of the contribution of POP re-suspension with aerosol particles to the total re-emission from underlying surface was performed. The possibility to the use of the CMAQ model for preparation of the data on aerosol content in the atmosphere was considered. Several model experiments were carried out on the example of the year 2005 to study the effect of modifications of currently used and updated parameterizations. Modelling results on the selected POPs were compared with available measurements of the EMEP monitoring network. Additionally, appropriate modifications of the hemispheric and regional MSCE-POP models were made due to extension of EMEP modelling domain.

3.1. Extension of the model domain

Following the recommendation of the Steering Body to EMEP [*ECE/EB.AIR/GE.1/2007/2*] to provide EECCA countries with estimates of transboundary transport the extension of EMEP modelling domain was carried out (Fig. 3.1). Comparing to the previous EMEP domain the new modelling area covers the whole territories of the Central Asian countries and the Asian part of the Russian Federation.

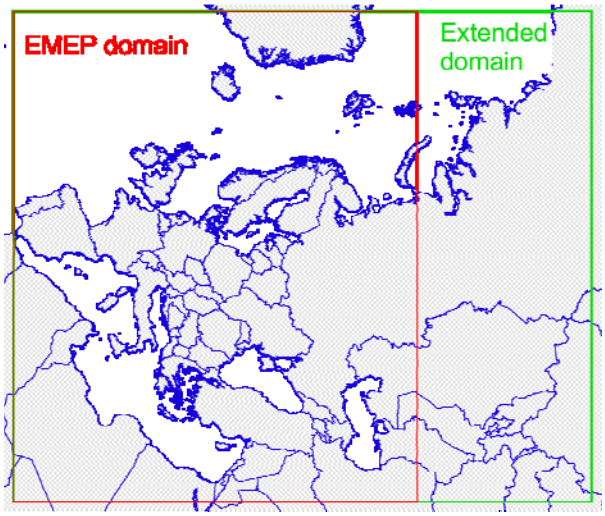


Fig. 3.1. *Extension of the EMEP modelling domain*

The changes of the model grid led to the necessity of modifications of the MSCE-POP model and preparation of the input data for the extended area. In particular, gridded information on emissions, meteorological input, land-cover, reactants content in the atmosphere, sea currents and soil properties was prepared. Updating of geophysical data for MSCE-POP model is described in the MSC-E Technical Report [*Gusev et al.*, 2008]. Information on POP emissions within the extended EMEP domain is presented in the Chapter 2.

Along with the modification of the MSCE-POP input data the description of environmental compartments within the extended modelling domain and modification of the model code had to be performed. In particular, the adaptation of the soil, vegetation, and seawater modules describing POP distribution, degradation, and exchange with atmosphere to the new EMEP grid was started.

Preliminary versions of these modules were prepared and used in model simulations for 2006. Further work is required to fully adapt these modules to the extended modelling area and to make them compatible with the hemispheric MSCE-POP model. Appropriate changes were also carried out for the hemispheric MSCE-POP model in order to support the preparation of initial and boundary concentrations for model simulations over the EMEP modelling area.

3.2. Data on aerosol content in the atmosphere for MSCE-POP models

Modelling of transboundary atmospheric transport of POPs requires the input data on concentrations of some other compounds in the atmosphere. In particular, to describe POP gas-particle partitioning, data on concentrations of particle-bound organic carbon or on specific aerosol surface are used in the MSCE-POP model. Degradation rates of POPs in the atmosphere depend on OH-radical concentrations. To perform experimental calculations of spatial and temporal distributions of PM and OH-radical air concentrations the Community Multiscale Air Quality modelling system (CMAQ) model [*Byun and Ching*, 1999] was used. Three dimensional 6-hour resolution data sets covering the extended EMEP domain were prepared for 2006. Below a short description of this work and the results obtained is given.

Spatial distributions of PM10 and PM2.5 mean annual concentrations in the surface air layer are shown in Fig. 3.2. Maximum levels of particulate matter concentrations in air take place over Sahara, Kara Kum and Gobi Deserts. Annual averages of PM10 concentrations in Europe normally do not exceed 20-25 μg/m^3 with the exception of some areas in Spain and Italy. A PM10 field differs from that of PM2.5 qualitatively by high concentration of sea salt appearing in the atmosphere mainly in the form of coarse particles (PM10 - PM2.5).

PM10 **PM2.5**

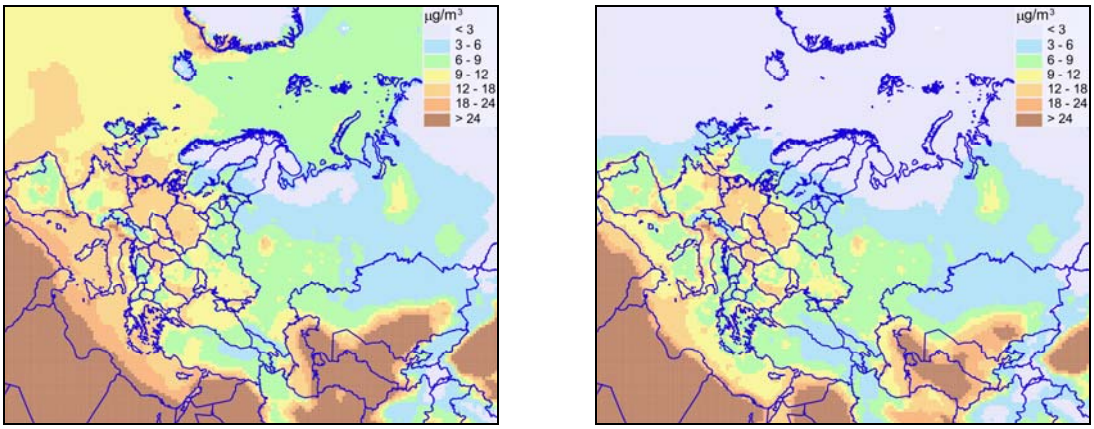


Fig. 3.2. *Spatial distributions of aerosol particles in the surface air layer for 2006 (annual averages), μg/m^3*

The comparison of calculated annual averages of PM concentrations in air with the data of measurements at EMEP sites available in the AIRBASE database [http://dataservice.eea.europa.eu] is shown in Fig. 3.3. The model underestimates PM10 concentrations by 30% on the average. One of the possible reasons for underestimation may be associated with the underestimation of dust emission in Europe. The average level of PM2.5 concentrations reproduced by the model is fairly reasonable. However, for some regions variations in mean annual concentrations are essential and due to this spatial correlation is not high (R_{corr} = 0.43).

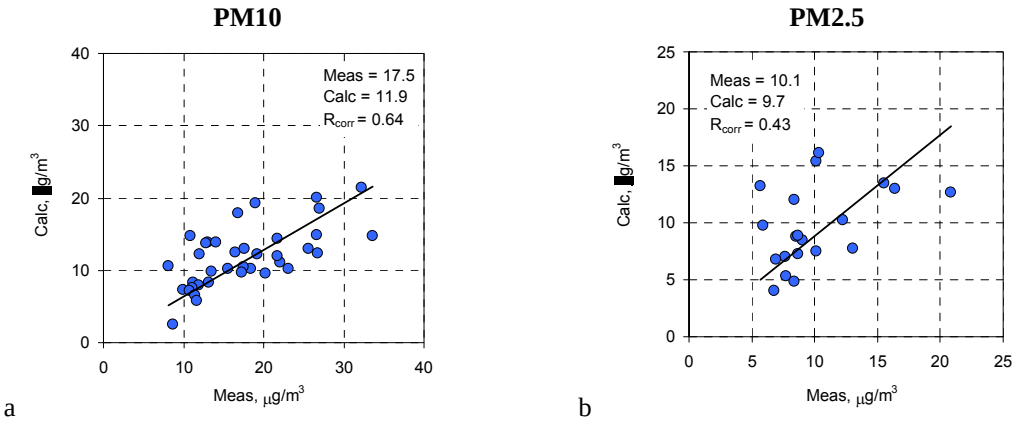


Fig. 3.3. *Comparison of calculated annual averages of PM concentrations in the air with data of measurements (EMEP sites) available in AIRBASE: a – PM10; b – PM2.5*

Calculated spatial distributions of aerosol organic matter and specific aerosol surface are shown in Fig. 3.4 and Fig. 3.5, respectively. It should be mentioned that spatial distribution of aerosol surface is similar to that of PM (Fig.3.2), but slightly differs due to the difference in fine particle size distributions in various parts of the domain.

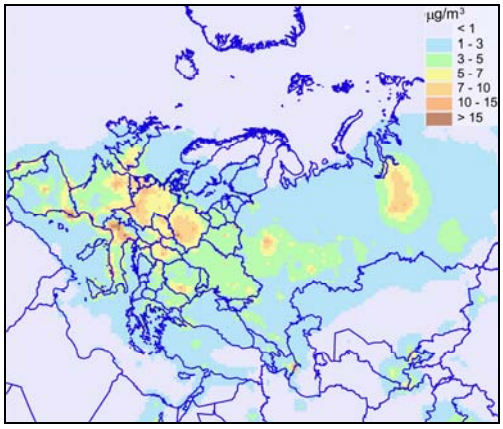


Fig. 3.4. *Spatial distribution of organic aerosol concentrations in surface air layer (annual averages), μg/m³*

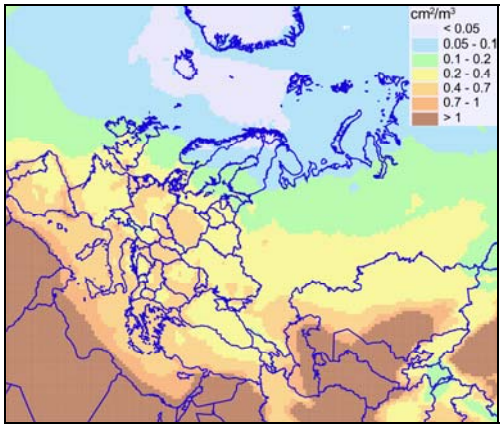


Fig. 3.5. *Spatial distribution of specific aerosol surface (annual averages, cm²/m³*

It should be mentioned that the values of specific aerosol surface in CMAQ model are calculated under assumption of spherical form of aerosol particles. Hence, the CMAQ may underestimate specific aerosol surface. For the obtaining more realistic estimates the use of correction factors is required.

Spatial distribution of annual averages of OH-radical concentrations in the atmosphere for 2006 calculated by CMAQ is displayed in Fig. 3.6. It can be seen that concentrations of OH-radical in the air strongly depend on geographical latitude. In general results of modelling are in line with the common view on OH-radical behaviour in the atmosphere. They are in reasonably good agreement with the available results of global calculations [*Bahm and Khalil,* 2004].

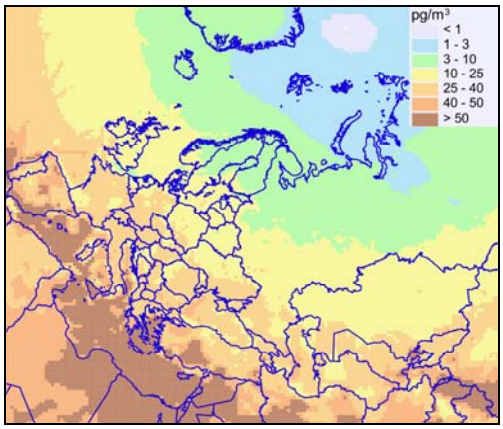


Fig. 3.6. *Spatial distribution of OH-radical concentrations in the surface air layer (averages for 2006), pg/m^3*

3.3. Modification of gas-particle partitioning scheme

The process of gas-particle partitioning is one of the most important processes influencing long-range transport of POPs both on regional and global scales. The reason for this is, first, that the gaseous phase of a POP is mostly subject to degradation in the atmosphere. So, the larger the relative fraction of a pollutant in the gaseous phase is, the faster the degradation process goes and, as a consequence, the pollutant is transported through less distance. Second, deposition velocities of gaseous and particle-bound POPs are quite different, so that the process of gas-particle partitioning strongly influences POP deposition process. Thus, the considered process plays a very important role in modelling of long-range transport of POPs.

This year the investigation of possible schemes of gas-particle partitioning for modelling purposes was performed. Here a short description of the obtained results is presented. The detailed analysis can be found in MSC-E Technical Report [*Gusev et al.*, 2008].

Two mechanisms of POP sorption on the atmospheric aerosol are most frequently used in modelling. They are adsorption at the surface of different aerosol particles (mineral dust, soot, etc.) and absorption by the aerosol organic matter. At the first stage of the analysis relative importance of these two mechanisms is investigated. As the parameter for such an analysis, the dimensionless distribution coefficient K_p^* between particulate and gaseous air concentrations is chosen:

$$K_p^* = C_p / C_g \,, \qquad (3.1)$$

where C_p is the concentration of particle-bound POP in the atmosphere (mol/m^3 air), and C_g is the concentration of the POP in the gaseous form (mol/m^3 air).

The values of coefficient (3.1) are compared for the two sorption mechanisms for three groups of pollutants: polyaromatic hydrocarbons (four indicator compounds – B[a]P, B[b]F, B[k]F and I_P), PCBs (8 congeners – PCB-28, PCB-52, PCB-101, PCB-105, PCB-118, PCB-138, PCB-153, PCB-180), and PCDD/Fs (4 congeners – 2,3,4,7,8-PeCDF, 1,2,3,6,7,8-HxCDD, 1,2,3,7,8,9-HxCDD, and 1,2,3,4,6,7,8-HpCDF). The choice of the above four PCDD/F congeners is conditioned by the fact that the mixture of these congeners can represent the transport of the mixture of all 17 toxic PCDD/F congeners with accuracy of 20% (see [*Dutchak et al.,* 2004]). The comparison was performed under the assumption that the ambient temperature is 10º C. This is reasonable since, though the values of K_p^* strongly depend on temperature, the relation between K_p^* values for two considered mechanisms is almost one and the same for different values of temperature (see [*Gusev et al.*, 2008]).

To obtain a comprehensive picture of the relation between the two considered mechanisms of gas-particle partitioning, the comparison of K_p* values was done for urban, suburban, background and remote regions. Calculations were performed with physical-chemical properties of the above pollutants and the values of environmental parameters taken from [*Lohman and Lammel*, 2004] (Table 3.1).

The comparison of relative importance of ad- and absorption mechanisms for each region type is presented by plots drawn in the plane (Log P_{oL}, Log K_{oa}) where the vapour pressure (P_{oL}) and octanol-air partition coefficient (K_{oa}) are the two pollutant-specific parameters determining the gas-particle partitioning for these mechanisms. Each plot contains the thin solid black line at which $K_{p,ad}^{*} = K_{p,ab}^{*}$, two dotted green lines, at which $K_{p,ad}^{*}$ and $K_{p,ab}^{*}$ differ by one order of magnitude and two solid thick green lines, at which $K_{p,ad}^{*}$ and $K_{p,ab}^{*}$ differ by two orders of magnitude. The points at these plots correspond to the values of P_{oL} and K_{oa} for each particular POP under consideration. The examples of such plots for background and remote regions are shown in Fig. 3.7.

Table 3.1. *Typical values of aerosol parameters needed for the description of gas-particle partitioning in various European regions according to [Lohman and Lammel, 2004]*

	urban	suburban	background	remote
θ [a], m^2/m^3	$1.1 \cdot 10^{-3}$	$3.5 \cdot 10^{-4}$	$1 \cdot 10^{-4}$	$1 \cdot 10^{-5}$
TSP [a], $\mu g/m^3$	55	22	14	7.7
f_{OM} [a]	0.4	0.25	0.19	0.13
C_{OC} [b], $\mu g/m^3$	22	5.5	2.7	1

[a] Taken from [*Lohman and Lammel*, 2004]
[b] Calculated on the basis of TSP and f_{OM}

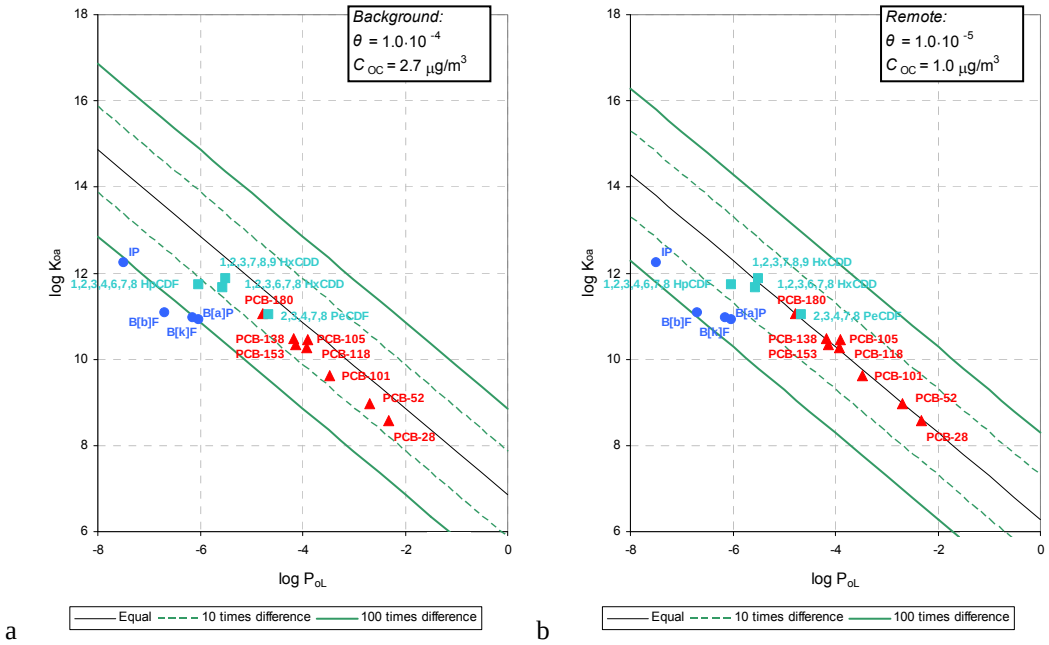


***Fig.* 3.7.** *Comparison of partitioning coefficients $K_{p,ad}^{*}$ and $K_{p,ab}^{*}$ for background (a) and remote (b) regions. Thin solid line represents the value of the parameters for which $K_{p,ad}^{*} = K_{p,ab}^{*}$, dotted lines correspond to points where $K_{p,ad}^{*}$ and $K_{p,ab}^{*}$ differ by an order of magnitude, and thick solid lines correspond to points where $K_{p,ad}^{*}$ and $K_{p,ab}^{*}$ differ by two orders of magnitude.*

Main conclusions from these calculations are:

1. For all considered pollutants except for PAHs the contributions of ad- and absorption mechanisms to the gas-particle partitioning differ not more than by an order of magnitude in urban, suburban and background regions (points corresponding to the mentioned above POPs are mostly within the area bounded by two dotted green lines in Fig. 3.7).

2. In remote regions the importance of ad- and absorption mechanisms for these pollutants is close to each other (the points corresponding to PCBs and PCDD/Fs are mostly very close to the black solid line in Fig. 3.7 b).

3. The importance of absorption mechanisms for the considered pollutants is lower than the importance of adsorption mechanism for urban, suburban and background regions (this is expressed by the fact that the points corresponding to all considered pollutants lie lower than the solid black line in Fig. 3.7).

4. For all region types absorption mechanism is of low importance for considered PAHs (the corresponding points on the Fig. 3.7 a is outside the area bounded by two dotted green lines). For PCBs and PCDD/Fs absorption can contribute considerably to gas/particle partitioning (in urban, suburban and background regions coefficients $K_{p,ab}^{*}$ is only 5 – 10 times less than $K_{p,ad}^{*}$).

At present it is recognized that for proper description of POP gas-particle partitioning several sorption mechanisms should be taken into consideration [*Lohman et al*., 2007; *Götz et al*., 2007]. To investigate the possibility of usage combined sorption mechanisms in modelling, the following model runs were used:

- Two model runs for B[a]P in 2005 using the description of gas-particle partitioning by single adsorption and by combined ad- and absorption mechanisms.

- Two model runs for PCB-153 in 2005 using the description of gas-particle partitioning by single adsorption and by combined ad- and absorption mechanisms.

For both pairs of runs emissions and meteorological data were one and the same, so that the only difference between two runs within each pair was the gas-particle partitioning mechanism used. The data on specific aerosol surface were taken the same as used in previous MSCE-POP simulations (see [*Gusev et al.,* 2005]). The data on concentrations of organic matter in the atmospheric aerosol were simulated by the CMAQ model. It should be taken into account that CMAQ can underestimate specific aerosol surface and OC concentrations in the atmospheric aerosol (see, e.g. [*Meng et al*., 2007]). The usage of elevated organic matter concentrations can lead to the enhanced role of absorption mechanism in calculation results.

The model calculations of B[a]P transport with two different mechanisms of gas-particle partitioning showed that air concentrations and deposition fluxes computed with the help of the two partitioning mechanisms practically coincide with one another. This is in a good agreement with the above analysis of relative importance of ad- and absorption mechanisms for PAHs.

More essential difference between the results using different gas-particle partitioning description was obtained for PCB-153. It should be noted that the change in particulate fraction of the pollutant influences mostly deposition processes. Therefore the effect of usage different partitioning mechanisms will be illustrated by the example of wet depositions.

The spatial distributions of wet depositions obtained in the model run using adsorption only and of the difference in wet deposition between model runs with two different partitioning schemes (adsorption only and combined ad- and absorption) are presented in Fig. 3.8 a and b, respectively.

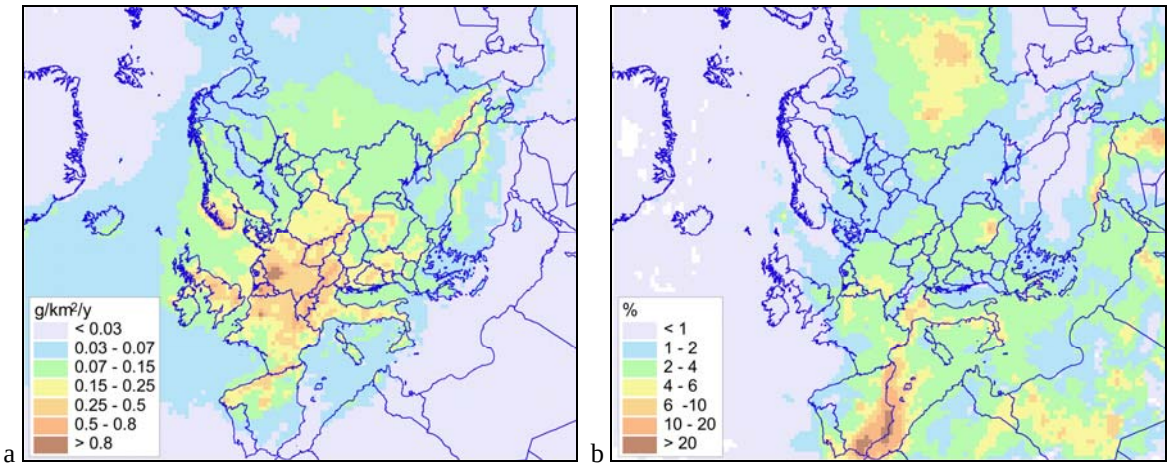


Fig. 3.8. *Calculated wet deposition fluxes of PCB-153 obtained by usage adsorption gas-particle partitioning scheme, g/km^2/y (a) and difference in PCB-153 wet depositions between calculations using adsorption only and combined ad- and absorption gas/particle partitioning schemes, % (b)*

Typical value of the difference between the results of the two model runs in Europe is 2% – 4%. However, in some regions this difference can be higher – from 4% to 6%. The highest values of the difference was obtained at the southern border of Spain – 10% – 20% and higher. This can be explained by lower levels of specific aerosol surface and higher concentrations of organic matter in the region compared with those in Europe as a whole (the values of specific aerosol surface and organic carbon concentrations at the southern border of Spain are $6.6 \cdot 10^{-4}$ m^2/m^3 and 5.4 μg/m^3, respectively whereas in Europe these values are $1.1 \cdot 10^{-3}$ m^2/m^3 and 2.4 μg/m^3 on the average).

From the above analysis it can be concluded that:

- There exist several mechanisms of gas-particle partitioning, which can act in the atmosphere simultaneously. The adsorption on particle surface and absorption on organic matter in the atmospheric aerosol are presently included into the model. In future relative influence of the other sorption processes should be investigated.

- The data on specific aerosol surface and on concentrations of organic carbon in the atmospheric aerosol generated by CMAQ can be underestimated. At the same time, these data play an important role in the model description of gas-partitioning process. Thus, further work on improvement of the data on the above two environmental parameters is needed.

- The influence of absorption mechanism in gas-particle partitioning for four indicator PAH congeners (B[a]P, B[b]F, B[k]F and I_P) seems to be negligible. However, for other pollutants (PCBs, PCDD/Fs) absorption mechanism can noticeably change gas/particle partitioning.

- Temperature dependence of the subcooled liquid vapour pressure P_{oL} and octanol-air partitioning coefficient K_{oa} do not affect relative influence of ad- and ab-sorption mechanisms.

- For PCB-153, the output parameter mostly influenced by the change of gas-particle partitioning scheme is wet deposition. The change of wet deposition due to the change of partitioning scheme strongly depend on the data on specific aerosol surface and on concentrations of organic carbon in the atmospheric aerosol.

3.4. Refinement of wet deposition for POPs in gaseous form

The description of wet deposition process in most of the POP transport models is based on the following assumptions:

- POP rain water concentrations are in an instantaneous equilibrium with atmospheric concentrations.

- Partitioning between air and rain water is determined by dimensionless air-water partitioning coefficient K_{aw} (Henry's law constant) of the considered POP.

However, in the atmosphere rain drops contain not only pure water but also some impurities. These impurities can essentially change the partitioning between atmosphere and rain drops. In this section the investigation of the influence of organic matter (being a part of atmospheric aerosol) on wet deposition of POPs is presented. To take this possible influence into account two different concentrations of a pollutant in a rain drop were considered: the concentration of the dissolved pollutant in the rain water and the concentration of the pollutant sorbed on organic matter contained in the rain water. It was supposed that concentrations of dissolved and sorbed POP are related to each other with the help of octanol-water partitioning coefficient K_{ow} and that the relation between dissolved concentration in the rain water and in the ambient air was determined by K_{aw}.

These two approaches will be referred below as *basic* and *modified* ones, respectively.

Here two possible approaches to model description of POP wet deposition are considered and the analysis of the influence of the choice of wet deposition scheme on model results (atmospheric concentrations and depositions) is presented. Two pollutants (PCB-28 and PCB-153) with different fractions of particulate form in the atmosphere were chosen for the analysis. For each of them two model runs using two different descriptions of wet deposition were carried out and calculation results were compared with each other. In conclusion, the comparison of calculation results with measurements at the EMEP monitoring network from the viewpoint of the relation between atmospheric concentrations and wet deposition rates was performed.

This approach to the description of wet deposition is referred below as a *base* one.

For each of the two above pollutants (PCB-28 and PCB-153) model runs using base and modified wet deposition schemes were performed with meteorological data for 2005. To take into account the influence of accumulation of PCBs in the environmental compartments and of emission sources located outside the EMEP domain, boundary and initial conditions were prepared on the basis of hemispheric simulations for the period from 1970 to 2005. Below the description of the obtained results is presented.

Calculation results

The spatial distributions of annual wet depositions for PCB-28 calculated on the basis of base and modified wet deposition schemes are presented in Fig. 3.9.

It can be seen that the values of wet deposition flux calculated with the modified scheme are higher than that calculated with the base scheme. More significant differences were obtained in the central part of Europe while at the periphery of the EMEP region they were less pronounced. This fact can be explained by enhanced atmospheric organic carbon (OC) concentrations in central parts of Europe (Fig. 3.4 in section 3.2).

Spatial distribution of wet deposition flux of PCB-153 for 2005 obtained with the two calculation schemes are presented at Fig. 3.10.

The difference in spatial distribution of wet deposition flux obtained for PCB-153 was considerably lower than that obtained for PCB-28. Again, more significant differences took place in the central part of Europe.

For PCB-28, the differences between annual wet depositions calculated with the help of base and modified schemes ranged from - 2% to 380% between various grid cells of the EMEP calculation grid with the average equal to 22%. For PCB-153 this range was from - 8% to 230% with the average estimated as 9%.

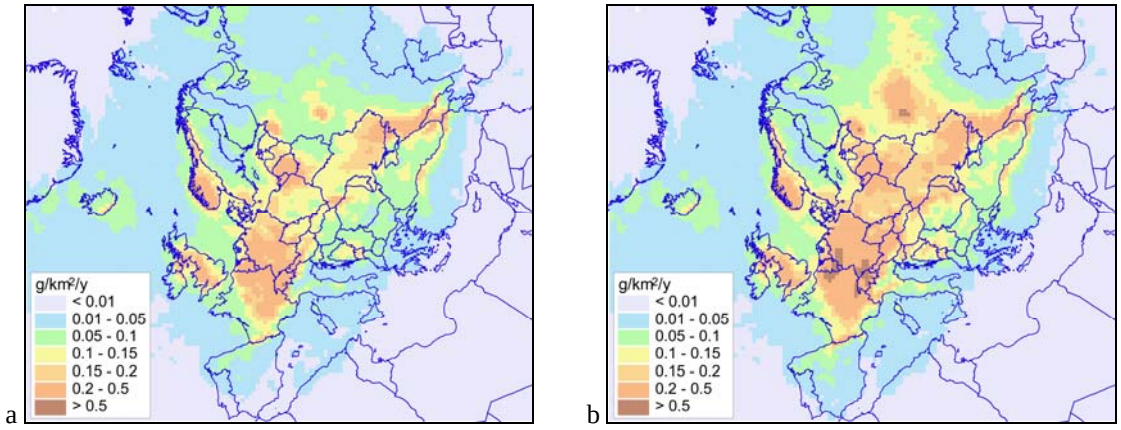


Fig. 3.9. *Annual wet depositions of PCB-28 in 2005: (a) calculations with base deposition scheme, (b) calculations with modified deposition scheme, g/km^2/y*

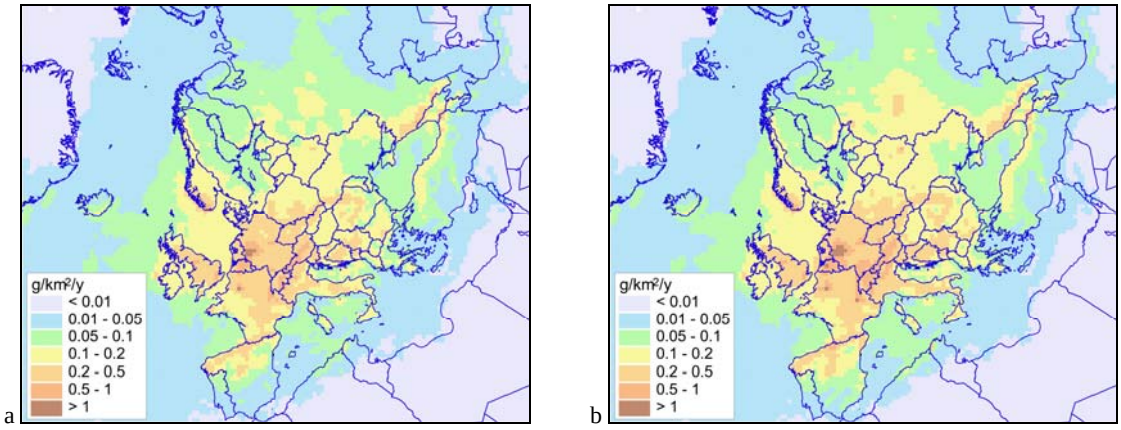


Fig. 3.10. *Annual wet depositions of PCB-153 in 2005: (a) calculations with base deposition scheme, (b) calculations with modified deposition scheme, g/km^2/y*

Comparison with measurements

The aim of the comparison was to evaluate approaches to model description of wet deposition. The focus of the comparison was put to the relation between air concentrations and wet depositions rather than absolute values of these parameters.

For the comparison, deposition values, calculated at locations of those monitoring sites where both air concentrations and depositions were measured, were normalized. Normalization coefficients were chosen in such a way that annual averages of measured and calculated air concentrations should coincide. After that calculated and measured values of wet deposition flux were compared. More precisely, average values of wet deposition fluxes (measured and calculated) are proportional to air concentrations:

$$F_c = k_c \cdot C_c, \tag{3.2}$$

$$F_m = k_m \cdot C_m, \tag{3.3}$$

where F_c and F_m are annual averages of wet deposition fluxes (calculated and measured, respectively), C_c and C_m are annual averages of air concentrations of the pollutant, and k_c and k_m are coefficients depending on washout ratios and precipitation rates.

The quality of wet deposition scheme was determined by closeness of the coefficients k_c and k_m. If calculated values of fluxes and concentrations are normalized in such a way that $C_c = C_m$, then closeness of the coefficients k_c and k_m is equivalent to the closeness of F_c and F_m. For the sites where measurements of air concentrations were absent the average of normalization coefficients over sites with simultaneous measurements in air and precipitation was used. Such normalization allows to exclude to some extent the uncertainties of emission data from the comparison.

PCB-28. Measurements of wet deposition flux were available at 7 monitoring sites: DE1, DE9, NO1, SE12, FI96, SE14 and IS91. However, at three last sites measurements were flagged as being below detection limit (all data at FI96, SE14 and 18 of 23 measurements at IS91), and these sites were excluded from the comparison. The comparison of normalized calculated values of wet deposition flux with the results of base and modified model runs at the rest sites is shown in Fig. 3.11.

It can be seen that the agreement between measurements and model calculations from the viewpoint of the quality of wet deposition scheme is reasonable. In most cases modified scheme was closer to measurements than the base one. At the same time, more simultaneous measurements for POPs in air and precipitation are needed for further evaluation of wet deposition schemes used in the model.

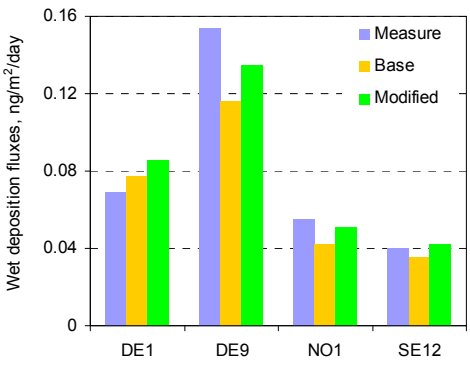


Fig. 3.11. *Comparison of calculated normalized annual wet deposition fluxes for PCB-28 in 2005 obtained by base and modified model runs with measurements at selected EMEP monitoring sites, ng/m^2/day*

PCB-153. Measurements of wet deposition flux of PCB-153 were available at 7 EMEP sites: DE1, DE9, NO1, FI96, SE14, SE12 and IS91. Measurements at two last sites contain values below detection limit and were excluded from consideration. The comparison of normalized calculated values of wet deposition flux for base and modified model runs at the rest sites is presented in Fig. 3.12.

Model calculations showed that the changes in the value of wet deposition flux due to the change of wet deposition scheme were lower than for PCB-28. Further, at all sites with exception of DE1 the agreement between calculated and measured values of wet deposition flux is reasonable. The reason of the discrepancy between calculations and measurements at DE1 can be due to the difference between measured precipitation amounts and those used for modelling (480 mm against 600 mm for the whole measurement period).

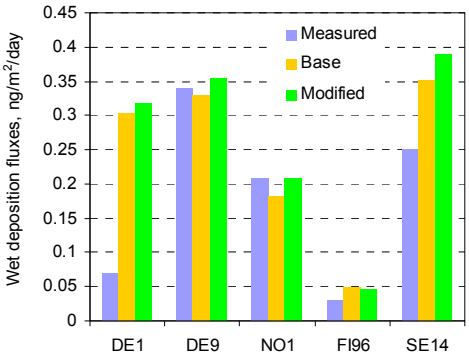


Fig.3.12. *Comparison of calculated normalized annual wet deposition fluxes for PCB-153 in 2005 obtained by base and modified model runs with measurements at selected EMEP monitoring sites, ng/m^2/day*

From the above analysis it can be concluded that:

- Modification of model description of wet deposition in MSCE-POP model can lead to significant changes in values of wet deposition flux at some locations. In particular, calculations show changes in wet deposition flux up to 4 times for PCB-153 and up to 2 times and more for PCB-28 among the cells of the EMEP grid.
- Changes of wet deposition flux are more pronounced for PCB-28 than for PCB-153. On the average, annual wet deposition flux for PCB-28 have been increased by 22% and for PCB-153 − by 9% only.
- It can be expected that enhanced values of wet deposition flux can strongly affect POP accumulation in the environmental compartments. This assumption is to be tested in future by long-term calculations.
- For PCB-28 comparison of calculations with measurement data obtained at the EMEP monitoring network shows that the model reasonably describes wet deposition process and that modified scheme of wet deposition is in most cases closer to measurements than the base one. For better validation of wet deposition schemes used in modelling more data on simultaneous measurements in air and precipitation are needed.

3.5. Parameterization of wind re-suspension of particle-bound POPs

The parameterization of wind re-suspension of particle-bound POPs was developed and included in the MSCE-POP model as described in the MSC-E Technical Report 1/2007 [*Gusev et al.*, 2007]. The pilot simulations for B[a]P presented in this Technical report showed that on average the contribution of B[a]P re-suspension flux to air pollution levels was relatively small in comparison to anthropogenic emissions and re-volatilization fluxes. At the same time it was shown that the re-suspension essentially varied over the Europe and in some regions under certain conditions its contribution could be quite significant. In particular, the re-suspension flux of B[a]P in several regions of the UK was obtained comparable with the re-volatilization flux from soils varying from 0.1 to 5 g/km^2/y (Fig. 3.13). On the average about 50% of B[a]P re-emitted to the atmosphere from these areas was contributed by the re-suspension. It can be also seen that the same levels of re-suspension took place in Belgium, Germany, Poland, the Czech Republic, and in some other regions of Europe. However, due to significant anthropogenic emissions the influence of re-suspension flux there was relatively low.

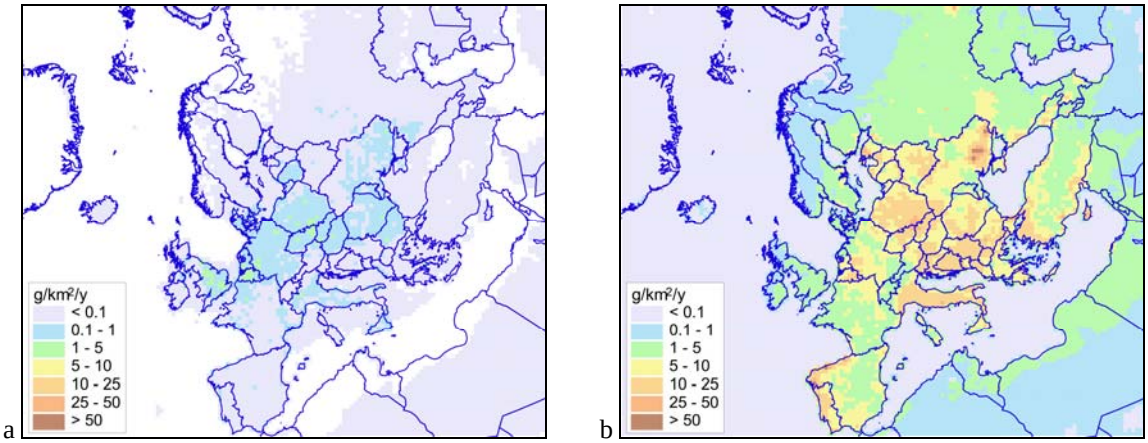


Fig. 3.13. *Spatial distribution of B[a]P re-suspension flux (a) and B[a]P re-volatilization flux (b) to the atmosphere from other compartments (soil, seawater, vegetation) for 2004, g/km^2/y*

An important parameter influencing the re-suspension flux of POPs from the soil is the POP soil concentrations. Computed levels of B[a]P concentrations were compared with available soil measurements. It should be noted that the number of studies which carried out measurements of PAH soil concentrations in Europe is quite limited. According to these data levels of B[a]P concentrations in soil essentially vary over the Europe. Measurements campaign [*Nam et al.*, 2008] performed in 1998 has obtained the levels of B[a]P concentrations in upper soil layer in the background locations ranging from 1.6 to 1600 μg/kg in the UK and from 0.5 to 86 μg/kg in Norway (Table 3.2). Results of this study have shown that B[a]P concentrations in soils in the UK were much higher than in Norway and the variations of concentrations is very significant.

Measurement of PAH concentrations in soils are performed on regular basis at the Košetice (CZ3) monitoring site in the Czech Republic. The computed value of soil concentrations at CZ3 is within the observed concentration range though there is some tendency to underestimate measured B[a]P soil concentrations.

The results of the comparison of calculated soil concentrations with measurements are summarized in Table 3.2.

Table 3.2. *Comparison of measured B[a]P concentrations in soil in different parts of the Europe with modelling results of MSCE-POP model, ng/g soil (dry weight soil)*

Location	Year	Measurements	Model results	Reference
UK	1998	1.6 - 1600	0.02 – 1.25	*Nam et al.* [2008]
Norway	1998	0.5 - 86	0.02 – 0.7	*Nam et al.* [2008]
Košetice (the Czech Republic)	2004	1.6 - 88	1.8	*Holoubek* [2008]

So, the comparison of modelling results with measurements revealed that the MSCE-POP model tend to underestimate the levels of B[a]P in soils and provide more smooth distribution of soil concentrations. The underestimation may be caused by several reasons, including underestimation of B[a]P emission in previous years, uncertainties in parameterization of B[a]P degradation in soil, and spatial resolution of the model. It might be necessary also to use longer simulation period to achieve higher levels of concentrations in soil. Taking this into account further work is required to refine model parameterization of PAH degradation in soil, to study historical emission of PAH, and to improve the agreement between the observed and calculated values of B[a]P concentrations in soil.

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

This Chapter is devoted to the model assessment of pollution levels and transboundary transport of selected POPs in the atmosphere of Europe and the Northern Hemisphere. Pollution levels and source-receptor relationships for PAHs were evaluated at the regional scale since these pollutants are mainly particle-bound. For the rest of selected POPs, namely, PCDD/Fs, PCBs, HCB, and HCHs, the evaluation of contamination of the EMEP region was carried out on the basis of hemispheric/regional modelling approach. In particular, the hemispheric MSCE-POP model was used to implement the nesting to the regional modelling. This approach allowed to take into account the contributions of non-EMEP emission sources and of re-emission of POPs from the environmental media within the Northern Hemisphere.

The first section describes the modelling results on four indicator PAHs and PCDD/Fs for 2006. The information on transboundary fluxes of B[a]P and PCDD/Fs between the EMEP countries is presented. Particular attention is paid to transboundary pollution of the Central Asian countries that are Parties (Kazakhstan, Kyrgyzstan) or candidates (Uzbekistan, Turkmenistan and Tajikistan) to the Convention. The second section provides the evaluation of the long-range transport of more volatile POPs, in particular, PCB-153, γ-HCH, and HCB.

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

4.1.1. Polycyclic Aromatic Hydrocarbons (PAH)

Assessment of pollution levels of the four indicator PAHs (B[a]P, B[b]F, B[k]F and I_P) for 2006 was performed with the help of regional MSCE-POP model. Model simulations were carried out over the extended EMEP domain with resolution 50x50 km^2. Emission data set used for modelling purposes is described above in Chapter 2. Modelling results were verified against available observations of PAH concentrations made at EMEP monitoring sites.

Evaluation of contamination levels

The spatial distributions of calculated B[a]P concentrations in surface atmospheric layer and of depositions in 2006 are shown in Fig. 4.1 a and b.

Average level of B[a]P annual mean air concentrations in 2006 over European countries was about 0.1 ng/m^3. Elevated levels of B[a]P air concentrations (> 0.1 ng/m^3) were obtained for the Central, Southern, and Eastern Europe. In particular, the most significant air concentrations, exceeding 0.5 ng/m^3, can be seen in Cyprus, the Ukraine, and Poland. In Northern Europe and mostly in Western Europe the calculated concentrations of B[a]P were below 0.1 ng/m^3.

B[a]P deposition fluxes in European countries in 2006 varied from 1 g/km^2/y to about 150 g/km^2/y. Similar to air concentrations, high values of deposition fluxes (20 – 150 g/km^2/y) were characteristic of the Central, Southern, and Eastern Europe. On the rest part of Europe (Scandinavian Peninsula, France, Spain, Portugal and the UK) deposition flux typically did not exceed 20 g/km^2/y. Elevated air concentrations and depositions in southern part of Spain are conditioned by emission sources located in this region.

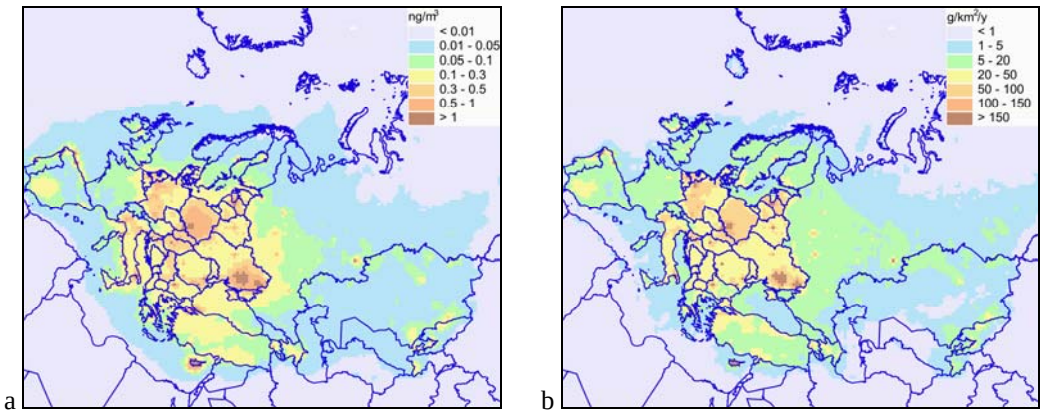


Fig. 4.1. *Calculated annual mean B[a]P air concentrations, ng/m^3 (a) and annual deposition fluxes, g/km^2/y (b) in 2006, g/km^2/y*

The spatial distributions of concentrations in surface atmospheric layer and of depositions in 2006 for the rest three indicator PAH compounds (B[b]F, B[k]F, and I_P) are shown in Fig. 4.2 below.

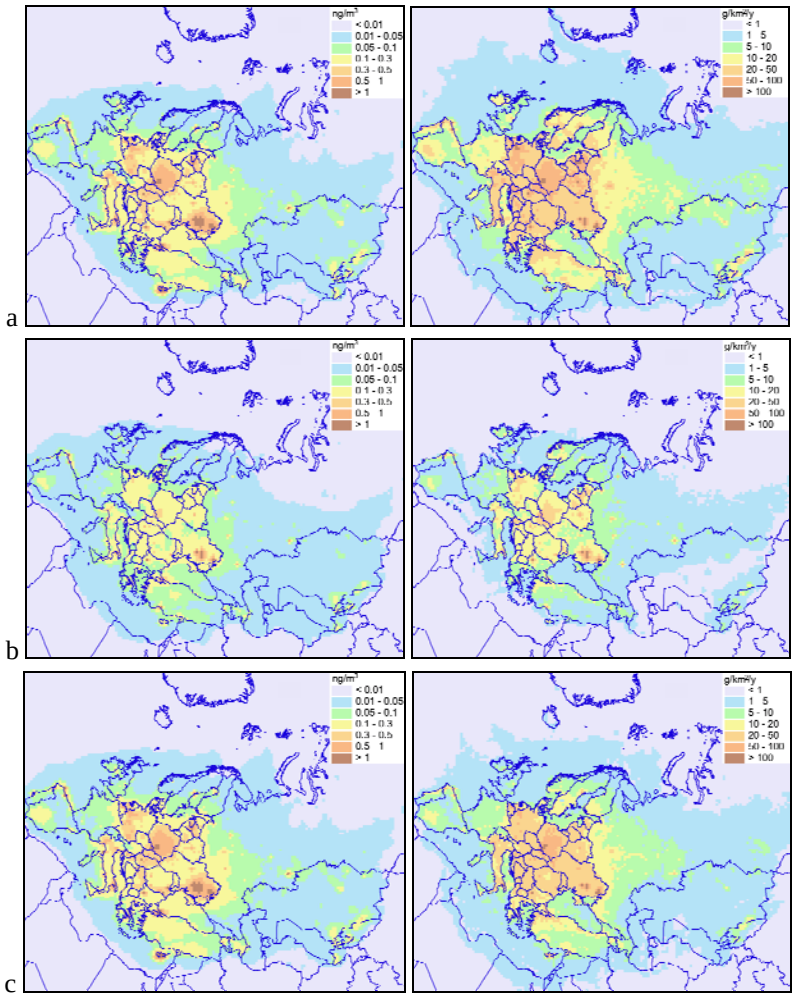


Fig. 4.2. *Calculated air concentrations, ng/m^3 (on the left) and deposition fluxes, g/km^2/y (on the right) in 2006, g/km^2/y for B[b]F (a), B[k]F (b) and I_P (c)*

Air concentrations of B[b]F and I_P varied from 0.05 ng/m^3 in northern part of Europe to more than 1 ng/m^3 in the regions of the Central, Eastern, and Southern Europe. Spatial distribution of B[b]F and I_P air concentrations are similar to those for B[a]P. The air concentrations of B[k]F are much smaller (from 0.01 ng/m^3 to 0.5 ng/m^3). This is conditioned by the relations between emissions of these compounds.

The same concerns deposition fluxes. For B[b]F and I_P they varied from low (5 – 10 g/km^2/y) in Northern Europe to rather high (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 for B[b]F in the northern part of Spain led to the increase of deposition levels in northern Spain and southern France for this pollutant 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 and 10 – 20 g/km^2/y in Central Europe). Absolute values of deposition fluxes are smaller than for the two above considered pollutants. Again, the reason is that 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 those for B[a]P, B[b]F and I_P.

In comparison with model results on PAHs for 2005 presented in previous Status Report [*Gusev et al.*, 2007] average air concentrations in the European countries in 2006 did not change essentially. The differences in particular countries are mostly within 30%. These changes are conditioned by the differences in the meteorological data and emissions between the years 2005 and 2006. The most essential change in emissions takes place for Cyprus (see Chapter 2). According to the official data, PAH emissions in Cyprus for 2006 are about 7 times higher than that for 2005 used for calculations of previous year (based on unofficial emission data). Besides, emission in Kazakhstan was enlarged in comparison to the previous year since Asian part of the country has been included in the EMEP domain. The value of total deposition to the European territory for 2006 is also almost the same as in calculations for 2005 made in the previous year.

Comparison with measurements

Comparison with measurements for 2006 was performed for B[a]P since there were more data for the comparison and emission data for this compound were more reliable.

Measurements of B[a]P atmospheric concentrations for 2006 are available at EMEP stations SE12, SE14, FI96, CZ3, NO42, GB14 and ES8. The comparison of annual means of measured and calculated air concentrations is shown in the plot in Fig. 4.3.

All calculated values at monitoring station locations except for ES8 agree with measurements within a factor of two. For three stations (SE12, FI96 and CZ3) calculations and measurements differ not more than by 25%. The differences between calculations and measurements at ES8 can be conditioned by the lack of information on emissions and their seasonal variations (at present no official information on Spain emissions are available and unofficial data are used for modelling). The reason of the

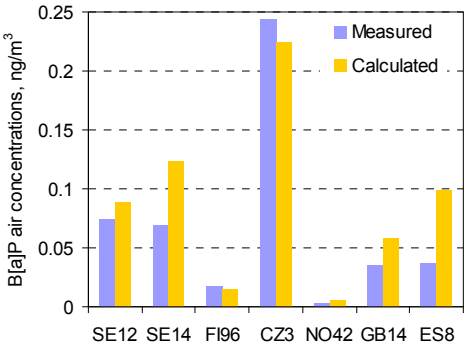


Fig. 4.3. *Calculated and measured annual means of air concentrations of B[a]P at EMEP monitoring stations in 2006, ng/m^3*

disagreement between calculations and measurements at SE14 is that the cell containing this measurement site contains also such powerful emission source as Gothenburg. Due to this fact, calculation results, being averaged over the whole cell, can differ from measurements, which are characteristic of a particular point in this cell. More detailed analysis of this phenomenon is given in [*Shatalov et al*., 2005].

The measurement information on concentrations in precipitation and deposition fluxes is available at stations DE1, DE9 (concentrations in precipitation), FI96, SE12 and SE14 (deposition fluxes). In the interpretation of the comparison of measured and calculated concentrations in precipitation and deposition fluxes it should be taken into account that these parameters strongly depend on precipitation amount − the parameter, which is characterized by strong variability. The comparison of measured and calculated wet deposition fluxes at these stations is shown in Fig. 4.4.

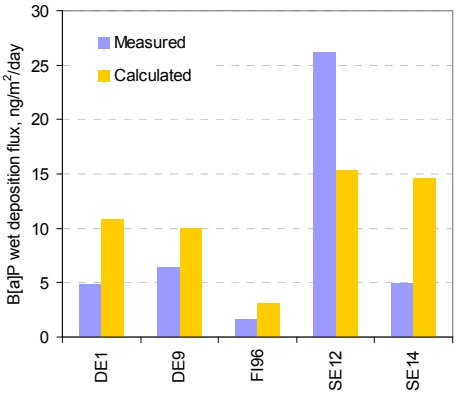


Fig. 4.4. *Calculated and measured annual means of wet deposition fluxes of B[a]P at EMEP monitoring stations in 2006, ng/m^2/day*

For all stations except for SE14 measured and calculated wet deposition fluxes agree within a factor of two. It should be noted also that the comparison of concentrations in precipitation at DE1 and DE9 is much better than that for the deposition fluxes. In particular, measured and calculated values of concentrations in precipitation at DE1 are 2.9 and 2.7 ng/L, respectively. For DE9 these values are 4.7 and 3.0 ng/L. Thus, differences in measured and calculated wet deposition fluxes can be conditioned by uncertainties in precipitation rates. The reason of disagreement between calculations and measurements at SE14 is the same as for air concentrations.

Transboundary transport

Since spatial patterns of contamination for all four indicator PAHs are similar to one another, calculations of source-receptor relationships have been performed for B[a]P only.

To evaluate the transboundary transport of B[a]P, the contributions to air concentrations and depositions from emission sources of each EMEP country are calculated in the process of simulation of long-range transport. Spatial distributions of depositions originated from emission sources of a particular country are exemplified by the Czech Republic and Italy in Fig. 4.5.

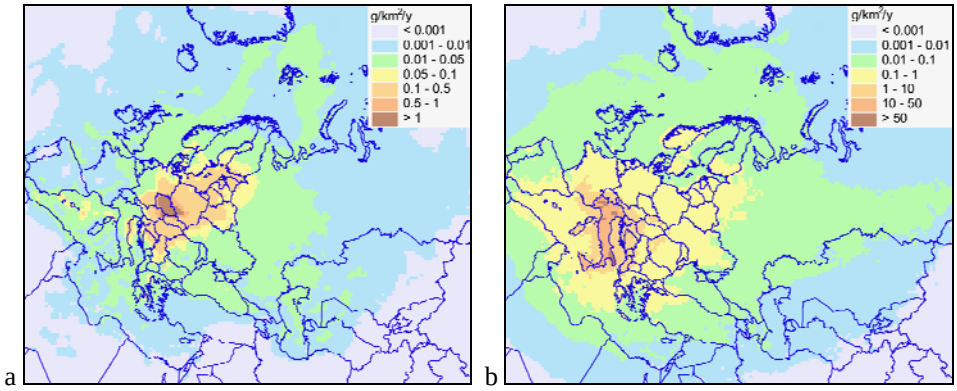


Fig. 4.5. *Annual total depositions of B[a]P originated from national emissions of the Czech Republic (a) and Italy (b) in 2006, g/km^2/y*

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 from national anthropogenic emission sources of a country within the EMEP region to deposition over the territory of the country itself and deposition to the rest EMEP territory (export) in 2006 is shown in Fig. 4.6.

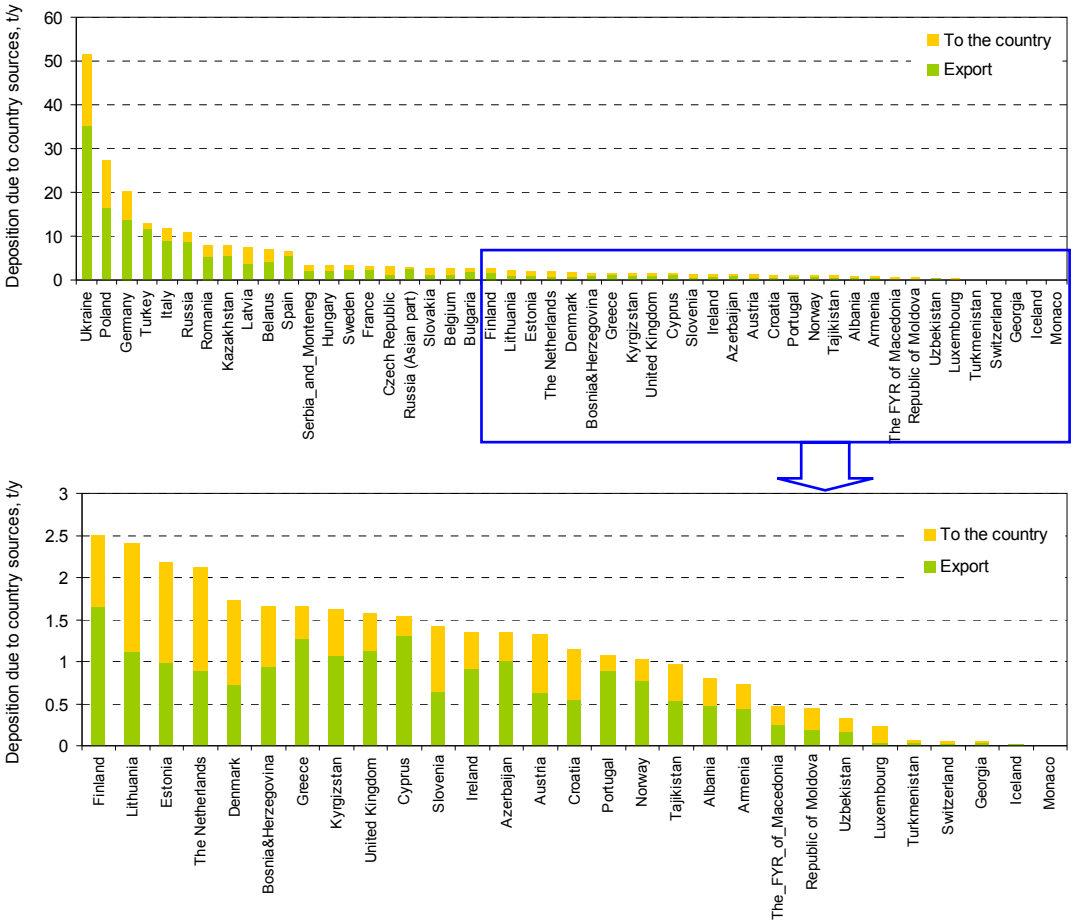


Fig. 4.6. *Depositions of B[a]P in 2006 from national emission sources of each EMEP country divided into the depositions to the territory of a country and exported depositions taking place over the rest EMEP territory, t/y*

It can be seen that the transboundary transport of B[a]P between the European countries is quite significant. In particular, from 20% to 60% of depositions caused by national emission sources took place outside the territories of the countries. The contribution of national emission sources to the transboundary transport depends on country area, geographical location, and meteorological conditions of the considered year.

The depositions from sources of a particular country can be further specified by calculation of fractions of total deposition from sources of a given country to other particular countries. Pie charts showing such specification for the Netherlands (export = 58%), Finland (export = 34%) and Portugal (export = 18%) are displayed in Fig. 4.7.

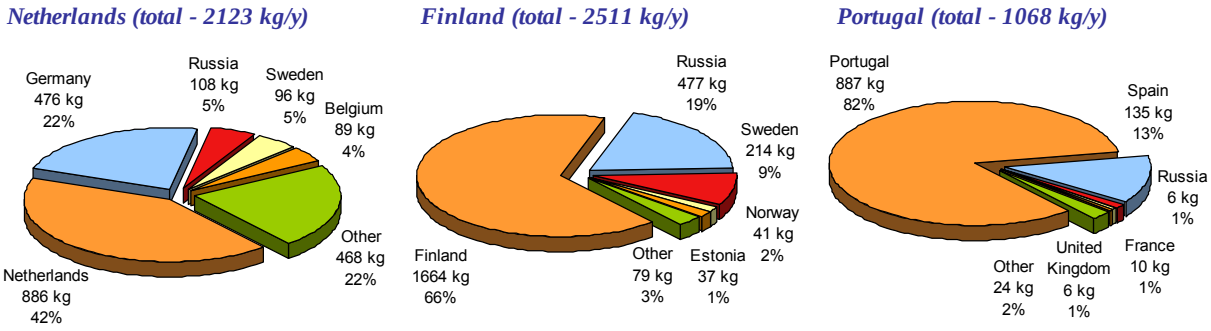


Fig. 4.7*. Transboundary transport of B[a]P from several countries, % of depositions in 2006*

Import. The calculated values of total depositions of B[a]P to the territories of European countries in 2006 can be split to the depositions due to own emission sources and due to the sources of other countries (import). This splitting is shown in Fig. 4.8.

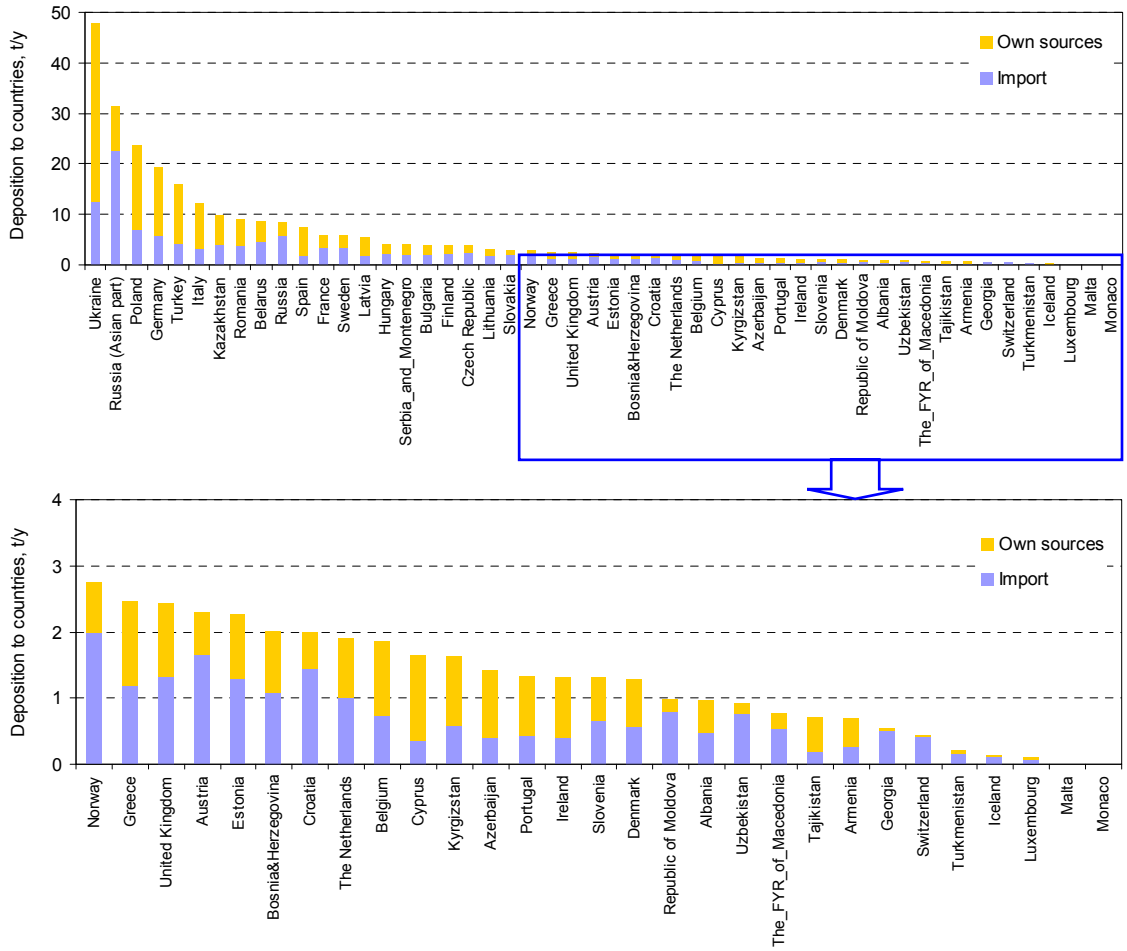


Fig. 4.8. *Total depositions of B[a]P to the territories of European countries in 2006 and contributions of own emission sources and transboundary transport, t/y*

Typically contributions of other European countries to the deposition levels of a particular country vary from 20% to 70%.

The information on transboundary transport can be further specified by splitting the depositions to a particular country from European sources to contributions originated by emission sources of each other country. Pie charts showing such specification for Norway (import = 68%), Hungary (import = 43%) and Germany (import = 18%) in Fig. 4.9.

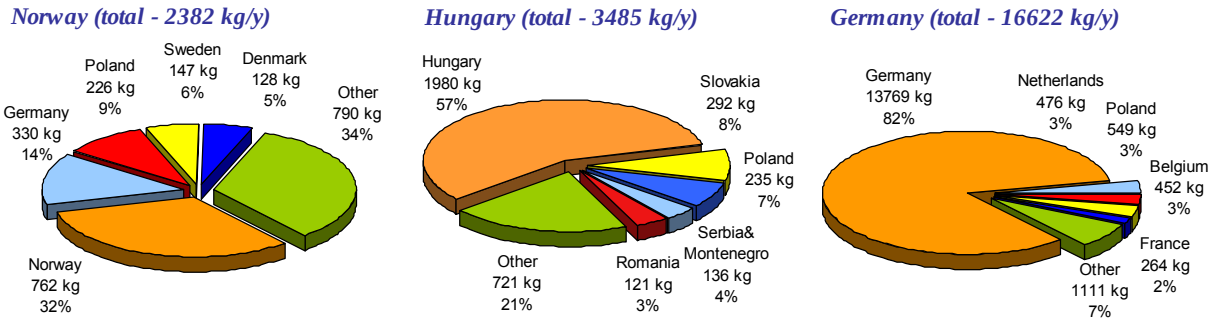


Fig. 4.9. *Fractions of B[a]P depositions to Norway, Hungary, and Germany originated from atmospheric transport of EMEP countries, %*

In contrast to the export, the import fraction depends not only on country's area, location, and meteorological conditions of the current year, but also on the fraction of national sources in emission totals. For example, import to Germany is low enough (18% only) due to high fraction of German emissions in the EMEP total (about 8%).

Finally, it should be noticed that import pie charts present only average figures of the contribution of transboundary transport over the country. However, these contributions are subject to strong spatial variations. An example of spatial distribution of transboundary fractions for particular countries can be found in the next subsection devoted to the contamination of the Central Asia countries.

Contamination of the Central Asia countries. Due to the extension of EMEP domain, it became possible to generate the full set of information on contamination levels and transboundary transport of B[a]P for the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan).

The information includes:

a) Spatial distribution of depositions to the EMEP domain originated from national sources.

b) Spatial distributions of deposition fractions due to transboundary transport.

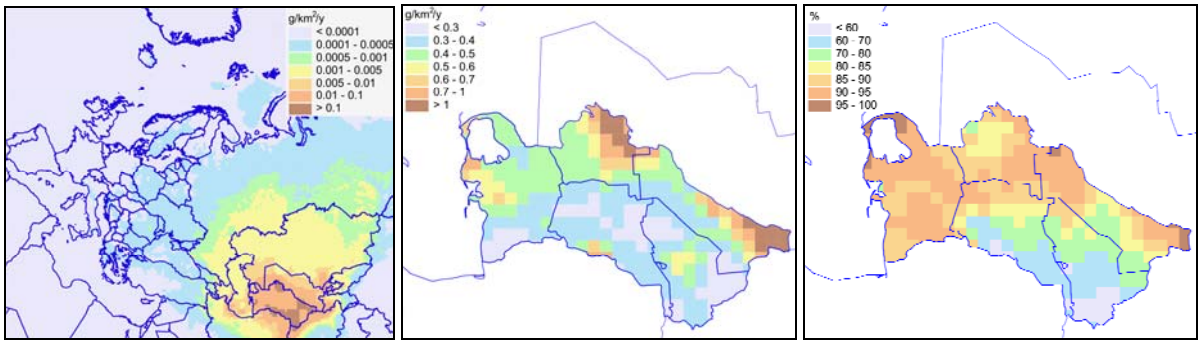
c) Spatial distribution of depositions to the country.

d) Export diagrams.

e) Import diagrams.

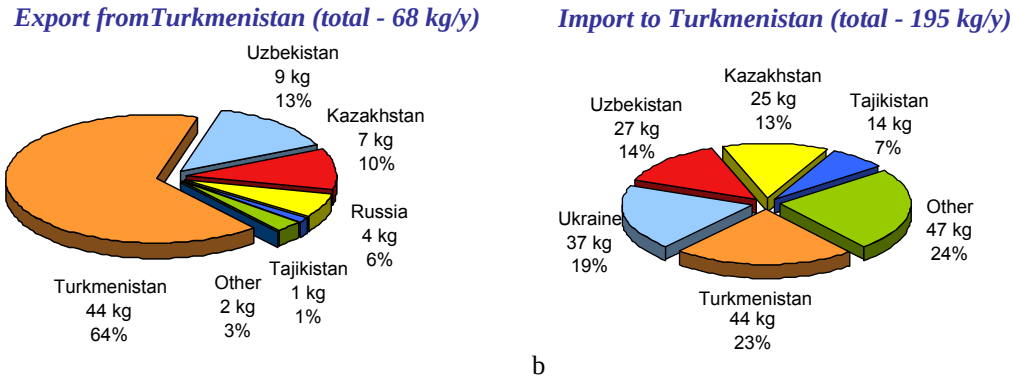
This information is exemplified below by Turkmenistan (Fig. 4.10, 4.11).

Full country-to-country matrices for B[a]P total annual depositions can be found in Annex B. The set of country-specific information will be put on the MSC-E web-site www.msceast.org in autumn 2008.



a b c

Fig. 4.10. *Information on B[a]P contamination and transboundary transport for Turkmenistan in 2006: spatial distribution of depositions to the EMEP domain originated by national emission sources, g/km²/y (a); spatial distribution of depositions to the country, g/km²/y (b); spatial distribution of deposition fractions due to transboundary transport, % (c)*



a b

Fig. 4.11. *Information on B[a]P contamination and transboundary transport for Turkmenistan in 2006: export diagram (a) and import diagram (b)*

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

Assessment of environmental pollution by PCDD/Fs for 2006 was carried out for the mixture of 17 toxic PCDD/F congeners. The calculations were made with the regional MSCE-POP model at the extended EMEP domain with resolution 50x50 km^2. Emission data set used for the modelling purposes is described above in Chapter 2. To take into account the influence of historical accumulation of PCDD/Fs in various environmental media (soil, seawater, vegetation) and the intercontinental transport from distant emission sources preliminary run of the hemispheric MSCE-POP model was done for the period 1970-2006. The results of this run were used for generation of initial and boundary conditions for the regional modelling.

In model calculations, physical-chemical properties of PCDD/F "indicator congener" 2,3,4,7,8-PeCDF were used. Such an approach allows evaluating the spatial distributions of total PCDD/F toxicity in the atmosphere with differences not exceeding 20% compared with the results of simulations of all 17 toxic congeners. The differences in country-to-country matrix are within a 5% range [*Dutchak et al.,* 2004].

Evaluation of contamination levels

The spatial distributions of calculated PCDD/F concentrations in surface atmospheric layer and depositions in 2006 are shown in Fig. 4.12.

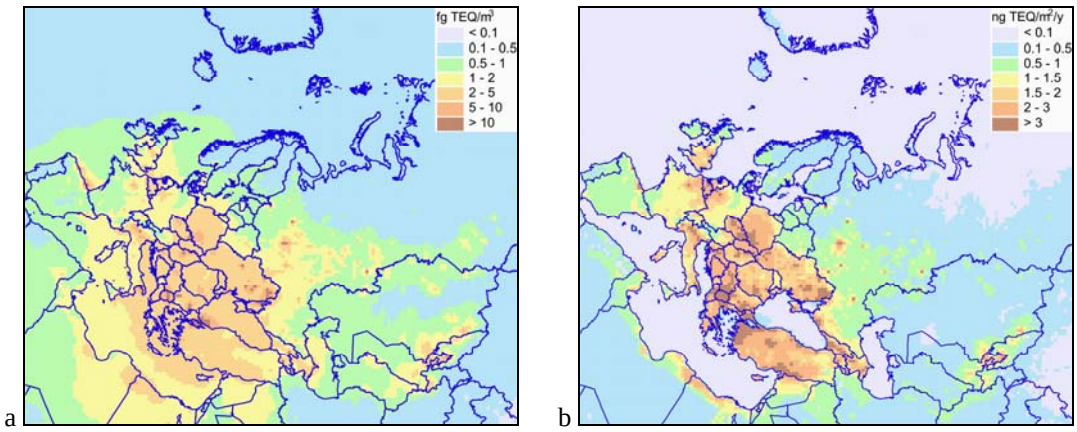


Fig. 4.12. *Calculated air concentrations, fg TEQ/m^3 (a) and deposition fluxes, ng TEQ/m^2/y (b) of PCDD/Fs in 2006*

Average level of annual mean PCDD/F air concentrations over European countries is about 1 fg TEQ/m^3. Elevated levels of PCDD/F air concentrations (2 fg TEQ/m^3 and above) are found in Central, Southern and Eastern Europe, namely in Macedonia, Bulgaria, Hungary, Serbia and Montenegro, the Ukraine, the Czech Republic, Slovakia, Croatia, Albania, Poland, Romania and Greece. Low values of air concentrations (below 0.5 fg TEQ/m^3) are characteristic of Western and Northern Europe.

PCDD/F deposition fluxes range from 0.1 – 1 ng TEQ/m^2/y in Western and Northern Europe to more than 3 ng TEQ/m^2/y in some regions Central, Southern and Eastern Europe.

In comparison with calculations of previous year [*Gusev et al.*, 2007] contamination levels obtained for 2006 in most of the European countries are close to those calculated for 2005. At the same time, there are some changes in particular countries due to the changes in meteorological conditions and emissions.

In particular, the changes in calculated depositions take place in Portugal, Romania, and Turkey. The reduction of depositions in Portugal (50 g TEQ/y against 470 g TEQ/y calculated earlier for 2005) is clearly connected with strong change of emission data. Emissions used in the calculations for 2006 are almost 50 times lower than that used in previous year calculations for 2005. For Romania, higher level of PCDD/F depositions in 2006 (480 g TEQ/y) in comparison with results for 2005 (290 g TEQ/y) is conditioned by more than twice increase of national emissions. Changes of depositions in Turkey are mainly due to the refinement of model description of deposition velocities to the underlying surface for this region. This has led to the increase of the contribution of re-emissions to depositions to the country.

Transboundary transport

In this section the calculated source-receptor relationships in the EMEP region for PCDD/Fs are presented. Source-receptor matrices for PCDD/Fs in 2006 were calculated both for deposition and for air concentrations. Below the source-receptor relationships by the example of deposition matrix are

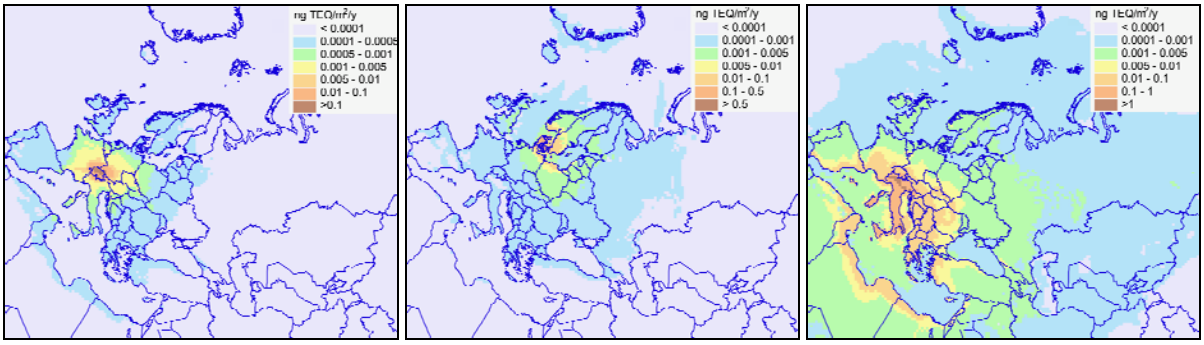
illustrated. In comparison with calculations of the previous year some sources and receptors were added (Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan and the whole Kazakhstan. The part of Asian Russia is also included into the current EMEP domain.

The following source groups are considered for the evaluation of source-receptor relationships 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 historical accumulation of PCDD/Fs in the environmental media from anthropogenic emission sources of the entire Northern Hemisphere.

Each European country is considered as a separate receptor.

To evaluate the transboundary transport of PCDD/Fs, the contributions to air concentrations and depositions from all above emission sources are calculated in the process of simulation of long-range transport. Fig. 4.13 shows spatial distributions of depositions due to emission sources of Switzerland, Denmark and Italy.



a b c

Fig. 4.13. *Annual total depositions of PCDD/Fs originated from national emissions of Switzerland (a), Denmark (b) and Italy (c) in 2006, ng TEQ/m^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 were evaluated.

Export. The splitting of total depositions to the EMEP region due to national anthropogenic emission sources of a country to deposition to the territory of the country itself and deposition to the rest EMEP territory (export) in 2006 is shown in Fig. 4.14.

Typically, from 20% to 60% of depositions caused by national emission sources of a country are deposited outside this country. This fraction depends on country area, location and meteorological conditions of the considered year.

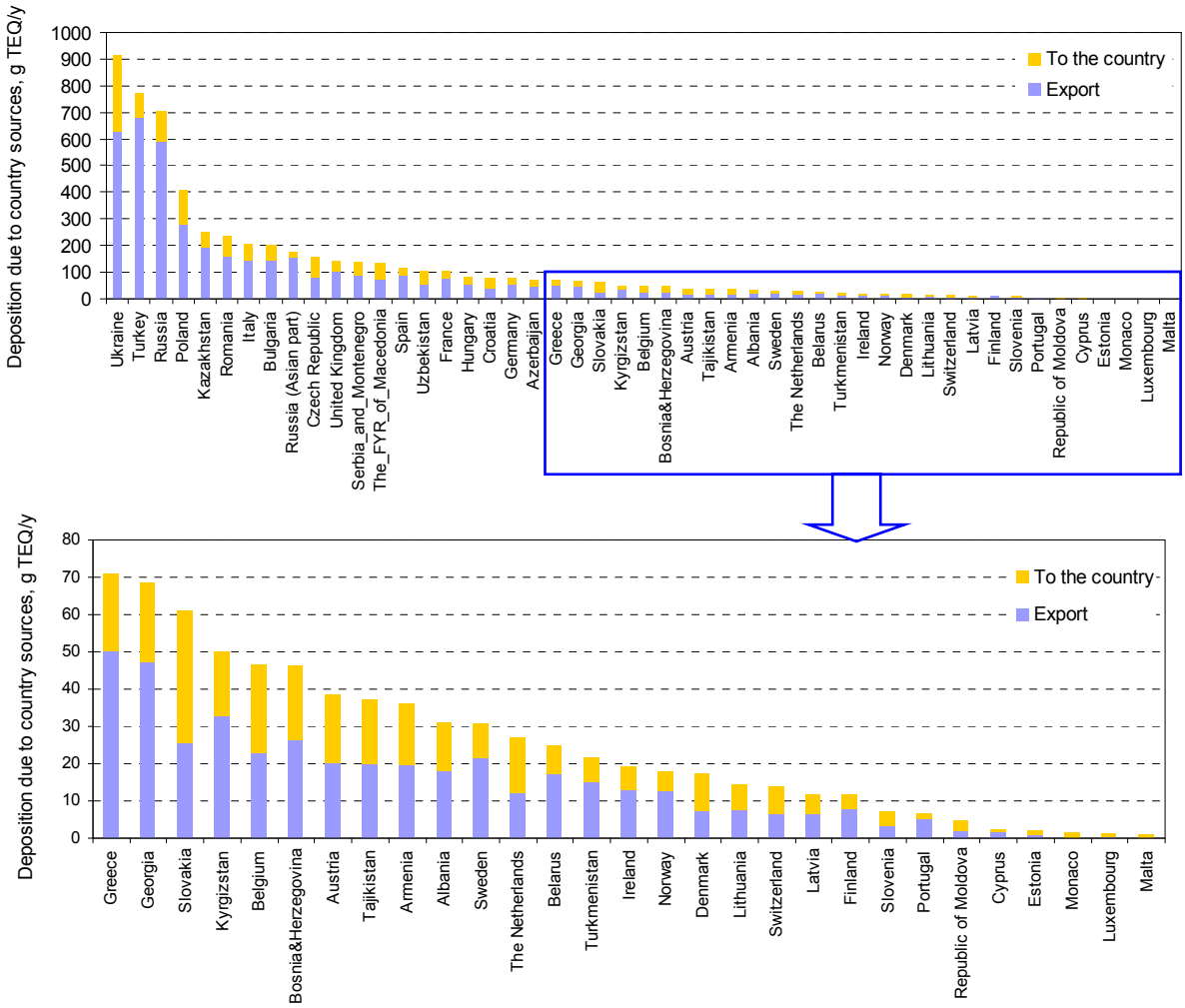


Fig. 4.14. *Depositions of PCDD/Fs in 2006 from national emission sources of each EMEP country divided into the depositions to the territory of a country and exported depositions taking place over the rest EMEP territory, g TEQ/y*

Export information may be represented in a more detailed form by the specification of calculation fractions of total deposition from sources of a given country to other particular countries. Such information is exemplified in Fig. 4.15 by export pie charts for the Netherlands (export = 55%), Finland (export = 34%) and Portugal (export = 20%).

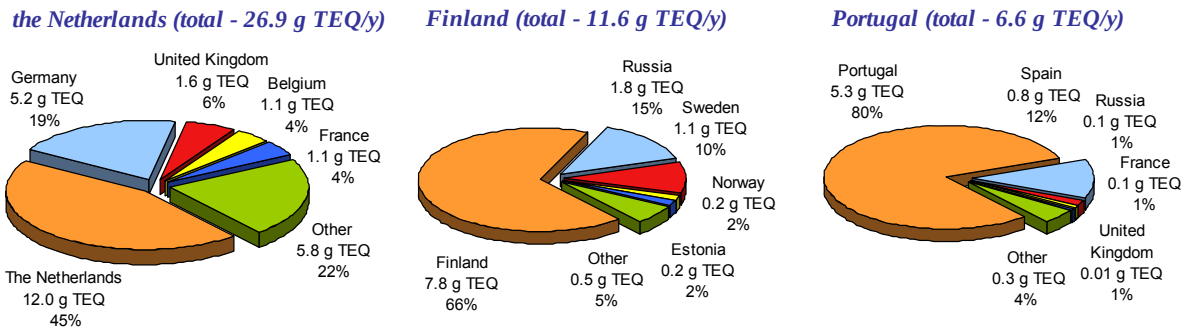


Fig. 4.15*. Transboundary transport of PCDD/Fs from several countries in 2006, % of depositions*

Import. The calculated values of total depositions of PCDD/Fs to the territories of European countries in 2006 can be split to depositions due to own sources (internal contribution), due to sources of other EMEP countries (EMEP transboundary transport), due to sources of the USA and Canada (non-EMEP sources) and due to accumulation in the previous years (re-emissions). This splitting is shown in Fig. 4.16.

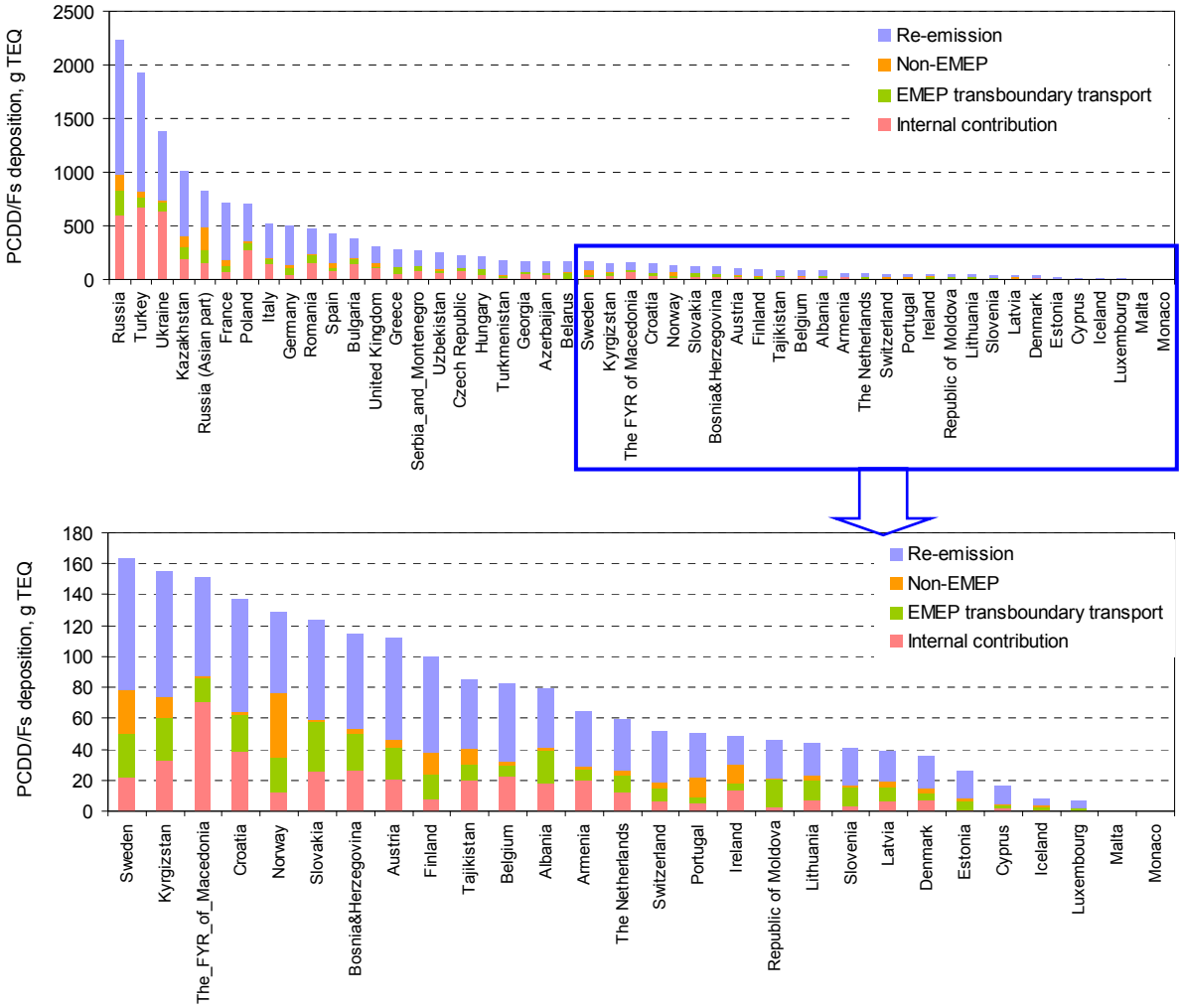


Fig. 4.16. *Structure of total depositions of PCDD/Fs to the territories of European countries in 2006, g TEQ*

The contribution of internal sources to total depositions to the country varies from 4% to 50%, of transboundary transport from other EMEP countries − from 3% to 60%, of transport from non-EMEP sources − from 1% to 33%, and of re-emission − from 30% to 70%. The re-emission contributions are high enough and should be taken into account in the assessment of pollution levels in the European countries.

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 Finland (import fraction 80%), Germany (import fraction 60%) and Hungary (import fraction 47%) (Fig. 4.17). Here for the analysis of transboundary transport re-emission fraction is temporarily excluded from total

depositions to European countries, so that only the transport of anthropogenic emissions (from European countries and non-EMEP sources − USA and Canada) is considered.

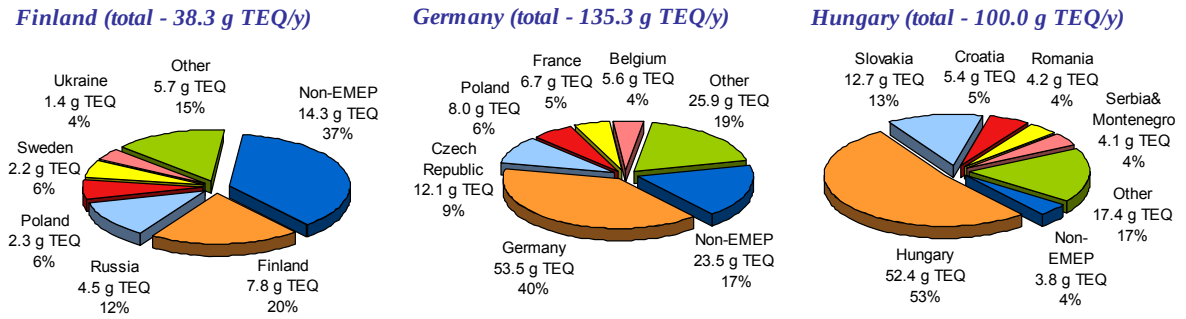


Fig. 4.17. *Fractions of PCDD/F depositions to Finland, Germany and Hungary originated from air transport in 2006, %*

It should be noticed that import pie charts present only average figures of the contribution of transboundary transport over the country. However, these contributions are subject to strong spatial variations. An example of spatial distribution of transboundary fractions for particular countries can be found in the next subsection devoted to the contamination of the Central Asia countries.

Putting together contributions of the atmospheric transport and re-emissions it is possible to evaluate total depositions for each European country in 2006 and contributions of all above categories of sources (European anthropogenic sources of other countries, non-EMEP sources and re-emissions). Examples of contributions of all these emission sources to the total depositions in 2006 are presented in Fig. 4.18 for some European countries.

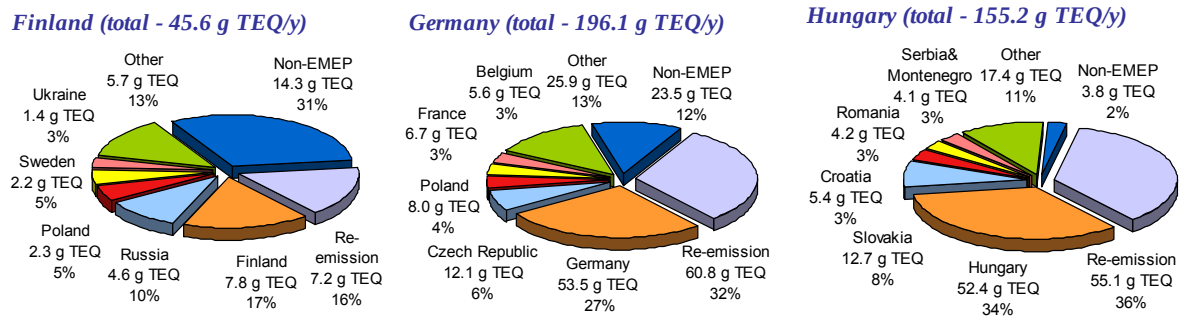


Fig. 4.18. *Contributions of all emission sources to PCDDF depositions over the territories of Finland, Germany and Hungary in 2006, %*

Contamination of the Central Asia countries. Due to the extension of EMEP domain, it became possible to generate the full set of information on contamination levels and transboundary transport of PCDD/Fs for the Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan).

The information includes:

a) Spatial distribution of depositions to the EMEP domain originated by national sources.

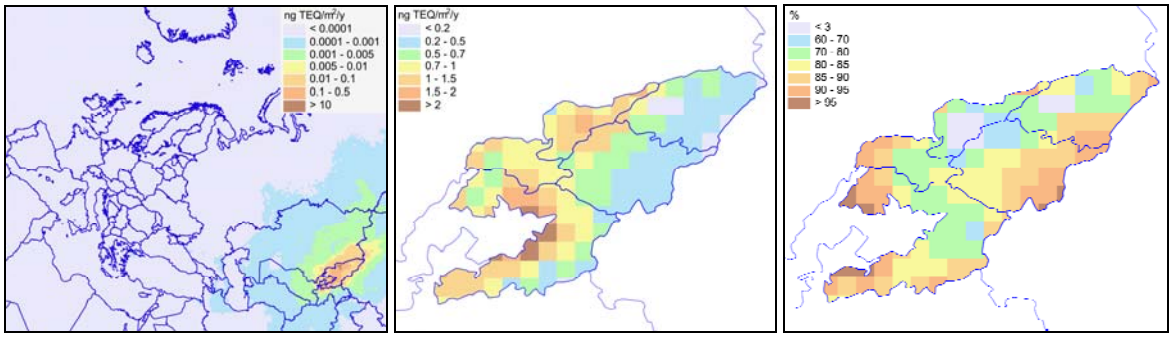
b) Spatial distribution of depositions to the country.

c) Export diagrams.

d) Import diagrams.

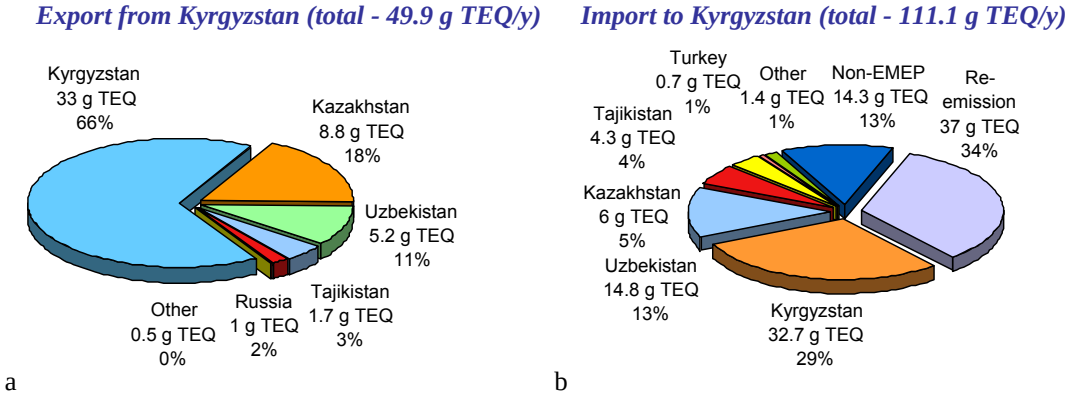
e) Spatial distributions of deposition fractions due to transboundary transport.

This information is exemplified below by Kyrgyzstan (Fig. 4.19, 4.20).



a b c

Fig. 4.19. *Information on PCDD/F contamination and transboundary transport for Kyrgyzstan in 2006: spatial distribution of depositions to the EMEP domain originated by national emission sources, ng TEQ/m^2/y (a); spatial distribution of depositions to the country, ng TEQ/m^2/y (b); spatial distribution of deposition fractions due to transboundary transport, % (c)*



a b

Fig. 4.20. *Information on PCDD/F contamination and transboundary transport for Kyrgyzstan in 2006: export(a) and import(b) diagrams*

Full country-to-country matrices for PCDD/F total annual depositions in 2006 can be found in Annex B. The set of country-specific information will be put on MSC-E web-site www.msceast.org in autumn 2008.

4.2. Hemispheric transport of POPs

Investigations of PCB-153, γ-HCH, and HCB intercontinental transport and pollution levels for 2006 on hemispheric and regional scales were continued. Comparing to the previos Status report [*Gusev et al.*, 2007] presenting the results of model simulations over the Northern Hemisphere only, the information on pollution levels of PCB-153, γ-HCH, and HCB for 2006 was obtained both for the hemispheric scale with resolution 2.5°x2.5° and for the extended EMEP region with resolution 50x50 km^2 using the nesting of the hemispheric and regional MSCE-POP models.

4.2.1. Polychlorinated biphenyls (PCBs)

Evaluation of PCB long-range transport and accumulation in environmental compartments within the Northern Hemisphere was performed with hemispheric MSCE-POP model for the period 1970-2006. Simulations were made for one indicator congener PCB-153 on the basis of the global emission inventory of PCBs prepared by *Breivik et al.* [2007]. Annual emissions of PCB-153 and their spatial distribution for 2006 used for model computations are described in Chapter 2. Modelling of PCB distribution in European region for 2006 was carried out using the regional MSCE-POP model over the extended EMEP grid. Simulation results were preliminary compared with PCB measurements of EMEP monitoring sites.

Air concentrations and deposition levels

Spatial distributions of annual mean PCB-153 concentrations in surface air for 2006 within the Northern Hemisphere and the EMEP grid are shown in Fig. 4.21a and b. It can be seen that most significant levels of air concentrations (3.6 pg/m^3 and above) are characteristic of European region. Moderate annual air concentrations (about 0.9-1.8 pg/m^3) were obtained for North America, Northern Africa, and the European part of the Russian Federation. This distribution corresponds with the spatial distribution of PCB-153 annual emission within the Northern Hemisphere (Fig. 2.13).

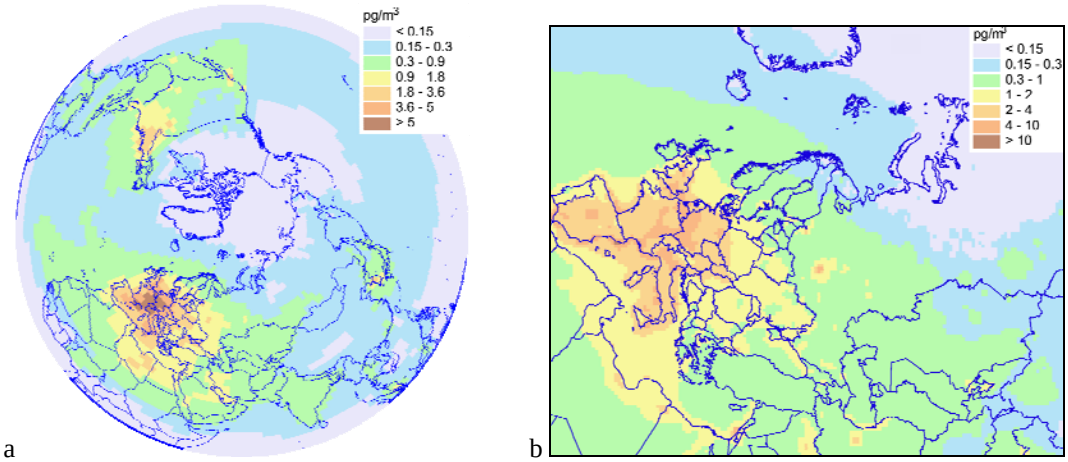


Fig. 4.21. *Spatial distribution of PCB-153 annual mean air concentrations for 2006 within the Northern Hemisphere (a) and the extended EMEP grid (b), pg/m^3*

Essential air concentrations of PCB-153 can be noticed for the Northern Atlantic, Southwest Asia, and the Central Asia countries which can be explained by the long-range transport of the pollutant from the areas with significant PCB emission. Levels of annual mean PCB-153 concentrations in air within the Central Asia region are in the range of 0.3-0.9 pg/m^3. Detailed distributions of annual mean PCB-153 air concentrations within the extended EMEP grid with resolution 50x50 km^2 obtained by regional MSCE-POP model is shown in Fig 4.21b. It can be seen that regional MSCE-POP model in general reflects major peculiarities of air concentrations pattern calculated by the hemispheric model.

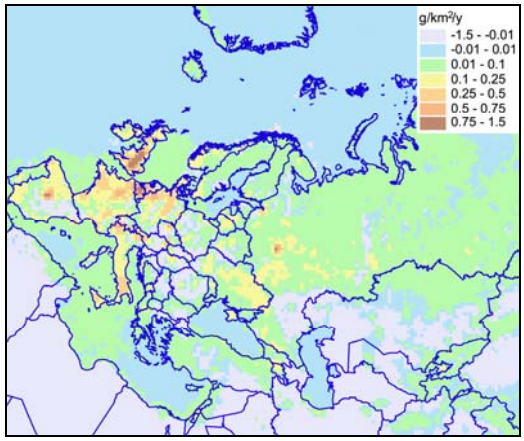


Fig. 4.22. *Spatial distribution of PCB-153 annual net deposition flux within the extended EMEP region for 2006, g/km^2/y*

Levels of PCB-153 net annual deposition fluxes over the EMEP grid are shown in Fig 4.22. The most significant net deposition fluxes (0.5 g/km^2/y and above) are characteristic of the UK, Belgium, Germany, and France. Essential levels of net deposition fluxes are noted for the countries of Southern and Eastern Europe, in particular, Spain, Italy, the Ukraine, etc.

It can be seen that the pattern of net deposition fluxes includes the deposition and re-emission fluxes. The re-emission of PCBs resulted from long-term accumulation in environmental compartments can become comparable with primary PCB emissions to the atmosphere especially when these emissions essentially decline. For countries with relatively significant emission the deposition fluxes from the atmosphere to the surface are dominating (e.g. the UK, Belgium, France, and Germany). In countries of Southern and Eastern Europe the re-emission fluxes from soil compartment prevail. Net deposition fluxes over the Central Asian countries are in the range -0.1 – 0.1 g/km^2/y.

Comparison of modelling results with measurements

Verification of obtained modelling results for PCB-153 was performed using the measurements of the EMEP monitoring network. Calculated PCB-153 concentrations in air and precipitation were confronted with data of 10 monitoring sites.

Results of the comparison of measured and calculated annual mean PCB-153 air concentrations for 2006 are presented in Fig. 4.23a. Computed concentrations reasonably agree with measurements for most of the sites. Significant spatial correlation between observations and model results can be noted. On average, the deviations between computed and measured air concentrations amount to approximately 60%. It can be seen that for the sites SE14, IS91, NO1, and FI96 model results are in good agreement with measurements (the differences do not exceed 10%). For the sites GB14 and SE12 the model significantly overestimated measured concentrations, in particular, by a factor of 3 and 5, respectively. Measurements of the site NO42 were underestimated by the model on average by a factor of 2.6.

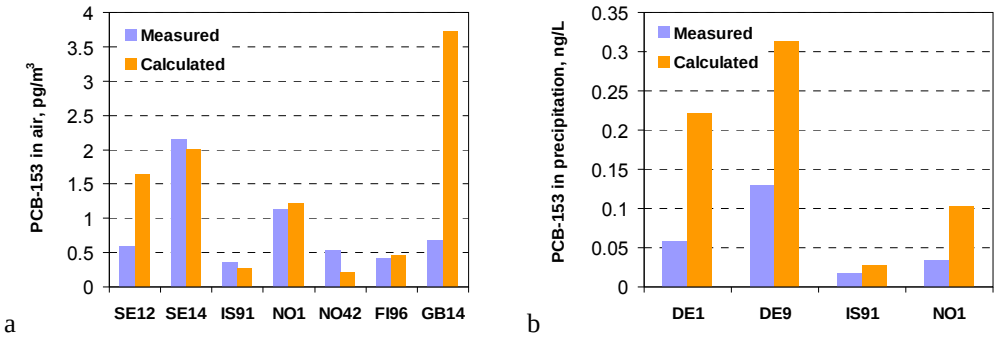


Fig. 4.23. *Comparison of computed annual mean air concentrations, pg/m^3 (a) and concentrations in precipitation, ng/L (b) of PCB-153 with measurements of EMEP monitoring sites for 2006*

The overestimation for the sites SE12 and GB14 is most likely connected with the uncertainties of spatial distribution of PCB emission over the 50x50 km^2 grid and representativeness of these sites for the 50x50 km^2 grid cells. In particular, the spatial distribution of PCB emission for this study was obtained by reallocation of gridded emission from the 1°x1° latitude-longitude grid to the grid system of the MSCE-POP regional model which is defined in the stereographic projection. Uncertainties in reallocation process can result in the elevated levels of emissions in grid-cells where the sites are located and smoothing of emissions over nearby grid-cells. Taking this into account further work on refinement of spatial distribution of PCB emissions within the extended EMEP model grid is required.

Comparison of calculated annual mean PCB-153 concentrations in precipitation was carried with the data of four EMEP sites, namely, DE1, DE9, IS91, and NO1 (Fig. 4.23b). It can be seen that the model reproduced low concentrations for the remote site IS91 and elevated levels for the sites in Western Europe (DE9). At the same time, the model overestimates the observed concentrations in precipitation at DE1, DE9, and NO1 on average by a factor of 2.8 which can be caused by the uncertainties in spatial distribution of PCB emissions and rough spatial resolution of the model. In case of NO1 there is significant difference between the observed precipitation amount and used in model calculations (more than a factor of three) which complicates the comparison.

It should be noted that the comparison of calculated and measured concentrations in precipitation is complicated by several factors and should be considered as indicative. In particular, differences can be connected with the description of wet deposition process in the model, where precipitation is equally distributed in model grid cell with resolution 50x50 km^2 while in reality the rainfall can be restricted to rather limited area. Additional discrepancies can be caused by different amount of precipitation used in the model and obtained at the monitoring sites.

4.2.2. Lindane (γ-HCH)

The application of lindane (γ-HCH) for agricultural purposes has been banned or severely restricted in the majority of European countries during two recent decades. Only several countries, namely, the UK, Spain, Belgium, Croatia, and Romania provided information on their emission for recent years (2000-2006). Most of other European countries reported no use or application of lindane.

Model simulation of γ-HCH long-range transport and accumulation in environmental compartments within the Northern Hemisphere was performed with hemispheric MSCE-POP model for the period 1985-2006. Annual emissions of γ-HCH for 2006 and their spatial distribution used for model computations are described in Chapter 2. Modelling of γ-HCH distribution in European region for 2006

was carried out using the regional MSCE-POP model over the extended EMEP grid. Simulation results were preliminary compared with γ-HCH measurements of EMEP monitoring sites.

Though these data are not complete and are subject of significant uncertainties their application in model simulations can be useful for the description of pollution levels on the hemispheric scale and within the European region.

Air concentrations and deposition levels

Spatial distributions of annual mean γ-HCH air concentrations within the Northern Hemisphere and the EMEP grid for 2006 are presented in Fig. 4.24 a,b. The most significant levels of air concentrations (100 pg/m^3 and above) are characteristic of southern Canada, the UK, and Spain. Moderate annual air concentrations (20-50 pg/m^3) were obtained for the USA, Mexico, eastern part of China, and Western Europe. It can be seen that pollution transport from Chinese emission sources and possibly from other Southeast Asian countries can be essential for Pacific Ocean and under favourable meteorological conditions for the North America. The contribution of γ-HCH emissions of North American and European sources can be important for the pollution of Northern Atlantic and the Arctic region.

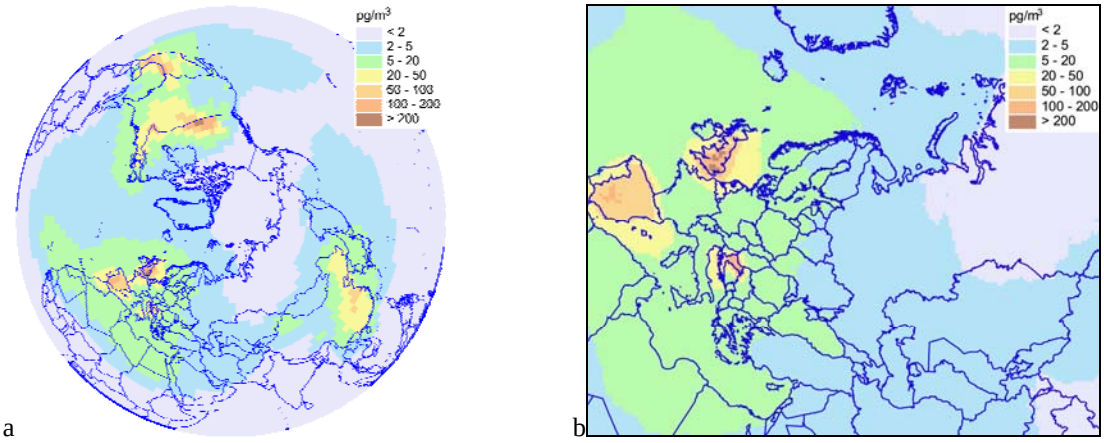


Fig. 4.24. *Spatial distribution of γ-HCH annual mean air concentrations within the Northern Hemisphere (a) and within the extended EMEP grid (b) for 2006 , pg/m^3*

Results of model simulations over the extended EMEP grid with finer spatial resolution 50x50 km^2 are shown in Fig 4.24b. It can be seen that similar to the hemispheric model results, elevated γ-HCH air concentrations (50 pg/m^3 and above) in 2006 are characteristic of the UK, Spain, and Croatia. Moderate levels of air concentrations were obtained for the countries of Western and Central Europe (5 – 20 pg/m^3). The countries of Eastern Europe and Central Asia are characterized by particularly low γ-HCH air concentrations (2-5 pg/m^3), which is mainly connected with the absence of information on emissions for these regions.

Levels of γ-HCH net annual deposition fluxes over the extended EMEP grid are shown in Fig 4.25. The most significant net deposition fluxes (2.5 g/km^2/y and above) are characteristic of the UK, Spain, the Netherlands, and Croatia. Essential level of net deposition fluxes are noted for other countries of Western and Central Europe. Low values of deposition fluxes (0 – 0.25 g/km^2/y) can be seen in countries of Eastern Europe and Central Asia and over the North Atlantic. For the Baltic, North, Mediterranean, Black, and Caspian seas the re-emission from seawater can be noted.

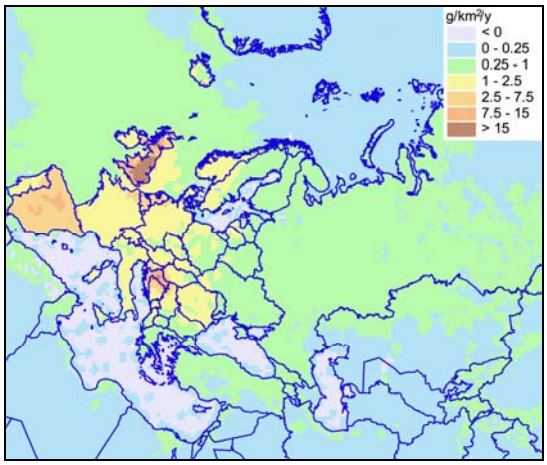


Fig. 4.25. *Spatial distribution of γ-HCH annual net deposition flux within the extended EMEP region for 2006, g/km²/y*

Comparison of modelling results with measurements

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. Information of 10 monitoring stations on measured γ-HCH concentrations in air and precipitation was used for the comparison. Results of the comparison of annual mean measured and computed concentrations are given in Fig. 4.26.

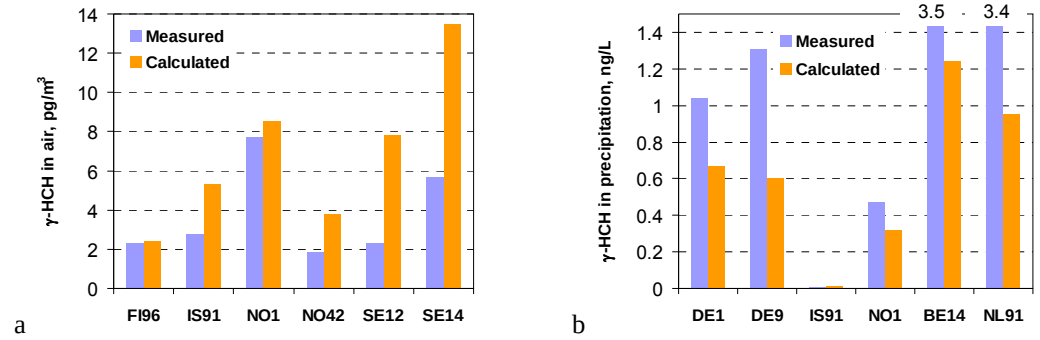


Fig. 4.26. *Comparison of computed annual mean air concentrations of γ-HCH in air, pg/m³ (a) and in precipitation, ng/L (b) with measurements of EMEP monitoring sites for 2006*

On the whole, it can be seen that the regional MSCE-POP model better describes the levels of γ-HCH air concentrations in comparison with the concentrations in precipitation. There is some tendency for overestimation of observed air concentrations by modelling results (on average by 80%). The most significant differences in air concentrations accounting for more than a factor of two are encountered for the sites SE14 and SE12. The reason of the overestimation can be connected with the uncertainties of lindane emissions, its spatial distribution, and seasonal variations especially for countries surrounding Sweden (the UK, France, Germany, etc.). Additional source of differences can be uncertainties in γ-HCH physical-chemical properties and their temperature dependence. For other monitoring sites the differences are lower than a factor of two.

In case of γ-HCH concentrations in precipitation the model tend to underestimate measured levels by a factor of 2.6 on the average. The most essential underestimation takes place for the sites BE14 and NL91. There is a need to note that significant part of measured concentrations in precipitation at BE14 and NL91 were below the detection limit. So the actual concentrations could be somewhat lower than the reported estimates. For other sites computed concentrations agree with measurements nearly within a factor of two.

Considering the comparison results it can be seen that parallel measurements of γ-HCH concentrations in air and precipitation in 2006 were performed only at two EMEP sites NO1 and IS91. Other sites carried out only one of these types of measurements. In case of IS91 the model predictions overestimate both observed air concentrations by approximately 90% and concentrations in precipitation by 60%. The values of annual mean calculated and measured γ-HCH concentrations in precipitation for IS91 are equal to 15 and 9 pg/L, respectively.

In case of NO1 the comparison of γ-HCH concentrations in air demonstrated rather small overestimation of observed values (by 10%). At the same time the comparison of concentrations in precipitation for this site is complicated by the significant difference in measured precipitation amount and used by the model (more than a factor of three). On the whole, taking into account results of this preliminary analysis and significant uncertainties in the emission data used for modelling, the level of agreement between the measurements and model results can be regarded as reasonable.

4.2.3. Hexachlorobenzene (HCB)

Evaluation of HCB pollution levels within the European region for 2006 was performed on the basis of combined hemispheric/regional modelling approach. The hemispheric MSCE-POP model was applied to evaluate the distribution of HCB from several groups of emission sources within the Northern Hemisphere for the period 1970-2006. The emission data used in model simulations for this period are described in Chapter 2.

The aim of this study was to investigate distribution of HCB over the extended EMEP grid with fine spatial resolution and to perform preliminary analysis of agreement of model results with available measurements of the EMEP monitoring network. Taking into account significant uncertainties in HCB emissions and its spatial distribution the modelling results on HCB long-range transport and pollution levels are currently of a preliminary character.

Air concentrations and deposition levels

Spatial distribution of annual mean HCB air concentrations in air within the Northern Hemisphere for 2006 is shown in Fig. 4.27a. Elevated levels of HCB air concentrations (50 pg/m^3 and above) are obtained for countries of Southeast Asia, European part of Russia, Spain, and Portugal. Significant level of HCB air concentrations (100 pg/m^3 and above) is characteristic of India. Moderate air concentrations (20 – 50 pg/m^3) of HCB can be noted for eastern part of the USA and countries of Western and Central Europe. Low values of air concentrations (below 15 pg/m^3) were calculated for eastern Russia, Canada, and the Arctic region.

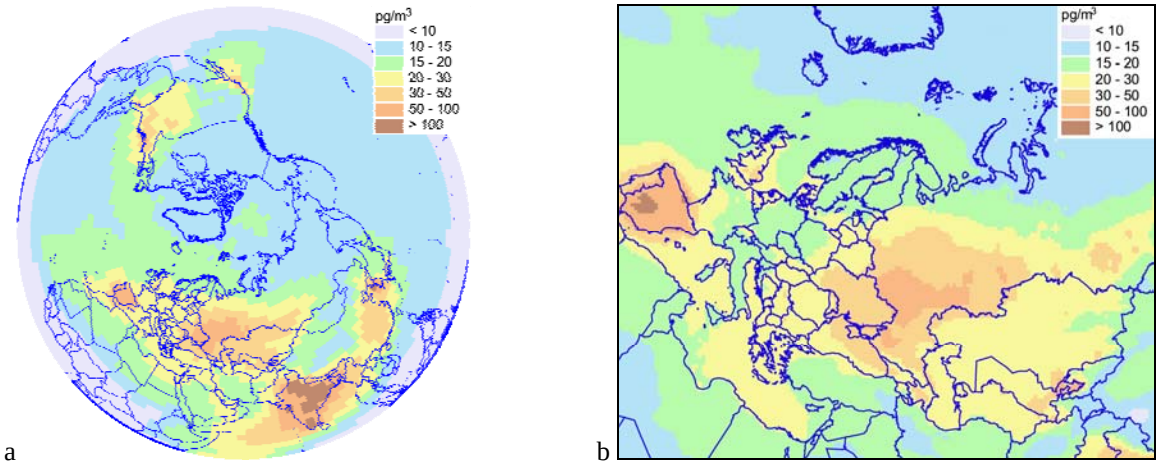


Fig. 4.27. *Spatial distribution of HCB annual mean air concentrations within the Northern Hemisphere (a) and the extended EMEP grid (b) for 2006, pg/m^3*

Modelling results over the extended EMEP grid with finer spatial resolution 50x50 km^2 are shown in Fig. 4.27b. It can be seen that levels of air concentrations over Spain and the Russian Federation are essentially higher than that over other European countries. These differences can be explained by the uncertainties in currently available information on HCB emissions and, in particular, by significantly different values of HCB emissions used in modelling. In particular, according to these emission data the levels of emission fluxes in Spain and the Russian Federation are essentially higher in comparison with other countries. Moreover, the contribution of annual HCB emissions of Spain and the Russian Federation to the total European emission for 2006 amounted to 28% and 36%, respectively. It can be seen that the emissions of these countries have substantial influence on the pollution levels of surrounding countries. For instance, countries of Eastern Europe and Central Asia are characterized by elevated HCB air concentrations (20-50 pg/m^3).

Net annual deposition fluxes of HCB over the extended EMEP grid are given in Fig 4.28. For the significant part of the extended EMEP grid the prevailing of HCB re-emission fluxes over the deposition fluxes can be noticed. This can be explained by essential volatility of this pollutant. The deposition fluxes are higher only in areas with high emission (Spain, the Russian Federation), over Northern Atlantic region, and in areas with comparatively low air temperatures.

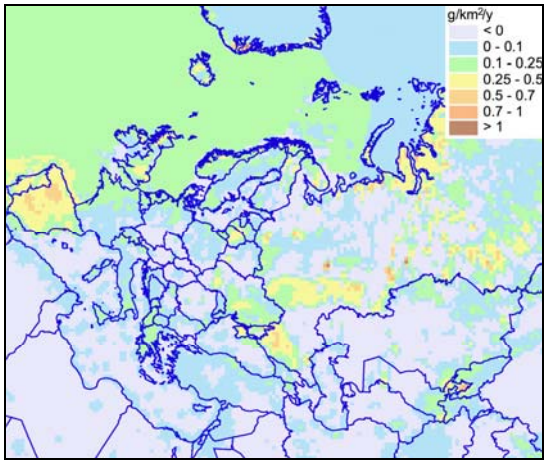


Fig. 4.28. *Spatial distribution of HCB annual net deposition flux within the extended EMEP region for 2006, g/km^2/y*

Comparison of modelling results with measurements

Preliminary comparison of obtained modelling results with measurements of HCB concentrations in air and in precipitation of 5 EMEP monitoring sites was performed. Summarized results of the comparison of annual mean values of concentrations are presented in Fig. 4.29.

Measurements of HCB concentrations in air were carried out at three EMEP sites NO1, IS91, and NO42. The model underestimates observed levels of HCB in air at sites NO1 and NO42 whereas the observed values at the site IS91 were overestimated by the model. The underestimation of observed concentrations can be connected with the uncertainties of the officially reported HCB emission.

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 NO1. However, analysis of deviations between model results and observed concentrations for the site NO1 is complicated by the significant difference between precipitation amount measured at the site and used in modelling (more than a factor of three).

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) can be noted.

Results of this preliminary comparison indicate that the levels of HCB emission in Europe are likely more significant than currently available emission data especially in countries of Western and Northern Europe. An indirect confirmation of this fact is that emissions in Spain and the Russian Federation are significantly higher than in other countries. Therefore, further work on the refinement of HCB emission data is required.

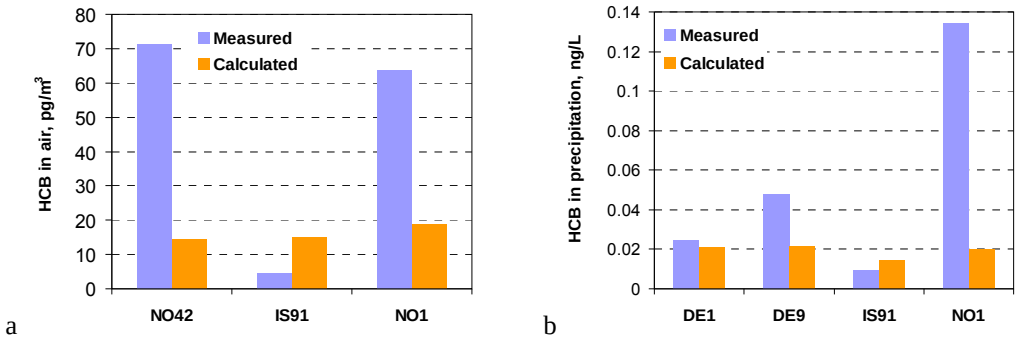


Fig. 4.29. *Comparison of computed annual mean air concentrations of HCB in air, pg/m^3 (a) and in precipitation, ng/L (b) with measurements of EMEP monitoring sites for 2005*

5. CO-OPERATION

5.1. Task Force on Hemispheric Transport of Air Pollutants

POP session

During the Joint International Conference on Intercontinental Transport of Atmospheric Mercury and Persistent Organic Pollutants held by UNEP and TFHTAP in Rome in April 2008 national experts from Canada, the Czech Republic, Japan, the Netherlands, Switzerland, the UK and representatives from CCC, MSC-E, European Commission and the Stockholm Convention contributed to the discussion on POP issues. A special session devoted to the further investigation of intercontinental transport of POPs was organized and chaired by MSC-E. The main aim of the POP session was to evaluate the progress in monitoring, emission inventories and modelling activities targeting at the 2009 assessment objectives “increased understanding of intercontinental transport of air pollution”.

Substantial progress in investigation of POP intercontinental transport has been achieved due to UNEP and EMEP research and operational monitoring activities. POP Global Monitoring Programme (GMP) was initiated under the Stockholm Convention. One of the important parts of UNEP and EMEP monitoring strategies was initiation of POP passive sampling campaigns on global (UNEP Global Atmospheric Passive Sampling) hemispheric (EMEP/CCC) and regional (RECETOX, the Czech Republic) scales.

The work on the improvement of POP emission inventories is also ongoing. At present global emission expert estimates on PAHs, PCBs, α-HCH, γ-HCH and HCB as well as emissions on polychlorinated dibenzo(p)dioxins and dibenzofurans in Europe and in North America are available. However, it was stressed that for the time being the activities on generation of POP global emissions were based on specific research and national initiatives only. It was recognized that the development of POP global emission inventories based on existing EMEP inventories in close cooperation with AMAP, ECHA (European Chemical Agency), the Stockholm Convention, UNEP Chemicals, and other international and national programmes was needed.

To improve the evaluation of pollution levels of the EMEP countries EMEP global modelling framework is generated by MSC-E and MSC-W following the recommendation of the EMEP Steering Body. The elaboration of nested global/regional/local approach to the assessment of pollution levels for long-living POPs is in progress.

For better understanding of POP atmospheric transport at global scale, further development of EMEP/POP model description of processes such as POP gas-particle partitioning, degradation and gas exchange with underlying surface are on going. A method of evaluation of atmospheric pathways of pollutants based on trajectory analysis is also under development.

ECHA (European Chemical Agency)

It should be noted that during this joint UNEP/TFHATP conference a representative of ECHA presented information on its activities in the framework of the EU new regulation REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) and possible ways of cooperation with the Convention.

REACH being a legislation of the European Union could be a driving force for international activity on protection of human health and the environment at the global level especially with regard to identification and restriction of substances of Very High Concern (SVHC) like POPs and PBTs. REACH is based on precautionary principle. It requires the industry to prove that their substances do not adversely affect human health or the environment before they are produced or supply. That in its turn will cause more systematical assessment of chemicals and involve best available techniques into this process. At that a substantial amount of data on physical-chemical, toxicological and ecotoxicological properties of chemicals and their emissions will be generated by industries and accumulated by ECHA. These data as well as advanced approaches to exposure estimation and risk characterization of SVHC developed for the REACH purposes could be very useful for the purposes of CLRTAP, for example, such as emission inventory, modelling activity, preparation of risk profiles and evaluation of new POP-like substances and others. Focus on identification and phasing out of SVHC is one of the common objectives of the CLRTAP and REACH. The CLRTAP Protocol on POPs as well as the Stockholm Convention covering a certain number of priority pollutants at the same time include provisions to widen the initial list of controlled substances to further identification of POPs. Therefore possible cooperation between the Convention on LRTAP and REACH on different scientific and technical issues could be of mutual benefit.

Participants of the conference recognized profit of close interaction with ECHA and stressed that the new EU regulation REACH could be one of the driving forces for the Convention

5.2. Task Force on Measurement and Modelling

MSC-E reported to the TFMM on the progress in the development of the EMEP global modelling framework and on output of joint technical meeting of CCC, MSC-E and MSC-W held in March 2008 in Gjerdrum (Norway). The main objectives of the meeting were to foster the collaboration between the scientists involved in the EMEP work, to discus common reporting to the Steering Body to EMEP and to agree further plans on improving EMEP global model activity.

Task Force participants were informed that Centres recognized that the EMEP global model should be developed as flexible, modular framework for evaluation of different pollutants and linked global, regional and local scales. It was noted that the current stage of the common work was focused on the unification of land cover, LAI data, testing of meteorological preprocessors, and on the development and testing of two pilot global models based on the existing MSC-E and MSC-W approaches. Detailed information on this issue is described in the Joint Technical report of the three EMEP Centres [*Tarrason and Gusev*, 2008].

5.3. OSPAR Commission

In 2008 at the request of the OSPAR Commission MSC-E contributed to the work of the Working Group on Inputs to the Marine Environment preparing a report on the assessment of the deposition of lindane (γ-HCH) and polychlorinated biphenyl (PCB-153) to the OSPAR maritime area in the period 1990-2005. The depositions and atmospheric transport were evaluated on the basis of EMEP officially submitted emission data and emission expert estimates. Besides, this report provided detailed information about emissions of selected POPs in the OSPAR countries and comparison of modelling results against measurement data collected by OSPAR Comprehensive Atmospheric Monitoring Programme (CAMP) in 2005.

The analysis of the emission data showed that annual emissions of PCB-153 from OSPAR countries decreased by around 77% in the period 1990-2005. The decline of PCB-153 total annual deposition following the emission reduction varied within the OSPAR maritime area from 3.3 to 3.7 times. Maximum reduction of total PCB-153 deposition took place in the Region V (Winder Atlantic). The reduction of net deposition flux was more significant and was accounted in the most regions for an about 4 times.

According to officially reported information and expert estimates γ-HCH emissions to the atmosphere decreased in the period 1990-2005 by almost 90% in the OSPAR countries. Total annual depositions of lindane to the OSPAR maritime area essentially declined in the considered period from 5.5 to 9.3 times depending on the particular region. Maximum decrease of deposition took place in the Region II (Greater North Sea) and the Region IV (Bay of Biscay). Following the essential reduction or elimination of γ-HCH emission substantial influence of re-emission could be noted for a number of sub-regions of the Region II (Greater North Sea).

Modelling results obtained in framework of this study are illustrated below.

The spatial distribution of total and net annual depositions of PCB-153 for 2005 is shown in Fig. 5.1. Maximum levels of PCB-153 deposition in 2005 can be noted for the Greater North Sea region ($5 \cdot 10^{-5}$ mg/m^2/y and higher). They have a pronounced declining gradient from Europe to the open sea in northern and western directions. The lowest values of deposition flux are characteristic of the Arctic region (about $1 \cdot 10^{-5}$ mg/m^2/y and lower).

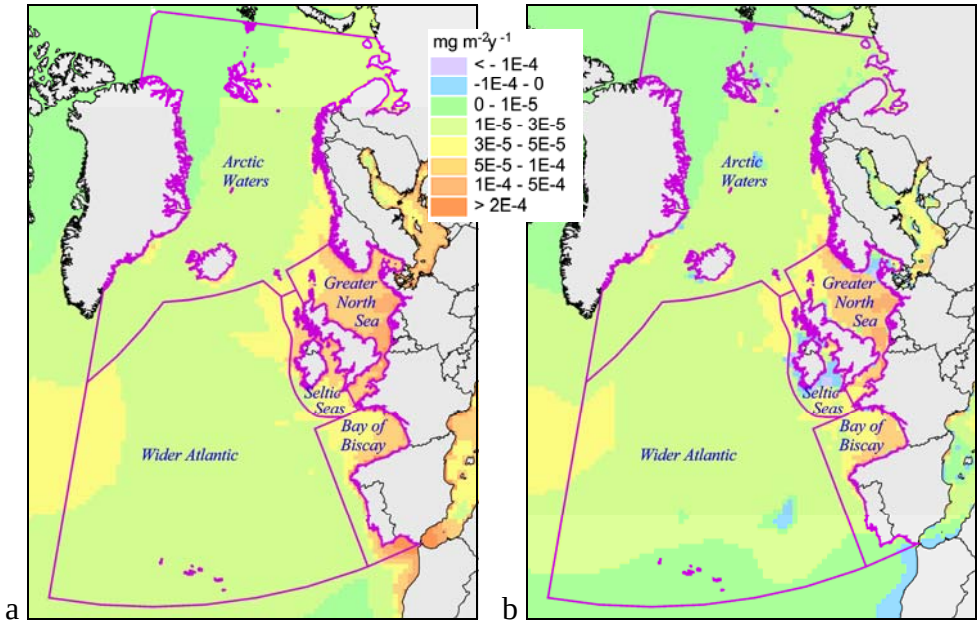


Fig. 5.1. *Spatial distribution of annual total deposition flux (a) and net deposition flux (b) of PCB-153 over the five main OSPAR regions in 2005, mg m^{-2} y^{-1}*

Long-term trends of total depositions and net deposition flux for γ-HCH in period 1990-2005 are presented in Fig. 5.2.

The report was approved by the OSPAR Commission, recommended to be published on its website and it was decided to include products of this work as contribution into the 2009 CAMP data assessment report.

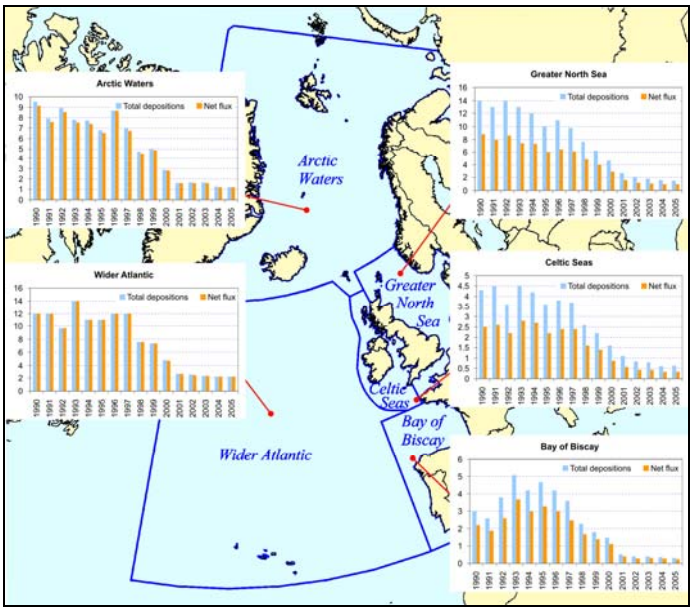


Fig. 5.2. *Time series of modelled total annual deposition and net deposition flux of γ-HCH to the five main OSPAR regions, t/y*

5.4. Helsinki Commission

According to the Memorandum of Understanding between the Baltic Marine Environment Protection Commission (HELCOM) and the United Nations Economic Commission for Europe on cooperation in the field of monitoring of air pollutants EMEP Centres (CCC, MSC-E and MSC-W) annually prepared a joint report on the evaluation of airborne pollution load to the Baltic See. MSC-E had the main responsibility for the evaluation of atmospheric transport and depositions of PCDD/Fs to the Baltic Sea. Officially reported emission data on PCDD/Fs to EMEP were used in simulations for the Helsinki Commission. Results on comparison of modelling against measurements were described.

Besides, the environmental indicator report with regard to temporal variations of PCDD/F emissions to the atmosphere and their depositions over the Baltic Sea in the period from 1990 to 2005 has been prepared. The indicator report is available in the Internet at the HELCOM web site [www.helcom.fi].

The most significant drop of PCDD/F emissions can be noted for Denmark (62%), Estonia (42%), and Sweden (35%). Some decrease of emission can also be noted for Germany (27%), Russia (25%), Poland (21%), and Finland (13%).

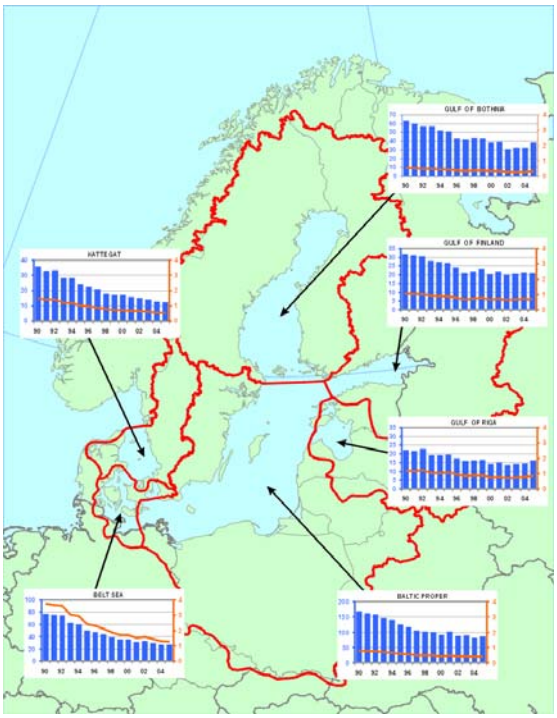


Fig. 5.3. *Time-series of computed total annual atmospheric deposition of PCDD/Fs to six sub-basins of the Baltic Sea for the period 1990-2005 in t/y as bars (left axis) and total deposition fluxes in μg TEQ/km^2/y as lines (right axis)*

Annual emissions of dioxins and furans have decreased in HELCOM countries during the period from 1990 to 2005 by 24%. In particular, the most significant changes of PCDD/F emissions can be noted for Denmark (62%), Estonia (42%), and Sweden (35%).

Total annual atmospheric depositions of PCDD/Fs to the Baltic Sea have decreased in the period 1990-2005 by 50% (Fig. 5.3). On the level of individual sub-basins the most significant drop in PCDD/F depositions took place for the Belt Sea (66%) and the Kattegat (65%). For other sub-basins the decrease of depositions varies from 28% to 49%. The highest levels of PCDD/F depositions over the Baltic Sea can be noted for its southern-western part (the Belt Sea). Lowest level of PCDD/F deposition fluxes is obtained for the Gulf of Bothnia. Among the HELCOM countries the most significant contributions to depositions over the Baltic Sea in 2005 belonged to Poland, Sweden, and Finland.

6. FUTURE ACTIVITIES

In order to further improve the quality of estimates of POP pollution levels in the EMEP region, the following activities are proposed for 2009:

1. Model development

    1.1. Further improve regional version of MSCE-POP model over the extended EMEP domain including preparation of input data for modelling, in particular, on sea currents.

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

    1.3. Further refine the description of POP gas/particle partitioning and deposition of POPs in gaseous form on the basis of the information on spatial and temporal aerosol distribution and its chemical composition.

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

    1.5. Further develop inverse modelling approach for the analysis of the agreement between measurements and modelling results.

2. Input data preparation

    2.1. Prepare spatial distributions of anthropogenic emission for modelling for 2007 based both on official and unofficial data.

    2.2. Compile measurement data on POPs in air and precipitation from national and international programs for the purpose of models evaluation.

    2.3. Continue to evaluate the POP passive measurements campaign on the hemispheric level and compare with modelling, evaluate the EMEP monitoring strategy in relation to the outcome of this campaign as well as the UNEP global monitoring strategy.

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

2.5. Prepare meteorological data for regional and global models based on the ECMWF analysis.

3. Evaluation of pollution

3.1. Prepare information on PAHs, PCBs, PCDD/Fs, HCB, and γ-HCH air concentrations and ecosystem-dependent depositions (in co-operation with the effect community) over the extended EMEP grid in 2007 with resolution 50x50 km. Compare modelling results with monitoring data.

3.2. Perform calculations of PCBs, PCDD/Fs, HCB, and γ-HCH dispersion at the hemispheric/global scale for evaluation of European pollution from global sources and boundary conditions for the regional (EMEP) modelling

3.3. Prepare country-to-country deposition matrices for PAHs, PCDD/Fs, and PCBs for 2007.

4. Co-operation

4.1. Continue to co-operate with TF HTAP on evaluation of the intercontinental transport of POPs.

4.2. Co-operate with international bodies: EU, ECHA, AMAP, HELCOM, OSPAR, Stockholm Convention, UNEP, WMO, and WHO.

4.3. Co-operate with national experts on POP issues, including support and training in EECCA countries.

CONCLUSIONS

This Status Report presents the progress in the evaluation of pollution levels and transboundary transport of POPs within the European region and at the hemispheric scale.

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

Monitoring of POPs

- Monitoring of POP concentrations in 2006 was performed at 15 monitoring sites among which only 6 sites made parallel measurements of POPs in air and precipitation. Even though the spatial distribution of the EMEP monitoring network for POPs has improved due to a new site in the Mediterranean area it is still need for additional sites in the South and Eastern Europe.
- A passive air sampling campaign, organized by EMEP/CCC in collaboration with the Lancaster University and the GAPS, was carried out across Europe during the summer of 2006. The key objectives of this campaign were to gain insight into the spatial patterns of POPs in European background air, to assess limitations of the current EMEP measurement network, and to evaluate the use of passive air samplers as a complementary and cost efficient tool regarding possible future monitoring strategies within EMEP. The campaign included measurements of PCBs, PAHs, HCB, HCHs, PBDEs, DDT, and various other organochlorine pesticides.
- In the course of this campaign, passive air samplers were deployed in 33 European countries at 85 background sites for 3 months during late summer of 2006. Furthermore, duplicate samples were deployed at 6 EMEP sites where POPs in air were measured on a regular basis. The PAS results from these sites will be compared with measured air concentrations, corresponding to the actual PAS deployment period.
- In 2006 measured PCB concentrations in the Czech Republic were much higher than those observed in the Nordic countries. It is explained by the high historical usage of PCBs in central Europe. The PCB28/PCB180 ratio tends to increase from south which confirms that there are marked differences in the long-range transport potential 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 γ-HCH measured at higher latitudes have also been observed in seawater.

Emission data

- Official information on emissions of PAHs, PCDD/Fs, HCB, PCBs, and HCHs for at least one year within the period from 1990 to 2006 was reported by 36 European countries and Canada. It can be noted that the number of countries submitting official emission data is gradually increasing. In particular, Georgia and Portugal have begun emission data reporting on PAHs and PCDD/Fs, and Italy – on HCB. 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 considered POPs tend to decrease from 1990 to 2006. In particular, emissions in the European region of four indicator PAHs decreased by 20 - 27% during this period depending on particular PAH, of PCDD/Fs by almost 50%, of HCB by 13%, of PCBs by 50%, and of γ-HCH by 98%.

Model development

- In the current year the work on the implementation of the TFMM recommendations on further development of MSCE-POP models was continued. In particular, the investigation of different approaches to model description of gas-particle partitioning (adsorption, absorption and combined approach) of POPs was performed. Modelling results suggested that the influence of absorption mechanism in gas-particle partitioning for the four indicator PAHs (B[a]P, B[b]F, B[k]F and I_P) seemed to be negligible. At the same time, for the other pollutants (PCBs, PCDD/Fs) absorption mechanism can noticeably change gas/particle partitioning.
- The possibility to use the CMAQ model for the preparation of the input data on aerosol particles and OH concentrations in the atmosphere with detailed spatial and temporal resolution for the regional MSCE-POP model was further elaborated.
- Investigations of possible influence of organic matter in rain water on wet deposition of POPs in gaseous phase were carried out. Modifications of model parameterization of wet deposition were considered and experimental model simulations were made. It was obtained that the sorption of POPs on the organic matter within the rain drops could lead to enhanced values of wet deposition fluxes. The comparison of these modelling results with measurements showed that the use of modified parameterization of wet deposition led in most cases to better agreement with observed concentrations in precipitation.
- Further work on the development of parameterization of POP re-suspension with aerosol particles was carried out. It was obtained that on average the contribution of POP re-suspension to the total re-emission flux was comparatively small. However, model results showed that it essentially varied over the Europe being comparable with re-volatilization flux from soil in some regions (e.g. in the UK). The comparison of computed B[a]P soil concentrations with measurements revealed that the MSCE-POP model tended to underestimate observed levels of B[a]P soil concentrations which could lead to relatively lower re-suspension fluxes.
- Appropriate modifications of the regional and hemispheric MSCE-POP models were performed as a result of the extension of the EMEP modelling domain. These modifications permitted to include the Central Asia countries (Kazakhstan, Turkmenistan, Uzbekistan, Kyrgyzstan, and Tajikistan) and the Asian part of Russia into routine POP long-range transport calculations.

Model assessment of POP pollution levels

- Model evaluation of environmental pollution levels was performed for the four indicator PAHs (B[a]P, B[b]F, B[k]F and I_P), PCDD/Fs (the mixture of all 17 toxic congeners), PCB-153, γ-HCH and HCB for 2006. Estimates of transboundary transport for PAHs were obtained at the regional scale since these pollutants are mainly particle-bound. For the rest of selected POPs the evaluation of contamination of the EMEP region was carried out on the basis of hemispheric/regional modelling approach.
- Annual mean B[a]P concentrations in surface atmospheric layer in 2006 within the European region varied from 0.01 to 1 ng/m^3. Average level of B[a]P air concentrations over the European countries was about 0.4 ng/m^3. Elevated B[a]P air concentrations (0.5 ng/m^3 and above) were obtained for the countries in Central and Eastern Europe. Spatial distribution of pollution levels for the rest three indicator PAHs (B[b]F, B[k]F, and I_P) in 2006 was similar to that of B[a]P. The levels of B[k]F air concentrations were somewhat lower comparing to the air concentrations of the rest three indicator PAHs.

- Levels of B[a]P deposition fluxes in 2006 within the European region differed from 1 g/km^2/y to about 150 g/km^2/y. High values of deposition fluxes (20 – 150 g/km2/y) were characteristic of the Central, Southern, and Eastern Europe. The contribution of transboundary transport to B[a]P air concentrations and depositions in particular countries was essential and varied typically from 20 to 70%.
- The comparison of calculated air concentrations and deposition fluxes of B[a]P in 2006 with data of EMEP monitoring sites showed reasonable agreement between calculations and measurements. Almost all calculated annual mean air concentrations and deposition fluxes agree with measurements within a factor of two. For the stations SE12, FI96 and CZ3 calculated and observed values differ not more than by 25%.
- Average level of PCDD/F annual mean air concentrations over European countries in 2006 was about 1 fg TEQ/m^3. Elevated levels of PCDD/F air concentrations were obtained for the Central, Southern, and Eastern Europe whereas values of air concentrations below 1 fg TEQ/m^3 were characteristic of the Western and Northern Europe.
- Calculated PCDD/F deposition fluxes ranged from 0.1 – 1 ng TEQ/m^2/y in the Western and Northern Europe to more than 3 ng TEQ/m^2/y in some regions of the Central, Southern and Eastern Europe. In comparison with modelling results for 2005 contamination levels in most of the European countries in 2006 did not change significantly.
- The transboundary transport of PCDD/Fs was evaluated taking into account national anthropogenic emissions of European countries, non-EMEP anthropogenic sources, and re-emissions. The contribution of transboundary transport to the pollution of the EMEP countries in 2006 ranged from 3% to 60%. Non-EMEP sources contributed to the pollution levels up to 33%, and re-emission − from 30% to 70%. It can be noted that the re-emission of PCDD/Fs is essential and should be taken into account in the assessment of pollution levels in the European countries.
- Estimates of PCB-153 intercontinental transport and pollution levels within the European region for 2006 were obtained using unofficial inventory of global PCB emission. Most significant levels of air concentrations (3.6 pg/m^3 and above) are characteristic of the European region. Essential air concentrations of PCB-153 can be noticed for the Northern Atlantic, Southwest Asia, and the Central Asia countries which can be explained by the long-range transport of the pollutant from the areas with significant PCB emission. Computed PCB-153 air concentrations reasonably agree with measurements for most of the sites. Significant spatial correlation between observations and model results can be noted.
- The application of lindane (γ-HCH) for agricultural purposes has been banned or severely restricted in the majority of European countries during two recent decades. Only several countries, namely, the UK, Spain, Belgium, Croatia, and Romania provided information on their emission for recent years (2000-2006), while other European countries reported no use or application of lindane. Significant levels of air concentrations (50-100 pg/m^3 and above) are characteristic of some regions of North America, the Western and Southern Europe. The contribution of γ-HCH emissions of North American and European sources can be important for the pollution of Northern Atlantic and the Arctic region.
- Investigation of HCB distribution within the Northern Hemisphere and the extended EMEP domain for 2006 was carried out on the basis of officially reported emissions complemented by unofficial estimates. Elevated levels of HCB air concentrations (50 pg/m^3 and above) were obtained for countries of Southeast Asia, European part of Russia, Spain, and Portugal. Preliminary comparison of obtained modelling results with measurements of HCB concentrations in air and in precipitation showed that the model tended to underestimate observed levels of concentrations.

Taking into account significant uncertainties in HCB emissions and its spatial distribution the modelling results on HCB long-range transport and pollution levels are of a preliminary character.

Co-operation

- MSC-E contributed to the Joint International Conference on Intercontinental Transport of Atmospheric Mercury and Persistent Organic Pollutants held by UNEP and TFHTAP and chaired a special session devoted to the further investigation of intercontinental transport of POPs. POP session was focused on the evaluation of the progress in monitoring, emission inventories, modelling activities and cooperation with relevant international organizations such as cooperation AMAP, ECHA, the Stockholm Convention, UNEP Chemicals.
- Progress and future plans in the development of the EMEP global modelling framework were discussed at the EMEP Task Force on Measurements and Modelling in spring this year. It was recognized that the EMEP global model should be developed as flexible, modular framework for evaluation of different pollutants and linked global, regional and local scales and should be based on the existing MSC-E and MSC-W approaches.
- In the framework of the cooperation between the OSPAR Commission and EMEP, MSC-E carried out the work on the assessment of the atmospheric depositions of lindane (γ-HCH) and polychlorinated biphenyl (PCB-153) to the OSPAR maritime area in the period 1990-2005. The results of this work were considered at the OSPAR INPUT meeting, approved by the OSPAR Commission, and recommended to be included as contribution into the 2009 CAMP data assessment report.
- EMEP Centres continued preparation of joint report on the evaluation of airborne pollution loads to the Baltic Sea for Helsinki Commission. MSC-E prepared information on the assessment of atmospheric depositions of dioxins and furans for 2006. Moreover, the environmental indicator reports with regard to temporal variations of PCDD/F emissions of HELCOM countries to the atmosphere and their depositions over the Baltic Sea in the period from 1990 to 2006 were updated.

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ANNEX A

EMEP work-plan for POPs in 2008

[ECE/EB.AIR/GE.1/2007/10]

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 France 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 2007 monitoring data (CCC, MSC-W, MSC-E), and assess uncertainties relating to, and the representativeness of, monitoring data on heavy metals and POPs (CCC, MSC-E);

(k) Review heavy metals and persistent organic pollutants (POPs) monitoring data generated in the framework of the Working Group on Effects, and make recommendations for their use in model validation (CCC, MSC-E);

(m) Support the organization of 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);

(n) Continue to evaluate the POPs passive measurements campaign on the hemispheric level and compare with modelling, evaluate the EMEP monitoring strategy in relation to the outcome of this campaign as well as the UNEP global monitoring strategy, and report conclusions to the Task Force (MSC-E, CCC).

Main activities and time schedule for atmospheric modelling in general:

(b) Further develop and validate the regional as well as hemispheric/global scale EMEP models, and report on progress, taking into account the recommendations of the EMEP Task Force experts (MSC-E, WSC-W);

(e) Initiate work for a common EMEP global modelling system (MSC-E and MSC-W).

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 2006 for air concentrations and depositions over Europe, comparison of modelling results (concentration in air and precipitation, deposition fluxes) with monitoring data,

country-to-country matrices, and estimates of depositions on marginal seas (Mediterranean, Baltic, Black and North Seas) (MSC-East, CCC);

(b) Evaluate dispersion of PCBs, HCB and γ-HCH at the hemispheric scale, evaluate the EMEP regional pollution in 2006 by regional calculations with the use of boundary and initial conditions obtained by hemispheric modelling, and present the results to the Task Force on Hemispheric Transport of Air Pollution (MSC-East);

(c) Evaluate ecosystem-dependent depositions of POPs in cooperation with the Working Group on Effects (MSC-East, CCC);

(d) Support the work of the Task Force on POPs in the evaluation of possible new POPs (MSC-East);

(e) Further develop the POPs regional model in accordance with the recommendations of the model review, refine the datasets of physical-chemical properties used in modelling, and continue the development of the model parameterization for POPs re-suspension (MSC-East);

(f) Refine the spatial and temporal aerosol distribution with regard to its chemical speciation for more precise description of POPs particulate degradation and gas/particle partitioning (MSC-East);

(g) Investigate possible approaches to the evaluation of the influence of climate change on the fate and behaviour of POPs (MSC-East);

(h) Prepare input data for the model application, use the ECMWF re-analysis for the data preprocessing, and prepare POPs emission data set for modelling purposes on the basis of both official and expert estimates (MSC-East);

(i) Prepare scientific papers on the results of the POPs model intercomparison study focused on the interpretation of similarities and differences of participating models (MSC-East, Parties);

(j) Prepare meteorological and geophysical data for hemispheric/global modelling (MSC-East).

2.4. Hemispheric transport of air pollution

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 HTAP Model Intercomparison and model evaluation exercise (TF HTAP; CCC, MSC-East, MSC-West);

(d) Continue the work on an integrated observation system relevant for the assessment of intercontinental transport of air pollution, including the development of intercomparison tools and information infrastructure, and an observational database for model evaluation for ozone, PM, Hg and POPs, as well as improved emission inventories;

(h) Hold the fourth Task Force meeting and consider assessing intercontinental transport of air pollution by Hg and POPs in April 2008 in Rome.

Annex B

COUNTRY-TO-COUNTRY DEPOSITION MATRICES FOR 2006

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

Country/Region/Sea	Code	Country/Region/Sea	Code
Albania	AL	Lithuania	LT
Armenia	AM	Luxembourg	LU
Austria	AT	Malta	MT
Azerbaijan	AZ	Monaco	MC
Belarus	BY	Netherlands	NL
Belgium	BE	Norway	NO
Bosnia and Herzegovina	BA	Poland	PL
Bulgaria	BG	Portugal	PT
Croatia	HR	Republic of Moldova	MD
Cyprus	CY	Romania	RO
Czech Republic	CZ	Russian Federation (European part)	RU
Denmark	DK	Russian Federation (Asian part)	RUA
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	Tajikistan	TJ
Ireland	IE	Turkey	TR
Italy	IT	Turkmenistan	TM
Kazakhstan	KZ	Ukraine	UA
Kyrgyzstan	KZ	United Kingdom	GB
Latvia	LV	Uzbekistan	UZ

***Table B.2**. Matrix of B[a]P country-to-country depositions in 2006, kg/y*

Receptors ↓ Emitters →

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CS	CY	CZ	DE	DK	
AL	**482.4**	0.09	0.81	0.13	4.95	0.37	27.72	1.52	0.02	95.66	1.78	1.82	4.59	0.34	**AL**
AM	0.04	**436.6**	0.03	82.84	0.05	0.05	0.27	0.44	0.00	0.19	2.31	0.11	0.42	0.09	**AM**
AT	1.57	0.13	**631.4**	0.26	7.12	16.35	2.94	8.01	1.89	10.65	0.33	128.2	514.3	3.90	**AT**
AZ	0.11	60.51	0.15	**1012**	0.17	0.22	0.85	2.20	0.00	0.62	3.63	0.50	1.96	0.39	**AZ**
BA	20.91	0.12	9.31	0.22	**930**	2.45	13.78	4.60	0.11	164.7	1.28	17.96	33.77	1.69	**BA**
BE	0.17	0.02	2.07	0.05	0.56	**1135**	0.26	1.34	0.20	0.63	0.04	3.62	197.4	2.28	**BE**
BG	14.84	0.45	4.17	0.94	13.54	2.34	**1943**	14.62	0.07	187.9	4.13	10.98	28.08	2.29	**BG**
BY	2.40	0.28	11.37	0.72	8.20	12.29	8.36	**4183**	0.27	18.07	0.28	48.17	126.5	24.29	**BY**
CH	0.45	0.02	8.96	0.04	1.33	5.34	0.70	0.94	**22.49**	1.42	0.09	2.66	87.52	0.47	**CH**
CS	99.55	0.32	9.75	0.56	158.8	3.91	125.8	8.35	0.13	**2089**	3.48	22.04	48.29	2.76	**CS**
CY	0.04	0.14	0.01	0.09	0.04	0.01	0.08	0.06	0.00	0.10	**1306**	0.03	0.11	0.01	**CY**
CZ	1.39	0.12	91.46	0.24	5.96	18.78	3.25	13.08	1.08	12.00	0.21	**1423**	599.8	7.30	**CZ**
DE	2.28	0.33	129.3	0.71	7.12	452.5	3.67	27.36	15.60	10.09	0.44	217.5	**13769**	104.2	**DE**
DK	0.15	0.04	1.04	0.09	0.53	22.38	0.25	3.60	0.09	0.73	0.02	3.87	155	**726.2**	**DK**
EE	0.30	0.03	2.49	0.11	0.92	6.08	0.96	39.20	0.10	1.88	0.03	10.21	61.63	9.62	**EE**
ES	2.27	0.12	3.71	0.24	5.83	12.24	3.16	1.66	0.32	6.43	0.22	4.86	60.65	4.01	**ES**
FI	1.07	0.19	7.00	0.54	3.26	24.74	4.02	83.87	0.35	7.45	0.13	26.44	191.2	42.54	**FI**
FR	5.23	0.32	23.25	0.67	18.30	224.5	7.78	9.25	9.30	19.25	0.68	29.47	717.8	10.49	**FR**
GB	0.33	0.07	3.52	0.15	1.04	69.53	0.88	5.53	0.25	1.70	0.17	9.19	164.9	14.96	**GB**
GE	0.25	64.81	0.29	84.64	0.39	0.36	2.13	3.16	0.01	1.51	3.18	1.17	3.23	0.86	**GE**
GR	40.58	0.38	2.09	0.75	5.30	1.13	99.90	8.37	0.05	44.89	12.64	5.70	14.22	1.37	**GR**
HR	10.79	0.10	23.70	0.21	221.6	2.49	7.24	4.83	0.15	76.43	0.46	25.48	40.15	1.68	**HR**
HU	5.66	0.22	64.43	0.40	49.99	6.31	12.45	11.65	0.29	136.0	0.72	64.49	95.04	4.19	**HU**
IE	0.08	0.01	0.71	0.02	0.21	9.37	0.18	0.89	0.06	0.31	0.02	1.59	30.63	2.38	**IE**
IS	0.09	0.03	0.48	0.08	0.21	2.34	0.21	1.43	0.04	0.35	0.02	1.41	14.44	2.96	**IS**
IT	25.34	0.28	53.63	0.58	54.98	6.75	24.28	8.65	2.57	54.02	1.40	30.29	121.9	2.69	**IT**
KY	0.01	0.22	0.01	0.61	0.01	0.02	0.03	0.10	0.00	0.03	0.15	0.03	0.13	0.02	**KY**
KZ	0.58	3.77	2.80	21.52	1.85	4.86	3.77	47.51	0.09	4.52	1.39	10.09	42.97	8.02	**KZ**
LT	0.54	0.04	4.61	0.13	1.64	6.24	1.68	173.3	0.14	3.65	0.03	21.25	66.23	11.23	**LT**
LU	0.02	0.003	0.30	0.01	0.06	8.67	0.03	0.12	0.03	0.07	0.01	0.45	27.50	0.13	**LU**
LV	0.45	0.03	3.85	0.12	1.43	6.75	1.39	103.6	0.14	2.96	0.03	16.84	70.65	10.82	**LV**
MC	0.00	0.00	0.002	0.00	0.002	0.00	0.001	0.00	0.00	0.002	0.00	0.002	0.01	0.00	**MC**
MD	0.53	0.09	0.64	0.21	0.85	0.41	3.73	9.70	0.01	2.93	0.16	2.54	5.66	1.35	**MD**
MK	46.69	0.06	0.80	0.11	3.49	0.36	86.54	1.51	0.01	102.9	1.08	2.11	4.77	0.37	**MK**
MT	0.01	0.00	0.002	0.00	0.01	0.002	0.01	0.002	0.00	0.01	0.001	0.004	0.02	0.001	**MT**
NL	0.11	0.02	1.32	0.04	0.39	339.9	0.18	1.23	0.10	0.49	0.03	3.01	297.5	3.78	**NL**
NO	1.14	0.24	8.53	0.63	4.09	65.67	2.25	34.7	0.51	6.05	0.19	24.38	329.6	127.8	**NO**
PL	3.72	0.39	53.26	0.90	17.75	44.39	8.56	255	1.20	36.70	0.20	587.6	772.6	96.87	**PL**
PT	0.18	0.01	0.45	0.02	0.48	1.33	0.27	0.20	0.04	0.51	0.02	0.61	8.24	0.52	**PT**
RO	14.76	0.62	13.18	1.24	43.22	6.36	73.45	37.62	0.25	235.7	1.52	34.61	82.10	7.30	**RO**
RU	8.70	23.57	41.68	90.28	26.56	76.44	33.77	1324	1.36	58.89	8.05	154.2	672.6	105.0	**RU**
RUA	1.99	2.99	7.21	14.44	5.69	13.57	8.05	98.79	0.24	12.71	2.26	22.45	108.3	17.79	**RUA**
SE	0.76	0.28	10.87	0.80	3.26	75.58	2.27	78.51	0.59	6.30	0.18	42.17	522.6	324.6	**SE**
SI	1.17	0.06	46.35	0.13	9.19	1.17	1.69	2.30	0.09	7.51	0.13	14.01	26.08	0.68	**SI**
SK	2.54	0.07	31.66	0.15	14.35	4.66	5.62	9.02	0.20	32.62	0.12	139.5	72.16	4.40	**SK**
TJ	0.00	0.07	0.003	0.27	0.004	0.01	0.01	0.04	0.00	0.01	0.05	0.01	0.04	0.01	**TJ**
TM	0.04	1.68	0.12	8.24	0.08	0.23	0.27	1.91	0.004	0.24	0.46	0.44	1.88	0.32	**TM**
TR	3.40	130.5	2.29	27.15	3.77	2.22	36.4	15.61	0.06	16.17	176.1	6.26	22.65	2.87	**TR**
UA	5.21	1.4	16.82	3.37	19.64	12.85	24	455.9	0.38	46.06	1.35	63.03	155.5	30.34	**UA**
UZ	0.03	0.83	0.12	4.1	0.07	0.23	0.23	1.73	0.00	0.22	0.28	0.46	1.93	0.36	**UZ**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CS**	**CY**	**CZ**	**DE**	**DK**	

***Table B.2**. Matrix of B[a]P country-to-country depositions in 2006, kg/y (continued)*

Receptors ↓ Emitters →

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KY	
AL	0.19	1.24	0.12	0.82	0.22	0.01	42.69	1.83	4.51	0.13	0.00	55.47	0.003	**AL**
AM	0.06	0.05	0.03	0.04	0.04	1.94	0.19	0.03	0.14	0.03	0.00	0.21	0.02	**AM**
AT	1.19	7.85	0.52	15.83	5.54	0.01	1.50	15.59	62.46	2.20	0.01	170	0.01	**AT**
AZ	0.32	0.21	0.18	0.19	0.19	3.24	0.56	0.12	0.56	0.12	0.00	0.84	0.1	**AZ**
BA	0.49	2.97	0.31	2.79	1.15	0.02	10.40	113.4	64.79	0.57	0.00	124.4	0.01	**BA**
BE	0.49	11.09	0.27	75.04	14.86	0.002	0.19	0.53	1.06	3.01	0.01	6.98	0.002	**BE**
BG	1.67	1.29	1.00	1.77	1.33	0.08	74.30	5.90	28.41	0.77	0.00	35.6	0.03	**BG**
BY	34.84	6.53	13.81	9.46	6.96	0.04	3.71	8.30	44.31	3.59	0.03	34.8	0.05	**BY**
CH	0.38	7.37	0.14	37.21	2.22	0.001	0.48	1.79	2.00	0.85	0.00	176.6	0.002	**CH**
CS	0.89	3.29	0.58	3.47	2.00	0.04	33.26	46.22	112.70	1.10	0.01	106.4	0.01	**CS**
CY	0.01	0.01	0.01	0.01	0.01	0.004	0.27	0.02	0.07	0.00	0.00	0.11	0.001	**CY**
CZ	1.62	6.91	0.81	15.70	6.91	0.01	1.24	10.09	58.13	3.18	0.01	37.18	0.01	**CZ**
DE	9.91	72.02	4.78	264.3	65.09	0.03	2.33	7.49	24.07	22.88	0.11	110.5	0.03	**DE**
DK	2.06	6.70	1.40	10.24	12.65	0.003	0.14	0.50	1.74	4.89	0.03	4.35	0.003	**DK**
EE	**979.9**	2.99	37.19	3.98	2.49	0.004	0.39	1.06	4.37	1.05	0.01	9.10	0.01	**EE**
ES	0.36	**5627**	0.35	49.59	4.67	0.01	3.09	4.77	6.15	3.12	0.03	71.93	0.01	**ES**
FI	226.0	13.63	**1664**	16.68	16.74	0.03	1.17	3.32	13.00	8.36	0.13	29.53	0.12	**FI**
FR	2.78	396.3	1.49	**2420**	46.95	0.03	5.29	18.73	25.65	18.22	0.08	433.9	0.02	**FR**
GB	4.34	66.48	3.61	54.12	**1117**	0.01	0.56	1.14	3.60	246.8	0.16	12.11	0.02	**GB**
GE	0.41	0.31	0.20	0.28	0.33	**40.27**	1.01	0.24	1.32	0.23	0.00	2.21	0.03	**GE**
GR	1.09	2.37	0.64	1.77	0.71	0.05	**1275**	2.69	11.10	0.43	0.00	49.14	0.03	**GR**
HR	0.50	4.58	0.28	3.48	1.19	0.01	5.39	**547.9**	123.1	0.55	0.00	219.3	0.005	**HR**
HU	0.95	4.68	0.59	6.01	2.78	0.03	4.95	102.6	**1980**	1.37	0.01	86.93	0.01	**HU**
IE	0.78	16.65	0.51	8.02	42.17	0.001	0.17	0.21	0.58	**918.4**	0.05	2.48	0.004	**IE**
IS	0.90	7.66	1.52	3.25	4.37	0.003	0.16	0.22	0.62	4.65	**15.57**	2.81	0.11	**IS**
IT	1.19	13.46	0.62	19.50	2.58	0.03	30.17	56.65	53.43	1.16	0.01	**9045**	0.03	**IT**
KY	0.01	0.03	0.01	0.02	0.01	0.01	0.04	0.01	0.03	0.01	0.00	0.23	**1069**	**KY**
KZ	9.50	4.15	6.88	4.06	3.53	0.47	1.14	1.65	8.69	2.09	0.03	17.28	297.8	**KZ**
LT	14.12	2.83	5.21	4.59	2.99	0.004	0.64	1.93	9.94	1.33	0.01	15.69	0.02	**LT**
LU	0.04	0.79	0.02	9.27	0.46	0.00	0.02	0.06	0.12	0.13	0.00	0.96	0.00	**LU**
LV	105.6	3.13	12.75	4.81	2.95	0.005	0.57	1.61	7.38	1.20	0.01	16.63	0.02	**LV**
MC	0.00	0.002	0.00	0.01	0.00	0.00	0.00	0.002	0.003	0.00	0.00	0.15	0.00	**MC**
MD	0.66	0.26	0.35	0.35	0.28	0.01	0.99	0.56	3.43	0.19	0.00	8.96	0.005	**MD**
MK	0.19	0.45	0.12	0.41	0.20	0.01	52.57	1.35	5.44	0.11	0.00	26.82	0.003	**MK**
MT	0.00	0.004	0.00	0.003	0.00	0.00	0.02	0.004	0.006	0.00	0.00	0.26	0.00	**MT**
NL	0.69	9.00	0.36	28.89	12.75	0.002	0.10	0.36	0.93	3.07	0.01	5.47	0.003	**NL**
NO	21.04	42.85	40.57	42.20	65.32	0.02	1.10	3.92	13.44	37.82	0.32	41.82	0.13	**NO**
PL	10.98	13.61	5.87	28.87	17.88	0.04	3.24	22.94	131.7	8.53	0.04	131.6	0.05	**PL**
PT	0.04	181.08	0.05	2.58	0.49	0.001	0.32	0.41	0.52	0.31	0.00	6.36	0.001	**PT**
RO	3.23	3.78	2.01	5.49	3.47	0.09	14.97	20.21	156.9	2.07	0.01	152.5	0.03	**RO**
RU	599.3	46.03	437.2	56.64	43.60	6.23	14.54	24.66	114.1	23.32	0.35	208.0	3.45	**RU**
RUA	35.48	10.82	39.46	10.63	9.94	0.39	3.10	4.92	21.70	6.11	0.13	52.63	35.43	**RUA**
SE	86.22	28.83	214.0	40.59	42.72	0.03	0.79	3.64	16.16	21.07	0.20	37.65	0.12	**SE**
SI	0.29	1.79	0.13	1.53	0.49	0.01	1.13	68.39	29.36	0.21	0.00	183.3	0.003	**SI**
SK	0.78	2.17	0.46	3.91	1.91	0.01	2.14	20.26	234.5	0.90	0.00	50.71	0.01	**SK**
TJ	0.00	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.08	39.24	**TJ**
TM	0.44	0.17	0.11	0.17	0.20	0.12	0.16	0.07	0.34	0.11	0.00	0.80	2.60	**TM**
TR	1.83	1.62	1.34	2.01	1.45	2.22	50.18	2.17	10.08	0.90	0.01	52.52	0.20	**TR**
UA	18.58	7.30	9.67	10.30	7.75	0.28	8.95	16.76	120.6	4.52	0.03	132.1	0.16	**UA**
UZ	0.44	0.17	0.27	0.18	0.19	0.08	0.11	0.06	0.38	0.11	0.00	0.82	172.4	**UZ**
	EE	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KY**	

***Table B.2**. Matrix of B[a]P country-to-country depositions in 2006, kg/y (continued)*

Receptors ↓ Emitters →

	KZ	LT	LU	LV	MC	MD	MK	NL	NO	PL	PT	RO	
AL	0.13	0.23	0.02	0.54	0.00	0.48	36.78	0.24	0.06	7.97	0.02	14.86	**AL**
AM	0.33	0.07	0.00	0.18	0.00	0.07	0.01	0.03	0.01	0.95	0.00	0.75	**AM**
AT	0.29	3.04	1.65	6.98	0.00	0.54	0.51	9.05	0.94	179.9	0.34	13.33	**AT**
AZ	3.64	0.32	0.01	0.94	0.00	0.24	0.06	0.14	0.07	4.21	0.01	3.01	**AZ**
BA	0.24	1.01	0.21	2.13	0.00	0.72	2.51	2.06	0.32	68.94	0.09	33.86	**BA**
BE	0.07	0.66	23.36	1.81	0.00	0.04	0.04	88.85	0.61	12.90	0.48	0.79	**BE**
BG	1.37	2.33	0.19	5.64	0.00	8.48	30.66	2.00	0.49	66.82	0.07	446.9	**BG**
BY	2.80	241.23	0.94	325.55	0.00	7.06	1.02	11.93	4.32	969	0.40	67.85	**BY**
CH	0.06	0.33	0.76	1.17	0.00	0.08	0.14	2.24	0.21	8.85	0.43	2.11	**CH**
CS	0.44	1.38	0.29	3.05	0.00	2.60	41.52	2.94	0.45	77.63	0.08	187.9	**CS**
CY	0.01	0.01	0.00	0.02	0.00	0.01	0.01	0.01	0.00	0.14	0.00	0.16	**CY**
CZ	0.38	4.88	1.82	9.54	0.00	0.57	0.50	14.93	1.36	705.5	0.24	13.82	**CZ**
DE	1.15	13.66	65.27	37.92	0.00	0.74	0.50	476.2	9.45	549.1	2.65	13.28	**DE**
DK	0.12	1.72	0.70	4.83	0.00	0.06	0.04	27.08	6.18	42.23	0.42	1.06	**DK**
EE	0.55	38.81	0.52	458.8	0.00	0.33	0.13	6.71	1.98	138.8	0.23	4.29	**EE**
ES	0.26	0.38	0.75	1.03	0.00	0.24	0.55	7.19	0.74	14.59	135	6.12	**ES**
FI	3.89	50.79	1.62	250.5	0.00	1.22	0.53	26.17	19.03	307.7	1.10	17.55	**FI**
FR	0.76	3.86	54.14	9.73	0.005	0.75	1.44	61.75	2.71	96.39	10.45	21.80	**FR**
GB	0.39	2.98	2.60	11.11	0.00	0.24	0.11	65.45	6.47	58.47	5.64	4.04	**GB**
GE	0.91	0.86	0.03	2.45	0.00	1.01	0.20	0.34	0.21	16.47	0.04	14.40	**GE**
GR	1.37	1.21	0.09	2.94	0.00	2.88	55.46	0.88	0.27	29.57	0.06	65.07	**GR**
HR	0.24	1.31	0.26	2.71	0.00	0.58	1.37	1.99	0.34	82.23	0.12	23.65	**HR**
HU	0.38	2.73	0.56	5.36	0.00	1.05	1.93	4.86	0.66	235.1	0.21	121.1	**HU**
IE	0.07	0.44	0.55	1.73	0.00	0.04	0.02	5.97	0.99	6.40	2.06	0.62	**IE**
IS	1.33	0.72	0.20	2.59	0.00	0.04	0.03	2.51	2.07	14.29	0.88	0.64	**IS**
IT	1.06	3.18	1.03	7.48	0.003	2.16	8.57	5.58	0.92	132	1.69	59.55	**IT**
KY	155.2	0.03	0.00	0.09	0.00	0.02	0.01	0.02	0.01	0.45	0.01	0.24	**KY**
KZ	**5635**	15.79	0.47	45.37	0.00	4.14	0.49	6.24	3.99	158.6	0.50	40.74	**KZ**
LT	0.70	**1127**	0.61	413.5	0.00	1.27	0.32	8.12	2.54	495.2	0.29	12.70	**LT**
LU	0.01	0.06	**38.51**	0.15	0.00	0.00	0.01	1.60	0.05	1.31	0.10	0.09	**LU**
LV	0.94	239.5	0.77	**3571**	0.00	0.92	0.28	10.56	3.31	318.1	0.46	10.28	**LV**
MC	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.01	0.00	0.003	**MC**
MD	0.43	1.71	0.05	3.25	0.00	**193.3**	0.59	0.59	0.30	49.16	0.02	191.8	**MD**
MK	0.11	0.25	0.03	0.58	0.00	0.52	**241.8**	0.33	0.07	9.70	0.02	18.27	**MK**
MT	0.00	0.00	0.00	0.001	0.00	0.001	0.003	0.001	0.00	0.02	0.00	0.02	**MT**
NL	0.11	0.89	2.72	3.08	0.00	0.05	0.03	**886.3**	1.38	15.62	1.12	0.78	**NL**
NO	3.63	23.20	3.70	73.75	0.00	0.80	0.44	76.65	**762.4**	225.8	4.60	12.44	**NO**
PL	2.73	77.49	5.60	88.46	0.00	4.04	2.30	65.12	13.94	**16571**	1.28	92.17	**PL**
PT	0.03	0.09	0.13	0.27	0.00	0.02	0.05	1.21	0.22	2.42	**887.1**	0.59	**PT**
RO	2.11	7.59	0.78	16.73	0.00	67.56	13.50	7.27	1.54	302.7	0.30	**5336**	**RO**
RU	401.9	363.8	6.65	1382	0.00	30.82	5.38	89.00	44.29	2172	4.29	321.1	**RU**
RUA	1397	38.48	1.40	130.3	0.00	6.05	1.25	18.68	13.16	316.8	1.60	68.13	**RUA**
SE	5.00	62.01	4.76	247.5	0.00	1.30	0.35	96.04	109	481.9	2.84	16.78	**SE**
SI	0.15	0.86	0.18	1.88	0.00	0.27	0.33	1.11	0.19	44.12	0.11	8.31	**SI**
SK	0.37	3.00	0.64	5.91	0.00	0.63	1.18	5.75	0.83	635	0.17	39.39	**SK**
TJ	9.83	0.01	0.00	0.03	0.00	0.01	0.00	0.01	0.00	0.15	0.00	0.10	**TJ**
TM	25.28	0.49	0.02	1.63	0.00	0.15	0.03	0.26	0.10	4.99	0.02	1.74	**TM**
TR	4.99	4.64	0.26	11.02	0.00	7.50	3.93	2.76	0.83	75.33	0.16	133.7	**TR**
UA	12.53	58.48	1.57	111.4	0.00	98.37	5.92	17.71	7.89	1583	0.77	567.4	**UA**
UZ	153.6	0.45	0.02	1.46	0.00	0.17	0.03	0.24	0.12	5.39	0.02	1.76	**UZ**
	KZ	**LT**	**LU**	**LV**	**MC**	**MD**	**MK**	**NL**	**NO**	**PL**	**PT**	**RO**	

***Table B.2**. Matrix of B[a]P country-to-country depositions in 2006, kg/y (continued)*

Receptors ↓ Emitters →

	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	ReEmis	Total	
AL	0.74	0.03	0.21	0.66	1.96	0.001	0.002	7.78	25.12	0.003	**132**	**960**	**AL**
AM	1.02	0.02	0.04	0.02	0.08	0.01	0.03	31.33	7.96	0.02	**118**	**687**	**AM**
AT	2.30	0.08	1.45	115.3	40.75	0.002	0.01	2.68	27.27	0.01	**285**	**2301**	**AT**
AZ	10.67	0.73	0.23	0.10	0.34	0.07	0.35	23.75	34.92	0.19	**245**	**1418**	**AZ**
BA	1.33	0.06	0.83	10.36	20.89	0.002	0.01	5.98	37.76	0.01	**298**	**2009**	**BA**
BE	0.48	0.03	0.77	0.73	0.83	0.001	0.001	0.36	2.87	0.001	**279**	**1872**	**BE**
BG	9.60	0.25	2.09	3.97	14.40	0.01	0.03	96.47	388.3	0.03	**486**	**3945**	**BG**
BY	62.24	1.21	23.92	9.47	48.72	0.02	0.03	15.82	734.1	0.04	**1585**	**8723**	**BY**
CH	0.37	0.02	0.25	4.99	1.43	0.00	0.001	0.80	4.21	0.001	**55**	**445**	**CH**
CS	2.69	0.09	1.56	8.77	25.51	0.002	0.01	16.84	109.6	0.01	**611**	**3977**	**CS**
CY	0.07	0.00	0.01	0.01	0.02	0.00	0.001	11.46	1.05	0.001	**333**	**1653**	**CY**
CZ	3.23	0.11	2.51	17.35	135.2	0.003	0.01	1.77	36.35	0.01	**543**	**3813**	**CZ**
DE	9.38	0.37	15.05	10.83	23.09	0.01	0.02	4.67	64.75	0.02	**2863**	**19485**	**DE**
DK	1.16	0.05	10.56	0.65	1.72	0.001	0.002	0.27	8.05	0.003	**219**	**1284**	**DK**
EE	17.19	0.23	21.31	1.79	5.20	0.004	0.01	1.20	40.68	0.01	**353**	**2268**	**EE**
ES	0.91	0.08	1.16	5.40	2.57	0.003	0.01	2.60	15.86	0.01	**1260**	**7332**	**ES**
FI	104.9	1.85	243.2	5.13	13.65	0.04	0.03	4.56	138.4	0.05	**327**	**3904**	**FI**
FR	4.09	0.23	4.13	27.46	13.24	0.01	0.02	8.33	52.58	0.02	**1002**	**5822**	**FR**
GB	3.38	0.19	7.58	1.67	3.74	0.007	0.004	2.27	22.19	0.01	**445**	**2426**	**GB**
GE	15.79	0.09	0.70	0.29	1.37	0.02	0.05	110.6	79.59	0.03	**93**	**552**	**GE**
GR	8.09	0.25	1.09	1.79	5.78	0.01	0.02	157.3	238.1	0.03	**316**	**2471**	**GR**
HR	1.44	0.05	0.67	147.8	28.11	0.002	0.01	4.09	32.52	0.01	**345**	**1996**	**HR**
HU	2.53	0.10	1.64	65.53	292.4	0.003	0.01	4.01	102.2	0.01	**692**	**4178**	**HU**
IE	0.59	0.04	1.09	0.29	0.47	0.002	0.001	0.34	3.16	0.001	**250**	**1312**	**IE**
IS	2.22	0.58	2.55	0.37	0.76	0.05	0.01	0.40	5.15	0.02	**19**	**122**	**IS**
IT	5.93	0.26	1.68	146.2	31.64	0.01	0.02	31.10	146.8	0.02	**1930**	**12128**	**IT**
KY	0.79	0.13	0.02	0.02	0.04	120.1	0.46	2.11	4.18	51.58	**243**	**1650**	**KY**
KZ	371.9	147.9	13.72	3.07	11.30	71.2	7.38	56.75	989.4	56.30	**1583**	**9734**	**KZ**
LT	17.15	0.42	18.04	3.62	14.36	0.005	0.01	1.94	88.94	0.01	**550**	**3108**	**LT**
LU	0.05	0.00	0.05	0.09	0.10	0.00	0.00	0.04	0.31	0.00	**17**	**109**	**LU**
LV	20.49	0.40	30.15	3.31	11.31	0.01	0.01	2.25	90.86	0.01	**866**	**5557**	**LV**
MC	0.00	0.00	0.00	0.01	0.002	0.00	0.00	0.001	0.01	0.00	**0.03**	**0.2**	**MC**
MD	4.05	0.07	0.94	0.96	4.02	0.002	0.01	14.12	320.3	0.01	**159**	**990**	**MD**
MK	0.71	0.03	0.27	0.81	2.58	0.001	0.002	11.83	24.06	0.002	**114**	**765**	**MK**
MT	0.003	0.00	0.00	0.003	0.003	0.00	0.00	0.02	0.07	0.00	**0.02**	**0.5**	**MT**
NL	0.77	0.04	1.53	0.58	0.84	0.001	0.002	0.40	4.27	0.002	**263**	**1894**	**NL**
NO	21.94	1.69	146.7	6.44	13.99	0.05	0.03	3.14	84.06	0.05	**373**	**2754**	**NO**
PL	29.61	2.34	41.26	43.65	380.2	0.02	0.04	9.24	381.5	0.05	**3546**	**23613**	**PL**
PT	0.12	0.01	0.32	0.57	0.27	0.00	0.001	0.27	1.79	0.001	**231**	**1331**	**PT**
RO	15.24	0.35	5.43	20.23	70.69	0.01	0.05	79.08	895	0.05	**1379**	**9138**	**RO**
RU	8806	145	256.5	39.65	143.2	1.29	2.41	331	8748	3.14	**3756**	**31257**	**RU**
RUA	959.1	2518	43.20	8.94	26.72	10.34	2.07	54.18	1204	6.60	**909**	**8282**	**RUA**
SE	44.76	2.00	2358	6.77	20.25	0.04	0.05	3.81	135.6	0.07	**495**	**5654**	**SE**
SI	0.88	0.03	0.35	644.4	12.23	0.001	0.003	1.72	14.27	0.004	**180**	**1308**	**SI**
SK	2.76	0.10	2.19	24.36	1126	0.002	0.01	2.14	78.04	0.01	**398**	**2961**	**SK**
TJ	0.33	0.03	0.01	0.01	0.01	528.7	0.83	0.69	2.12	20.62	**102**	**705**	**TJ**
TM	7.76	0.73	0.38	0.13	0.39	14.37	44.28	7.13	37.44	26.79	**21**	**216**	**TM**
TR	39.88	0.69	3.09	3.22	8.93	0.10	0.17	11580	736.9	0.16	**2720**	**15910**	**TR**
UA	216.2	2.25	28.62	24.75	147.5	0.07	0.16	179.5	35368	0.20	**8268**	**47873**	**UA**
UZ	9.93	1.64	0.41	0.12	0.40	219.5	9.25	5.78	37.64	166.4	**138**	**938**	**UZ**
	RU	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**ReEmis**	**Total**	

***Table B.3**. Matrix of PCDD country-to-country depositions in 2006, g TEQ/y*

Receptors ↓ Emitters →

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CS	CY	CZ	DE	DK	
AL	**17.77**	0.01	0.04	0.01	0.26	0.01	1.45	0.01	0.01	3.73	0.004	0.11	0.02	0.01	**AL**
AM	0.01	**19.73**	0.003	2.83	0.01	0.002	0.06	0.001	0.001	0.02	0.01	0.01	0.003	0.001	**AM**
AT	0.07	0.01	**20.43**	0.02	0.23	0.22	0.17	0.02	0.40	0.40	0.001	5.68	1.13	0.04	**AT**
AZ	0.02	2.95	0.01	**47.61**	0.02	0.01	0.17	0.01	0.003	0.06	0.01	0.04	0.01	0.01	**AZ**
BA	0.76	0.01	0.27	0.02	**26.16**	0.04	0.60	0.01	0.03	5.35	0.004	0.74	0.11	0.02	**BA**
BE	0.01	0.002	0.04	0.00	0.01	**22.68**	0.02	0.004	0.03	0.02	0.00	0.13	1.09	0.02	**BE**
BG	0.52	0.03	0.15	0.06	0.42	0.04	**142.26**	0.05	0.03	6.97	0.01	0.50	0.09	0.03	**BG**
BY	0.05	0.01	0.15	0.03	0.11	0.12	0.29	**17.07**	0.03	0.28	0.001	1.16	0.24	0.20	**BY**
CH	0.04	0.003	0.32	0.01	0.06	0.10	0.07	0.003	**6.64**	0.08	0.001	0.14	0.30	0.01	**CH**
CS	2.95	0.02	0.29	0.03	3.99	0.05	3.54	0.02	0.03	**86.06**	0.01	1.00	0.13	0.03	**CS**
CY	0.01	0.01	0.002	0.01	0.01	0.001	0.03	0.001	0.001	0.01	**1.66**	0.00	0.00	0.00	**CY**
CZ	0.04	0.01	2.52	0.02	0.12	0.22	0.11	0.03	0.15	0.32	0.001	**80.16**	1.48	0.07	**CZ**
DE	0.09	0.02	3.26	0.04	0.16	5.58	0.20	0.07	2.48	0.31	0.002	12.11	**53.53**	1.12	**DE**
DK	0.01	0.002	0.02	0.01	0.01	0.21	0.01	0.01	0.01	0.02	0.00	0.18	0.37	**7.09**	**DK**
EE	0.005	0.002	0.02	0.01	0.01	0.05	0.02	0.07	0.01	0.02	0.00	0.16	0.10	0.08	**EE**
ES	0.23	0.02	0.17	0.03	0.30	0.28	0.43	0.01	0.12	0.46	0.003	0.35	0.29	0.05	**ES**
FI	0.02	0.01	0.06	0.03	0.04	0.20	0.10	0.12	0.02	0.10	0.001	0.44	0.30	0.28	**FI**
FR	0.37	0.03	0.62	0.06	0.60	4.87	0.61	0.04	1.97	0.85	0.01	1.37	3.62	0.13	**FR**
GB	0.04	0.01	0.10	0.02	0.05	1.60	0.11	0.02	0.06	0.11	0.001	0.44	0.93	0.21	**GB**
GE	0.04	3.25	0.02	4.48	0.03	0.01	0.42	0.01	0.01	0.12	0.02	0.09	0.02	0.01	**GE**
GR	1.75	0.06	0.11	0.09	0.34	0.04	17.19	0.04	0.03	2.19	0.03	0.35	0.08	0.02	**GR**
HR	0.48	0.01	0.70	0.02	5.61	0.05	0.40	0.01	0.03	2.91	0.002	1.16	0.13	0.02	**HR**
HU	0.13	0.01	1.63	0.02	1.00	0.08	0.39	0.03	0.04	4.11	0.001	2.87	0.24	0.04	**HU**
IE	0.01	0.002	0.02	0.005	0.01	0.19	0.03	0.004	0.02	0.02	0.00	0.08	0.14	0.03	**IE**
IS	0.01	0.00	0.01	0.01	0.01	0.05	0.02	0.003	0.01	0.02	0.00	0.05	0.05	0.03	**IS**
IT	1.72	0.04	1.79	0.08	2.29	0.19	2.24	0.04	0.77	2.81	0.01	1.73	0.48	0.04	**IT**
KY	0.01	0.08	0.01	0.18	0.01	0.00	0.06	0.002	0.002	0.02	0.003	0.02	0.01	0.002	**KY**
KZ	0.14	0.77	0.16	2.78	0.17	0.15	1.10	0.18	0.05	0.50	0.02	0.65	0.24	0.12	**KZ**
LT	0.01	0.003	0.06	0.01	0.02	0.07	0.05	0.47	0.02	0.06	0.00	0.54	0.16	0.16	**LT**
LU	0.001	0.00	0.01	0.00	0.001	0.18	0.002	0.00	0.01	0.002	0.00	0.02	0.16	0.001	**LU**
LV	0.01	0.003	0.04	0.01	0.02	0.07	0.04	0.25	0.01	0.04	0.00	0.37	0.16	0.14	**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	**MC**
MD	0.02	0.01	0.02	0.01	0.03	0.01	0.41	0.04	0.004	0.12	0.001	0.12	0.02	0.01	**MD**
MK	1.53	0.01	0.03	0.01	0.14	0.01	4.17	0.01	0.01	4.01	0.002	0.11	0.02	0.005	**MK**
MT	0.001	0.00	0.00	0.00	0.001	0.00	0.002	0.00	0.00	0.001	0.00	0.00	0.00	0.00	**MT**
NL	0.01	0.002	0.03	0.003	0.01	5.42	0.01	0.005	0.02	0.02	0.00	0.14	1.97	0.05	**NL**
NO	0.06	0.02	0.16	0.05	0.10	0.73	0.18	0.10	0.07	0.20	0.002	0.85	0.87	0.95	**NO**
PL	0.11	0.02	1.16	0.04	0.32	0.54	0.33	0.67	0.18	0.82	0.001	27.20	2.22	1.14	**PL**
PT	0.02	0.002	0.02	0.00	0.03	0.04	0.04	0.002	0.01	0.04	0.00	0.05	0.04	0.01	**PT**
RO	0.45	0.04	0.36	0.07	1.09	0.10	5.67	0.12	0.06	8.66	0.01	1.47	0.23	0.07	**RO**
RU	0.41	1.68	0.58	6.73	0.53	0.81	3.47	3.04	0.17	1.58	0.04	3.29	1.33	0.88	**RU**
RUA	0.20	0.42	0.23	1.34	0.25	0.35	1.21	0.25	0.08	0.66	0.02	1.00	0.48	0.26	**RUA**
SE	0.04	0.02	0.17	0.05	0.06	0.67	0.13	0.17	0.06	0.14	0.001	1.29	1.08	3.57	**SE**
SI	0.05	0.004	1.30	0.01	0.26	0.02	0.09	0.01	0.02	0.28	0.00	0.59	0.07	0.01	**SI**
SK	0.06	0.005	0.82	0.01	0.25	0.06	0.17	0.03	0.03	0.68	0.00	6.25	0.19	0.04	**SK**
TJ	0.004	0.03	0.00	0.08	0.00	0.001	0.02	0.001	0.001	0.01	0.001	0.01	0.002	0.00	**TJ**
TM	0.03	0.39	0.02	1.42	0.03	0.01	0.19	0.01	0.01	0.08	0.01	0.06	0.02	0.01	**TM**
TR	0.60	6.08	0.21	1.86	0.43	0.13	11.25	0.11	0.06	1.66	0.54	0.69	0.21	0.06	**TR**
UA	0.25	0.13	0.40	0.28	0.52	0.20	2.90	1.58	0.07	1.58	0.01	2.38	0.42	0.27	**UA**
UZ	0.02	0.20	0.02	0.62	0.02	0.01	0.13	0.01	0.01	0.06	0.01	0.06	0.02	0.01	**UZ**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CS**	**CY**	**CZ**	**DE**	**DK**	

***Table B.3**. Matrix of PCDD country-to-country depositions in 2006, g TEQ/y (continued)*

Receptors ↓ Emitters →

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KY	
AL	0.000	0.07	0.001	0.06	0.03	0.02	1.58	0.28	0.13	0.004	0.00	1.60	0.00	**AL**
AM	0.00	0.01	0.00	0.01	0.01	1.43	0.04	0.01	0.01	0.001	0.00	0.04	0.002	**AM**
AT	0.001	0.18	0.004	0.44	0.38	0.02	0.09	0.96	0.88	0.03	0.001	3.27	0.00	**AT**
AZ	0.00	0.02	0.001	0.02	0.03	3.31	0.09	0.02	0.03	0.003	0.00	0.10	0.01	**AZ**
BA	0.001	0.13	0.003	0.12	0.10	0.02	0.41	6.77	1.18	0.01	0.00	2.44	0.00	**BA**
BE	0.00	0.16	0.002	2.57	1.12	0.003	0.01	0.03	0.02	0.04	0.00	0.11	0.00	**BE**
BG	0.002	0.11	0.01	0.12	0.14	0.11	2.64	0.44	0.67	0.01	0.00	1.12	0.002	**BG**
BY	0.03	0.13	0.06	0.18	0.44	0.04	0.10	0.22	0.48	0.03	0.002	0.53	0.002	**BY**
CH	0.00	0.21	0.001	1.11	0.21	0.005	0.05	0.17	0.05	0.02	0.00	4.44	0.00	**CH**
CS	0.001	0.15	0.004	0.15	0.14	0.04	0.87	2.84	2.29	0.01	0.00	2.35	0.001	**CS**
CY	0.00	0.00	0.00	0.004	0.00	0.01	0.13	0.01	0.004	0.00	0.00	0.05	0.00	**CY**
CZ	0.002	0.14	0.01	0.38	0.43	0.01	0.05	0.44	1.09	0.03	0.001	0.55	0.00	**CZ**
DE	0.01	0.96	0.03	6.67	4.43	0.04	0.14	0.37	0.42	0.25	0.01	1.89	0.001	**DE**
DK	0.002	0.08	0.01	0.20	0.90	0.004	0.01	0.02	0.03	0.05	0.002	0.06	0.00	**DK**
EE	**1.04**	0.04	0.18	0.06	0.17	0.005	0.01	0.02	0.02	0.01	0.001	0.08	0.00	**EE**
ES	0.001	**87.72**	0.01	2.53	0.81	0.03	0.37	0.61	0.21	0.12	0.004	2.89	0.00	**ES**
FI	0.19	0.19	**7.82**	0.27	0.96	0.03	0.04	0.07	0.09	0.08	0.01	0.27	0.004	**FI**
FR	0.004	12.33	0.02	**76.60**	5.74	0.05	0.45	1.45	0.50	0.46	0.01	8.86	0.002	**FR**
GB	0.01	1.43	0.02	2.21	**107.58**	0.02	0.07	0.10	0.09	3.41	0.02	0.36	0.001	**GB**
GE	0.00	0.04	0.002	0.04	0.06	**47.11**	0.17	0.04	0.06	0.01	0.00	0.19	0.003	**GE**
GR	0.001	0.19	0.01	0.18	0.12	0.12	**50.27**	0.42	0.35	0.01	0.00	2.64	0.003	**GR**
HR	0.001	0.14	0.002	0.14	0.11	0.02	0.26	**38.90**	2.04	0.01	0.00	3.30	0.00	**HR**
HU	0.001	0.11	0.004	0.16	0.19	0.02	0.13	5.41	**52.36**	0.01	0.001	1.21	0.00	**HU**
IE	0.001	0.34	0.003	0.33	2.70	0.004	0.02	0.02	0.02	**13.22**	0.005	0.10	0.00	**IE**
IS	0.001	0.16	0.01	0.11	0.41	0.01	0.01	0.02	0.01	0.07	**0.43**	0.08	0.004	**IS**
IT	0.002	0.98	0.01	1.51	0.42	0.07	1.88	5.84	1.36	0.04	0.002	**145.84**	0.003	**IT**
KY	0.000	0.02	0.001	0.01	0.01	0.09	0.04	0.01	0.01	0.001	0.00	0.08	**32.71**	**KY**
KZ	0.01	0.36	0.06	0.31	0.68	1.41	0.44	0.26	0.35	0.06	0.004	1.22	8.82	**KZ**
LT	0.01	0.06	0.03	0.10	0.27	0.01	0.02	0.06	0.11	0.02	0.001	0.18	0.001	**LT**
LU	0.00	0.01	0.00	0.69	0.04	0.00	0.001	0.003	0.002	0.002	0.00	0.01	0.00	**LU**
LV	0.13	0.06	0.07	0.10	0.27	0.01	0.02	0.04	0.06	0.02	0.001	0.16	0.001	**LV**
MC	0.00	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.001	0.02	0.002	0.02	0.03	0.02	0.05	0.04	0.08	0.003	0.00	0.13	0.00	**MD**
MK	0.00	0.04	0.001	0.03	0.03	0.01	1.61	0.13	0.14	0.003	0.00	0.69	0.00	**MK**
MT	0.00	0.001	0.00	0.001	0.00	0.00	0.003	0.001	0.00	0.00	0.00	0.02	0.00	**MT**
NL	0.001	0.14	0.003	0.91	1.39	0.003	0.01	0.02	0.02	0.06	0.001	0.08	0.00	**NL**
NO	0.02	0.72	0.19	0.94	4.15	0.04	0.10	0.19	0.21	0.37	0.02	0.73	0.01	**NO**
PL	0.01	0.36	0.05	0.74	1.41	0.04	0.13	0.91	2.60	0.10	0.004	1.45	0.002	**PL**
PT	0.00	2.35	0.001	0.16	0.11	0.003	0.03	0.06	0.02	0.02	0.00	0.23	0.00	**PT**
RO	0.003	0.22	0.01	0.24	0.30	0.13	0.62	1.17	3.04	0.03	0.001	2.28	0.002	**RO**
RU	0.61	1.15	1.56	1.29	3.43	7.68	1.26	0.88	1.32	0.31	0.02	3.96	0.15	**RU**
RUA	0.03	0.70	0.19	0.62	1.55	0.88	0.53	0.39	0.49	0.16	0.01	1.77	1.01	**RUA**
SE	0.07	0.46	1.12	0.77	2.88	0.04	0.06	0.14	0.21	0.22	0.01	0.55	0.005	**SE**
SI	0.00	0.05	0.001	0.06	0.04	0.01	0.05	4.52	0.43	0.003	0.00	2.88	0.00	**SI**
SK	0.001	0.07	0.003	0.11	0.15	0.01	0.07	0.83	7.30	0.01	0.00	0.60	0.00	**SK**
TJ	0.00	0.01	0.00	0.004	0.00	0.04	0.02	0.004	0.004	0.00	0.00	0.03	1.67	**TJ**
TM	0.001	0.04	0.003	0.04	0.06	0.49	0.11	0.04	0.04	0.01	0.00	0.19	0.23	**TM**
TR	0.004	0.37	0.02	0.39	0.41	4.25	5.29	0.58	0.53	0.04	0.001	3.70	0.02	**TR**
UA	0.02	0.30	0.06	0.35	0.71	0.60	0.62	0.87	2.20	0.06	0.003	2.12	0.01	**UA**
UZ	0.001	0.04	0.004	0.03	0.05	0.30	0.07	0.03	0.03	0.005	0.00	0.15	5.25	**UZ**
	EE	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KY**	

***Table B.3**. Matrix of PCDD country-to-country depositions in 2006, g TEQ/y (continued)*

Receptors ↓ Emitters →

	KZ	LT	LU	LV	MC	MD	MK	MT	NL	NO	PL	PT	RO	
AL	0.01	0.003	0.00	0.002	0.003	0.01	9.63	0.02	0.01	0.002	0.18	0.001	0.57	**AL**
AM	0.03	0.001	0.00	0.00	0.00	0.002	0.02	0.001	0.001	0.001	0.03	0.00	0.05	**AM**
AT	0.01	0.01	0.01	0.01	0.01	0.005	0.16	0.01	0.11	0.02	2.25	0.01	0.41	**AT**
AZ	0.28	0.003	0.00	0.002	0.00	0.005	0.06	0.003	0.004	0.002	0.09	0.001	0.17	**AZ**
BA	0.01	0.01	0.001	0.004	0.01	0.01	0.72	0.01	0.03	0.01	0.92	0.004	1.00	**BA**
BE	0.002	0.003	0.15	0.003	0.001	0.00	0.01	0.001	1.13	0.02	0.13	0.003	0.02	**BE**
BG	0.05	0.02	0.001	0.01	0.004	0.08	8.15	0.01	0.03	0.01	0.93	0.003	12.83	**BG**
BY	0.07	1.54	0.003	0.49	0.003	0.05	0.19	0.004	0.12	0.08	11.30	0.01	1.17	**BY**
CH	0.004	0.002	0.01	0.002	0.02	0.001	0.08	0.005	0.04	0.01	0.14	0.01	0.09	**CH**
CS	0.02	0.01	0.001	0.01	0.01	0.02	10.53	0.02	0.03	0.01	1.29	0.004	5.54	**CS**
CY	0.001	0.00	0.00	0.00	0.00	0.00	0.03	0.001	0.001	0.00	0.01	0.00	0.02	**CY**
CZ	0.01	0.02	0.01	0.01	0.003	0.004	0.11	0.002	0.15	0.03	10.17	0.003	0.36	**CZ**
DE	0.03	0.09	0.33	0.07	0.02	0.01	0.17	0.01	5.22	0.22	7.99	0.02	0.42	**DE**
DK	0.004	0.02	0.002	0.01	0.00	0.001	0.02	0.00	0.35	0.12	0.78	0.002	0.03	**DK**
EE	0.01	0.16	0.001	0.70	0.001	0.002	0.02	0.001	0.05	0.04	1.03	0.001	0.05	**EE**
ES	0.02	0.01	0.01	0.01	0.03	0.01	0.37	0.04	0.15	0.04	0.40	0.82	0.34	**ES**
FI	0.08	0.16	0.005	0.28	0.002	0.01	0.08	0.002	0.22	0.31	2.31	0.01	0.22	**FI**
FR	0.04	0.03	0.44	0.02	0.81	0.01	0.65	0.04	1.08	0.11	1.38	0.10	0.69	**FR**
GB	0.02	0.03	0.02	0.03	0.003	0.003	0.07	0.004	1.61	0.20	0.88	0.05	0.13	**GB**
GE	0.07	0.01	0.00	0.004	0.001	0.02	0.14	0.005	0.01	0.005	0.31	0.001	0.63	**GE**
GR	0.08	0.01	0.001	0.01	0.01	0.04	17.11	0.08	0.02	0.01	0.66	0.004	2.51	**GR**
HR	0.01	0.01	0.001	0.005	0.01	0.01	0.45	0.01	0.03	0.01	1.24	0.003	0.72	**HR**
HU	0.01	0.02	0.003	0.01	0.005	0.01	0.34	0.01	0.06	0.02	3.89	0.003	4.16	**HU**
IE	0.004	0.01	0.003	0.005	0.001	0.00	0.02	0.001	0.12	0.04	0.11	0.02	0.03	**IE**
IS	0.04	0.005	0.001	0.005	0.001	0.00	0.02	0.001	0.05	0.08	0.16	0.01	0.02	**IS**
IT	0.06	0.03	0.009	0.02	0.38	0.02	2.73	0.20	0.11	0.03	2.14	0.03	1.78	**IT**
KY	5.98	0.001	0.00	0.00	0.00	0.001	0.04	0.002	0.003	0.001	0.04	0.001	0.05	**KY**
KZ	**191.20**	0.10	0.004	0.07	0.01	0.06	0.60	0.02	0.12	0.10	2.22	0.02	1.95	**KZ**
LT	0.02	**7.58**	0.002	0.67	0.001	0.01	0.04	0.001	0.07	0.04	5.54	0.002	0.19	**LT**
LU	0.00	0.00	**0.31**	0.00	0.00	0.00	0.002	0.00	0.02	0.001	0.01	0.00	0.00	**LU**
LV	0.02	1.41	0.002	**6.50**	0.001	0.004	0.03	0.001	0.08	0.05	2.82	0.002	0.12	**LV**
MC	0.00	0.00	0.00	0.00	**0.004**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MC**
MD	0.01	0.01	0.00	0.01	0.001	**2.18**	0.12	0.001	0.01	0.01	0.70	0.001	5.22	**MD**
MK	0.01	0.003	0.00	0.002	0.002	0.01	**70.77**	0.01	0.01	0.002	0.20	0.001	0.66	**MK**
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.002	**0.10**	0.00	0.00	0.001	0.00	0.001	**MT**
NL	0.003	0.01	0.01	0.01	0.001	0.00	0.01	0.00	**12.04**	0.04	0.23	0.003	0.03	**NL**
NO	0.11	0.14	0.01	0.13	0.01	0.01	0.17	0.01	0.86	**12.66**	2.84	0.04	0.37	**NO**
PL	0.06	0.54	0.02	0.17	0.01	0.03	0.33	0.01	0.51	0.21	**277.05**	0.01	1.77	**PL**
PT	0.003	0.001	0.001	0.001	0.002	0.001	0.03	0.00	0.02	0.01	0.06	**5.29**	0.03	**PT**
RO	0.07	0.06	0.004	0.03	0.01	0.69	2.16	0.02	0.08	0.04	4.45	0.01	**158.41**	**RO**
RU	10.09	1.48	0.02	1.60	0.02	0.23	1.96	0.05	0.87	0.79	18.71	0.06	7.34	**RU**
RUA	30.62	0.15	0.01	0.16	0.01	0.05	0.74	0.02	0.33	0.33	3.42	0.03	2.02	**RUA**
SE	0.12	0.28	0.01	0.42	0.004	0.01	0.11	0.004	0.81	2.17	5.80	0.02	0.39	**SE**
SI	0.004	0.004	0.001	0.002	0.01	0.002	0.08	0.003	0.01	0.004	0.57	0.002	0.20	**SI**
SK	0.01	0.02	0.002	0.01	0.002	0.01	0.16	0.003	0.05	0.02	10.11	0.002	0.99	**SK**
TJ	0.52	0.00	0.00	0.00	0.00	0.00	0.02	0.001	0.001	0.00	0.01	0.00	0.02	**TJ**
TM	1.97	0.01	0.00	0.003	0.00	0.01	0.10	0.004	0.01	0.01	0.16	0.002	0.21	**TM**
TR	0.35	0.06	0.004	0.03	0.02	0.15	2.99	0.12	0.10	0.04	1.89	0.01	6.86	**TR**
UA	0.33	0.37	0.01	0.18	0.01	1.13	1.38	0.02	0.20	0.13	20.57	0.01	15.25	**UA**
UZ	7.45	0.01	0.00	0.00	0.00	0.005	0.08	0.003	0.01	0.01	0.16	0.001	0.18	**UZ**
	KZ	**LT**	**LU**	**LV**	**MC**	**MD**	**MK**	**MT**	**NL**	**NO**	**PL**	**PT**	**RO**	

***Table B.3**. Matrix of PCDD country-to-country depositions in 2006, g TEQ/y (continued)*

Receptors ↓ Emitters →

	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	ReEmis	Back	Total	
AL	0.10	0.004	0.004	0.01	0.08	0.00	0.002	0.52	0.65	0.002	*37.98*	*1.89*	**78.9**	**AL**
AM	0.14	0.002	0.001	0.001	0.005	0.002	0.03	2.35	0.24	0.02	*34.98*	*2.14*	**64.3**	**AM**
AT	0.15	0.01	0.02	0.63	1.17	0.00	0.002	0.23	0.67	0.003	*66.17*	*5.37*	**112.5**	**AT**
AZ	1.32	0.08	0.004	0.002	0.02	0.01	0.25	2.09	0.82	0.13	*100.89*	*4.80*	**165.6**	**AZ**
BA	0.11	0.005	0.01	0.06	0.46	0.00	0.002	0.45	0.99	0.003	*61.54*	*3.37*	**115.0**	**BA**
BE	0.03	0.001	0.01	0.003	0.01	0.00	0.00	0.03	0.05	0.00	*50.59*	*2.58*	**82.9**	**BE**
BG	0.78	0.02	0.02	0.03	0.36	0.00	0.01	4.43	7.32	0.01	*182.00*	*5.36*	**379.0**	**BG**
BY	4.10	0.06	0.27	0.03	0.67	0.001	0.01	0.69	18.50	0.01	*94.38*	*8.28*	**164.0**	**BY**
CH	0.04	0.003	0.01	0.03	0.04	0.00	0.001	0.12	0.15	0.001	*33.64*	*3.87*	**52.3**	**CH**
CS	0.22	0.01	0.02	0.05	0.75	0.00	0.004	0.93	2.32	0.005	*143.78*	*4.91*	**277.5**	**CS**
CY	0.02	0.00	0.00	0.001	0.00	0.00	0.00	2.00	0.08	0.00	*11.55*	*0.52*	**16.2**	**CY**
CZ	0.17	0.01	0.03	0.07	2.02	0.00	0.002	0.12	0.72	0.002	*121.97*	*4.26*	**228.6**	**CZ**
DE	0.57	0.02	0.25	0.05	0.37	0.001	0.01	0.38	1.29	0.01	*363.64*	*23.53*	**498.9**	**DE**
DK	0.09	0.003	0.33	0.002	0.03	0.00	0.001	0.03	0.17	0.001	*20.11*	*3.70*	**35.1**	**DK**
EE	1.16	0.01	0.26	0.003	0.03	0.00	0.002	0.06	0.51	0.002	*16.95*	*2.15*	**25.4**	**EE**
ES	0.18	0.01	0.03	0.05	0.10	0.00	0.004	0.58	0.71	0.005	*269.63*	*55.30*	**426.9**	**ES**
FI	4.55	0.07	2.20	0.01	0.11	0.002	0.01	0.26	1.42	0.02	*61.23*	*14.27*	**99.6**	**FI**
FR	0.40	0.02	0.08	0.15	0.30	0.001	0.01	0.87	1.23	0.01	*531.11*	*51.26*	**712.5**	**FR**
GB	0.29	0.01	0.12	0.01	0.07	0.001	0.002	0.22	0.47	0.004	*150.03*	*35.64*	**308.9**	**GB**
GE	1.80	0.01	0.01	0.004	0.05	0.003	0.05	7.08	2.36	0.03	*96.71*	*4.35*	**169.9**	**GE**
GR	0.96	0.03	0.02	0.03	0.22	0.002	0.01	10.48	5.78	0.02	*163.23*	*7.29*	**285.2**	**GR**
HR	0.12	0.004	0.01	0.75	0.67	0.00	0.002	0.31	0.88	0.003	*72.61*	*2.96*	**137.3**	**HR**
HU	0.18	0.01	0.02	0.27	12.66	0.00	0.003	0.24	4.01	0.003	*112.84*	*3.85*	**212.8**	**HU**
IE	0.06	0.003	0.02	0.002	0.01	0.00	0.00	0.05	0.09	0.001	*18.19*	*12.95*	**49.0**	**IE**
IS	0.11	0.03	0.03	0.002	0.01	0.003	0.003	0.05	0.10	0.01	*3.53*	*2.11*	**8.0**	**IS**
IT	0.58	0.03	0.03	0.86	0.79	0.001	0.01	2.35	2.99	0.01	*319.46*	*20.32*	**527.2**	**IT**
KY	0.17	0.02	0.002	0.001	0.01	4.32	0.18	0.66	0.21	14.81	*80.75*	*14.30*	**154.9**	**KY**
KZ	27.16	10.30	0.18	0.03	0.32	2.21	1.73	6.49	14.47	14.85	*607.77*	*105.28*	**1008.3**	**KZ**
LT	1.21	0.02	0.21	0.01	0.15	0.00	0.002	0.07	1.60	0.003	*20.63*	*3.07*	**43.6**	**LT**
LU	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.01	0.00	*4.68*	*0.21*	**6.4**	**LU**
LV	1.09	0.02	0.34	0.01	0.09	0.00	0.002	0.09	1.24	0.004	*19.82*	*3.18*	**39.0**	**LV**
MC	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.01*	*0.00*	**0.0**	**MC**
MD	0.29	0.004	0.01	0.004	0.10	0.00	0.002	0.66	9.77	0.003	*25.01*	*1.31*	**46.6**	**MD**
MK	0.08	0.002	0.004	0.01	0.09	0.00	0.001	0.56	0.61	0.002	*63.57*	*1.46*	**150.8**	**MK**
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.002	0.00	*0.07*	*0.01*	**0.2**	**MT**
NL	0.05	0.002	0.03	0.002	0.02	0.00	0.00	0.03	0.08	0.001	*33.44*	*3.26*	**59.6**	**NL**
NO	1.31	0.08	1.17	0.02	0.22	0.003	0.01	0.37	1.82	0.02	*52.49*	*42.32*	**129.2**	**NO**
PL	1.79	0.15	0.56	0.12	5.30	0.00	0.01	0.40	11.76	0.01	*344.57*	*15.27*	**703.2**	**PL**
PT	0.02	0.002	0.01	0.005	0.01	0.00	0.00	0.06	0.08	0.001	*28.85*	*12.19*	**50.0**	**PT**
RO	1.18	0.02	0.07	0.08	2.07	0.001	0.01	3.68	24.24	0.02	*247.16*	*9.91*	**480.9**	**RO**
RU	**590.02**	7.08	2.15	0.12	1.58	0.09	0.72	20.72	117.11	0.96	*1257.92*	*139.52*	**2229.4**	**RU**
RUA	34.38	**159.41**	0.45	0.05	0.43	0.47	0.47	5.51	12.11	1.82	*336.34*	*216.34*	**820.8**	**RUA**
SE	2.17	0.09	**21.21**	0.02	0.26	0.002	0.01	0.32	2.42	0.02	*84.77*	*27.87*	**163.4**	**SE**
SI	0.05	0.002	0.004	**3.41**	0.24	0.00	0.001	0.10	0.28	0.001	*23.67*	*1.08*	**40.5**	**SI**
SK	0.15	0.005	0.03	0.08	**25.41**	0.00	0.002	0.13	2.66	0.002	*64.14*	*2.24*	**124.0**	**SK**
TJ	0.07	0.01	0.001	0.00	0.003	**20.08**	0.21	0.27	0.09	6.93	*44.23*	*10.53*	**84.9**	**TJ**
TM	1.11	0.09	0.01	0.004	0.03	0.98	**15.18**	1.79	1.10	10.67	*123.63*	*16.50*	**177.1**	**TM**
TR	6.54	0.08	0.07	0.06	0.43	0.02	0.12	**678.55**	26.05	0.13	*1107.26*	*61.83*	**1933.3**	**TR**
UA	16.14	0.11	0.33	0.09	3.22	0.01	0.05	10.54	**628.43**	0.07	*634.44*	*23.69*	**1375.6**	**UA**
UZ	1.00	0.14	0.01	0.003	0.03	9.04	2.65	1.23	0.95	**54.93**	*147.95*	*16.09*	**249.1**	**UZ**
	RU	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**ReEmis**	**Back**	**Total**	