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Persistent Organic Pollutants in the Environment

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EXECUTIVE SUMMARY

In accordance with the EMEP Work-plan for 2009, Meteorological Synthesizing Centre East (MSC-E) and Chemical Coordinating Centre (CCC) continued the investigations of pollution of the EMEP region by persistent organic pollutants (POPs). The outcomes of the studies are summarized in this Status Report.

Bearing in mind the importance of the work on the revision of the CLRTAP Protocol on POPs the Steering Body to EMEP recommended to support this activity and contribute to the preparation of technical documents on new proposed POP candidate substances for inclusion into Annexes of the Protocol [EB.Air/GE.1/2004]. Since 2004 MSC-E has provided TF on POPs (WGSR) with additional information on POP-like substance with respect to their long-range transport potential (LRTP) and persistence. Specific methodology for the evaluation of LRTP and persistence of POPs based on application of spatially resolved models was elaborated. It was recognized that such numerical characteristics as the overall persistence (Pover) and transport distance (TD), taking into account various processes in the main environmental compartments (the atmosphere, soil, water) and intermedia exchange, provided a relevant characterization of substance persistence and LRTP in the environment. This year, at the invitation of the Executive Body [ECE/EB.AIR/96], MSC-E made available to the Task Force on POPs supporting information for the review of LRTP and overall persistence of the newly proposed substances (endosulfan, dicofol, trifluralin, hexabromocyclododecane and pentaclorophenol).

Monitoring of POP concentrations in 2007 was performed at seventeen monitoring sites among which eleven sites made parallel measurement of POP content in air and precipitation. The number of sites measuring POP concentrations distinctly increased in recent years. In particular, Spain, the United Kingdom, and Latvia started measurements of POPs. The number of sites in Germany measuring POPs grew essentially and measurements of POP air concentrations were initiated. Particularly noteworthy is the increase in the reported PAH measurements.

To improve spatial coverage for POP measurement network, the passive sampling campaign was organized during late summer 2006 by CCC in close collaboration with the Lancaster University (the United Kingdom) and the GAPS initiative (Canada). 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 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. The comparison of measurements of passive and active samplers showed that the typical differences between their results were within a factor of two. At the same time significant differences can be expected between the measurements of active and passive samplers for chemicals extensively sorbed to atmospheric particles. At present monitoring of such chemicals requires active air sampling techniques and model calculations.

Model evaluation of the environmental pollution levels within the EMEP region was performed for the four indicator polycyclic aromatic hydrocarbons (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)), polychlorinated dibenzo-p-dioxins and dibenzofurans (the mixture of all 17 toxic congeners), polychlorinated biphenyls (PCB-153), lindane (γ-HCH), and hexachlorobenzene (HCB) for 2007. Pollution levels and source-receptor relationships for PAHs were evaluated at the regional scale since these pollutants were in the atmosphere mostly in particle-bound phase. 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 using nesting of hemispheric and regional scale modelling.

Emission datasets for model assessment of POP long-range transport within the EMEP region in 2007 were prepared by MSC-E with the financial support of the Russian Federation. It should be noted that, in spite of the gradual increase of number of countries reporing official information on POP emissions, the estimation of total emission within the European region still requires the use of unofficial emission data.

This year for the first time analysis of POP pollution within the European and the Central Asian countries was based on the combined consideration of the results of model assessments, regular EMEP measurements, and data of EMEP passive sampling campaign. The work with additional global and regional scale measurements of POP passive sampling campaigns carried out by MONET_CEEC in 2006-2008 and GAPS in 2005 has been initiated.

The spatial distribution of computed B[a]P concentrations along with regular measurements and data of the EMEP passive sampling campaign have shown that the highest levels of B[a]P concentrations are the characteristic of the countries in Central and Eastern Europe. Lower concentrations are seen in Northern and Western Europe and in the Central Asian countries. The most essential levels of PCB-153 concentrations in air were obtained by the MSCE-POP model for the countries of Western and Central Europe, while lower concentrations were evaluated for the Scandinavian, Eastern European, and the Central Asian countries. Similar distribution of PCB-153 air concentrations was obtained by the measurements of EMEP passive sampling campaign.

Reasonable agreement between the modelling results on B[a]P and PCB-153 and regular measurements of EMEP monitoring network was found. For most of the sites the deviations between the modelled and measured annual mean concentrations in air and in precipitation were about or less than a factor of two. The differences between the modelled and measured values were analysed. In order to determined the reasons of the differences joint case studies involving experts in emissions, monitoring, and modelling are needed.

Computed HCB air concentrations, obtained on the basis of official emission data, were essentially lower comparing to the measured levels of HCB air concentrations at the sites in Germany and southern Norway. Additional model simulations with unofficial expert estimates of HCB emission showed that higher emissions essentially improved the agreement between the measurements and model estimates. Same tendency to underestimate observed levels of HCB concentrations was obtained comparing modelled HCB concentrations with the measurements of EMEP passive sampling campaign. This indicates that the levels of HCB emission in Europe are likely more significant than that officially reported by the European countries and further refinement of HCB emission is required.

The application of lindane (γ-HCH) has been banned or severely restricted in the majority of the European countries. Most of countries reported no usage of lindane or insignificance of its emission and only several countries, namely, the United Kingdom, Spain, Belgium, Croatia, and Romania, provided information on the lindane emission for the recent years. Comparing the spatial distribution of measured and computed air concentrations of γ-HCH it can be seen that the model predictions and observed concentrations have similar pattern, in particular, for the United Kingdom, Spain, and Scandinavian countries. However, the MSCE-POP model essentially underestimated measurements of sites in a number of countries of Eastern and Southern Europe mostly due to incomplete information on γ-HCH emissions.

Transboundary transport of POPs is a significant source of pollution for the European and the Central Asian countries. Evaluation of transboundary transport for B[a]P and PCDD/Fs showed that its contribution to the deposition from anthropogenic emission sources exceeds 50% for 22 and 18 countries, respectively.

MSC-E continued the work on further development of multicompartment POP transport model. This year main attention was paid to the refinement of parameterizations of aerosol-related processes, namely, POP gas-particle partitioning and dry deposition. Along with that necessary model input data on aerosol particles and OH-radical concentrations required for modelling of POP long-range transport on regional and global scale were prepared.

Global scale data on spatial and temporal variations of aerosols and OH-radical air concentrations were provided by the Environment Canada (K. Puckett and S. Gong) to the MSC-E for the application in the experimental modelling of POPs on global scale using the common EMEP global modelling framework.

Regional scale data on aerosol and OH-radical content in the atmosphere for 2007 were generated using the CMAQ model. These data were analyzed, compared to the EMEP measurements, and adapted for use as the input information for the evaluation of POP pollution levels within the EMEP region. Experimental model simulations with the prepared CMAQ data, performed on the example of B[a]P and PCB-153, showed reasonable agreement of modelling results with measurement data.

Development of size-segregated approach for modelling of POPs was started. The sensitivity of modelling results to the size-segregated description of POP dry deposition was examined. Numerical experiments showed essential sensitivity of the model to the inclusion of size resolved information on aerosol particles.

The work on the assessment of POP pollution levels within the European region for 2007 was performed in close co-operation with the subsidiary bodies to the Convention and EMEP Task Forces (TF on POPs, TFMM, TFHTAP), international organizations (EU, ECHA, HELCOM, OSPAR, the Stockholm Convention, UNEP Chemicals), as well as with national experts.

CONTENTS

INTRODUCTION

This Status Report describes the progress in activities of the EMEP Centres − Meteorological Synthesizing Centre-East (MSC-E) and Chemical Coordinating Centre (CCC) − in the evaluation of contamination of the EMEP region by persistent organic pollutants (POPs). During 2009 investigations of POP long-range atmospheric transport and transboundary fluxes on the basis of measurements, emission data and modelling were continued. These activities were performed in accordance with the EMEP Work-plan for 2009 [ECE/EB.AIR/GE.1/2008/9].

Initiated in 2004, the work on the elaboration of supporting information on POP-like substances with respect to the evaluation of their long-range transport potential (LRTP) and persistence has been continued under MSC-E in accordance with the recommendation of the Steering Body to EMEP. MSC-E has developed specific methodology based on the application of spatially resolved models for the evaluation of LRTP and persistence of POPs. Up to now, 18 substances were evaluated and the corresponding Technical Notes were submitted to the Task Force on POPs as a contribution to the preparatory work for the review of the Protocol on POPs to the Convention. In 2009, at the invitation of the Executive Body additional information on new five POP candidates (endosulfan, dicofol, trifluralin, hexabromocyclododecane and pentaclorophenol) was made available to the Task Force on POPs. The results of the evaluation of overall persistence and transport distance for these substances were taken into account in preparation of the technical review of dossiers of the proposed substances.

Measurements of POP concentrations in air and precipitation, and wet deposition fluxes are carried out at the EMEP monitoring network. The information on the observed levels of POPs in air and in precipitation for 2007 is available from seventeen stations located in the northern, western, and central parts of Europe. Measurements of POPs were recently started in Spain, the United Kingdom, and Latvia and the number of sites in Germany measuring POPs grew essentially.

Valuable information for the evaluation of POP pollution levels is provided by passive sampling campaigns. In particular, measurements of passive sampling campaigns such as EMEP campaign, MONET-CEEC (the Czech Republic), and GAPS initiative (Environment Canada) are available. The comparison of passive sampling data with those obtained by active sampling showed that the results of passive and active measurements differed typically by not more than a factor of two.

In 2009, modelling studies 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). For model assessment of pollution levels and transboundary transport of POPs the MSCE-POP model was applied. Input information on emissions of the above-mentioned POPs for modelling was prepared by MSC-E with the financial support of the Russian Federation. Datasets for model assessments were based on the most recent officially submitted emission totals and information on spatial distribution of emissions along with available unofficial emission estimates. 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.

This year for the first time POP pollution levels in the European region were analyzed linking the information from regular EMEP observations, measurement data of passive sampling campaigns, and modelling results. Computed concentrations were considered together with monitoring data to provide more detailed description of contamination and to characterise the level of agreement between measurements and modelling results. To study the discrepancies between the modelled and observed concentrations backward trajectories analysis was applied.

The work on the development of MSCE-POP model is continued focusing on the refinement of the model parameterizations of POP gas-particle partitioning and deposition processes. Necessary input data for global and regional scale modelling were prepared. For this purpose the global data on aerosol particles and OH-radical concentrations produced by GEMAQ-EC model for 2001 was put at MSC-E disposal by the Environment Canada (K. Puckett and S. Gong). For the regional scale modelling within the EMEP grid the information on aerosol and OH-radical concentrations for 2007 was generated by CMAQ model and adapted for the use in MSCE-POP model simulations.

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 [*Gusev et al.*, 2009; *Aas and Breivik*, 2009] as well as on the Internet www.msceast.org and www.emep.int. Below the content of the report is briefly outlined.

Chapter 1 is devoted to the description of MSC-E activities performed for the support of technical reviews of POP-candidates. Brief discussion on the methodology of evaluation of long-range transport potential (LRTP) and environmental persistence (Pover) of POP-like substances is presented. The analysis of factors affecting LRTP and Pover including the dependence of these characteristics on physical-chemical properties of a substance, geographical location of emission source and meteorological conditions is given. Main results on evaluation of LRTP and Pover on the five newly proposed substances (dicofol, endosulfan, trifluralin, hexabromocyclododecane and pentaclorophenol) are summarized.

Chapter 2 presents the progress in the field of monitoring of POP concentration levels within the European region. The description of the EMEP monitoring network for POPs in 2007 is presented and the analysis of POP concentrations measured at the EMEP monitoring sites is performed. The perspective of usage of passive air sampling campaign for the evaluation of the pollution of the European region by POPs is discussed.

Chapter 3 is devoted to the assessment of pollution levels and transboundary transport of selected POPs in the European and the Central Asian countries. Levels of concentrations of selected POPs within the EMEP region are analyzed linking the information from regular EMEP observations, measurement data of passive sampling campaigns, and modelling results.

Chapter 4 describes the progress in the development of the EMEP multicompartment POP transport model (MSCE-POP) achieved in 2009. The results of test simulations applying the refined information on atmospheric aerosol and OH-radical for the description of gas-particle partitioning process are presented. The sensitivity of modelling results to the implementation of size-segregated description of POP dry deposition is examined.

Chapter 5 highlights the co-operation of MSC-E and CCC with the WGSR (TF on POPs), the EMEP Task Forces (TFMM, TF HTAP), international organizations and programmes (ECHA, HELCOM, OSPAR, UNEP), and national experts.

Chapter 6 contains a brief description of future activities related to POPs proposed by CCC and MSC-E for 2010.

The main results of the EMEP Centres work 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 2009 concerning the evaluation of pollution levels of POPs in the European region. Annex B presents detailed matrices of transboundary fluxes for 2007 calculated using MSCE-POP model for PCDD/Fs and B[a]P.

Acknowledgements

The authors of the report are grateful to I. Holoubek and J. Klanova (the Czech Republic) for providing measurements of POPs performed at the monitoring site Košetice (CZ3), data of MONET_CEEC passive sampling campaigns and co-operation in their interpretation and comparison with modelling results. The authors are also grateful to T. Harner for the measurement data on POPs of GAPS initiative and to K. Puckett and S. Gong (Canada) for the data on atmospheric aerosol and OH radicals kindly put at MSC-E disposal. Substantial contribution to the technical preparation of the report was made by I. Strizhkina (MSC-E).

1. EMEP CONTRIBUTION TO THE REVIEW OF POP PROTOCOL

In accordance with the recommendation of the Steering Body to EMEP to contribute to the preparatory work for the review of the Protocol on POPs to the Convention [EB.Air/GE.1/2004] MSC-E performs the elaboration of supporting information on POP candidate substances with respect to evaluation of their long-range transport potential (LRTP) and persistence. Specific methodology based on the model simulations for the evaluation of LRTP and persistence of POPs was worked out. In the framework of this activity technical notes on 18 substances proposed under CLRTAP as POP-candidates were prepared and submitted to the Task Force on POPs [*Vulykh et al.*, 2005a,b,c,d,e,; *Vulykh et al.*, 2006; *Vulykh et al.*, 2007; *Vulykh et al.*, 2009a,b,c]. The list of substances and their isomers included into the evaluation is given in Table 1.1 below. This year at the invitation of the Executive Body, the MSC-E made available additional information for the review of LRTP and overall persistence of the newly proposed substances (endosulfan, dicofol, trifluralin, hexabromocyclododecane and pentaclorophenol) and submitted this information to the TF on POPs.

The work of evaluation of POP-like substances from the viewpoint of their inclusion to international regulatory activities is performed also under the Stockholm Convention on POPs. It should be noted that most of the substances included into the EMEP evaluation activities are also studied under the Stockholm Convention. These substances are marked grey in Table 1.1.

Table 1.1. *The list of the considered pollutants with indication of model simulations. Substances considered under the Stockholm Convention are marked grey. The last two substances are used as benchmark ones.*

Substance	Source location		
	Europe	North America	South-east Asia
Chlordecone	×		
BDE-47	×		
BDE-28	×	×	×
BDE-99	×		
BDE-153	×	×	×
HxClDd	×		
HpClTd	×		
PeClD	×		
PeCBz	×	×	×
PCN-47	×	×	×
HCBD	×	×	×
α-endosulfan	×	×	×
β-endosulfan	×		
HBCD-mixture	×		
γ-HBCD	×		
Dicofol	×	×	×
PCP	×		
Trifluralin	×		
B[a]P	×		
HCB	×		

A lot of substances considered as POP candidates under international conventions are manufactured by the industry (e. g., pentachlorophenol, hexabromocyclododecane, bromodiphenilethers, endosulfan and others). The information on physical-chemical properties of such substances as well as evaluation of their toxicological and ecotoxicological effects is accumulated by the European Chemical Agency (ECHA) under the EU Regulation REACH (Registration, Evaluation, restriction and Authorization of

Chemicals). This information and approaches to the risk assessment for chemicals can be useful within international environment-protection activities.

For preparation of additional information on POP candidates various data sources were used. Primarily, the dossiers prepared by countries were used for this purpose. In the case of lack of the information in the dossiers, additional sources such as data from ECHA, the Stockholm Convention and additional literature sources were taken into account.

The evaluation of LRTP and persistence of substances was made with the use of spatially resolved model MSCE-POP. The usage of a spatially resolved model allows taking into account the variations in LRTP and persistence of substances depending on the geographical location of their emission sources, meteorological conditions and types of the underlying surface.

In this study one-year model simulations with the conventional emission source (1 tonne per year) located in Europe (5°E; 47.5°N) are used. In addition, to examine the dependence of LRTP on source location, additional calculations for sources located in North America (77.5°W; 40.0°N), China (110.0°E; 27.5°N) and Japan (137.5°E; 35.0°N) were performed. As an example, spatial distribution of HBCD concentrations originated by emissions from the European source is shown in Fig. 1.1. The list of POP candidates covered in this study is presented in Table 1.1. “Benchmark substances” B[a]P and HCB are included for the comparison with the characteristics of newly evaluated substances. B[a]P is chosen as a typical substance of regional concern, and HCB as a typical global pollutant.

On the basis of the above simulations several numerical parameters characterizing LRTP and persistence of chemicals are calculated.

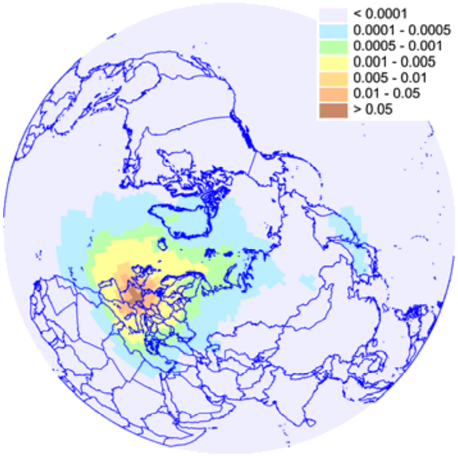


Fig. 1.1. *Spatial distribution of HBCD air concentrations (annual means) in the above-ground air in the Northern Hemisphere calculated by MSCE-POP model (relative units)*

LRTP evaluation

For the evaluation of long-range transport potential of substances two numerical parameters are used. The first is the half-life of a substance in the atmosphere. This parameter is included in the list of indicative criteria for recognizing a substance as a POP under CLRTAP. The second is the so-called transport distance characterizing the distance by which a substance can be transported from the location of its emission source. This parameter can be used as additional information for the characterization of LRTP. Below the definitions of these parameters are given.

Half-life in the atmosphere $T_{1/2}^{air}$ equals to the time by which the mass of a parcel of the considered pollutant in the atmosphere is reduced twice as a result of main processes removing the pollutant from the atmosphere (degradation, dry and wet deposition and gaseous exchange with the underlying surface).

Transport distance* (*TD_α*)** is determined as an average distance at which concentration of the pollutant drops $1/\alpha$ times compared with that at source location. Here α is a threshold level which can be chosen arbitrarily but one and the same for all considered pollutants. In this study threshold level $\alpha = 0.001$ is chosen. ***It should be stressed that numerical value of TD strongly depends on the evaluation methodology and on model design. Hence, values of transport distance obtained with the use of different methodologies can differ essentially. TD_α is an additional illustrative parameter which can be considered in line with the half-life in the atmosphere.

The specific methodology for LRTP evaluation worked out by MSC-E is considered in detail in EMEP/MSC-E Technical Report [*Gusev et al.*, 2009]. Here we remark only that the relation between TD_α and $T_{1/2}^{air}$ is not linear and these two characteristics together can better demonstrate the ability of a substance to the long-range transport. The empirical dependence between these two parameters is shown in Fig. 1.2.

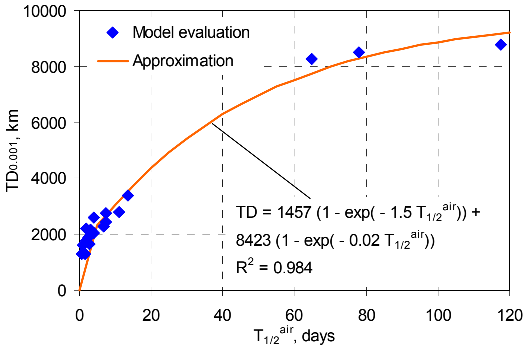


Fig. 1.2. *The dependence of $TD_{0.001}$ on $T_{1/2}^{air}$ for the considered substances and the approximation for calculations with the European source*

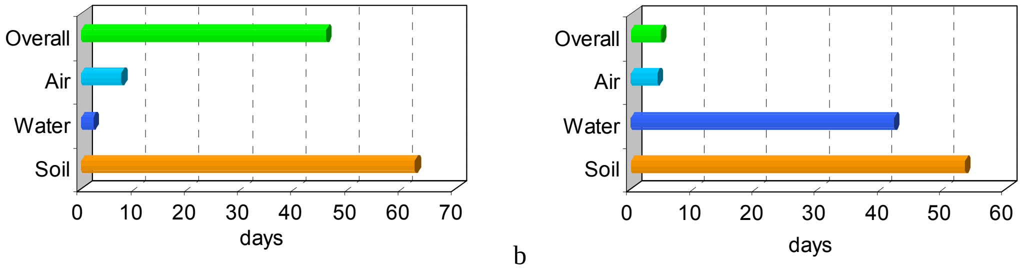
Persistence evaluation

Several numerical parameters are used for the evaluation of environmental persistence of substances. First of all, they are half-lives of a substance in soil and water. These parameters are included in the list of indicative criteria under CLRTAP. In addition, so-called overall persistence characterizing the stability of a substance in the entire environment is evaluated and can be helpful as a supporting information for the characterization of persistence of substances. This characteristic is integral and evaluates the persistence of a pollutant in the entire environment from multicompartment point of view in contrast to single-compartment approach using separate half-lives in the main media (soil, water).

Half-lives in the environmental media $T_{1/2}^{soil}$ and $T_{1/2}^{water}$ are evaluated on the basis of model simulations taking into account not only degradation processes in the considered media but also processes of gaseous exchange between them and the atmosphere.

Overall persistence (Pover) is enumerated by the half-life in the environment $T_{1/2}^{env}$. The latter is the time by which the mass of a parcel of the pollutant is reduced twice in the entire environment by degradation processes in all the media with allowance for the exchange between the atmosphere and underlying surface (soil, water).

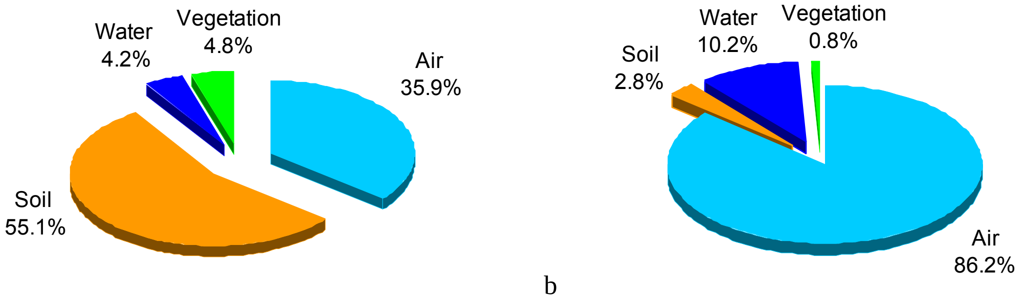
The notion of overall persistence can be exemplified by the evaluation of environmental persistence of two substances: pentachlorophenol (PCP) and β-endosulfan. Calculated values of half-lives in the main environmental media (air, water and soil) together with the half-life in the environment for these two substances are shown in Fig. 1.3.



a b

Fig. 1.3. *Persistence of PCP (a) and b-endosulfan (b) in the environment*

Both PCP and β-endosulfan have close value of the half-life in soil, and persistence of PCP in water is essentially lower than that for β-endosulfan. However, according to the model simulations, the half-life of PCP in the environment is greater than that for β-endosulfan. The explanation of this fact is that, due to exchange processes, β-endosulfan is re-volatilized from soil and seawater to the atmosphere and degrades there faster than PCP. This conclusion is illustrated by the plots in Fig. 1.4.



a b

Fig. 1.4. *Degradation of PCP (a) and b-endosulfan (b) in the environmental media*

According to these plots, about 86% of the overall β-endosulfan degradation in the environment take place in the atmosphere, and, hence, the atmosphere is the main medium removing this substance from the environment. On the opposite, for PCP main removal of the substance from the environment occurs in soil. That is why overall persistence of PCP is close to the persistence in soil whereas for β-endosulfan this does not take place.

Main results

First of all, we note that both long-range transport potential and persistence of POPs are affected by physical-chemical properties of the substance under consideration. This can be exemplified by the comparison of LRTP and Pover characteristics of PCN-47 and PeCBz.

According to model calculations, for the transport from North American source the values of $T_{1/2}^{air}$ are about 8 days for PCN-47 and about 57 days for PeCBz. The difference in the values of the half-life in the atmosphere between the considered two substances is conditioned by their physical-chemical properties. First, degradation half-life in the atmosphere of PeCBz (140 days) is much larger than that for PCN-47 (11 days). Second, subcooled liquid vapour pressure for PCN-47 is essentially higher than that for PeCBz. This leads to the fact that the fraction of the gaseous form in the atmosphere for PCN-47 is larger than for PeCBz (26% for PCN-47 against 3.7% for PeCBz on the average). So, PCN-47 is subject to the processes of degradation and gaseous exchange in greater extent than PeCBz. Finally, the value of air/water partitioning coefficient for PCN-47 is less than that for PeCBz which makes gaseous exchange with soil for PCN-47 to be more intensive.

As a consequence, transport distance $TD_{0.001}$ for PeCBz occurs to be much higher than for PCN-47. The maps of spatial distribution of pollution from the American conventional point source are presented in Fig. 1.5.

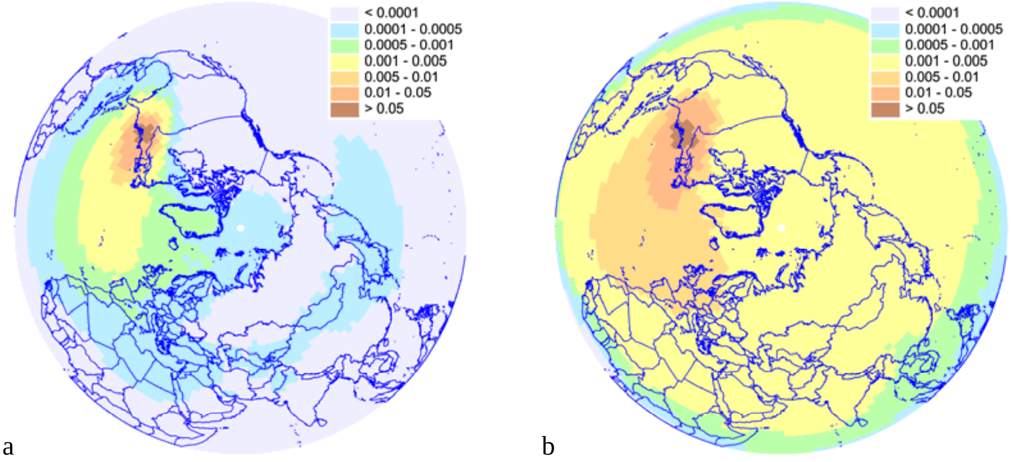


Fig. 1.5. *Spatial distribution of air concentrations for two substances (transport from a conventional point source in North America, annual means): (a) – PCN-47, (b) – PeCBz (relative units)*

The values of $TD_{0.001}$ calculated on the basis of these spatial distributions are 2450 km for PCN-47 and 8240 km for PeCBz.

Calculated values of the half-life in the environment for PCN-47 and PeCBz are 70 days and 200 days, respectively. It should be noted that the persistence of PCN-47 in seawater is the same as for PeCBz (half-lives in these media is about 1 year) and persistence in soil is even higher (half-life for PeCBz is about 1 year and for PCN-47 – about 4.7 year). Lower persistence of PCN-47 in the environment is conditioned by exchange processes and lower stability in the atmosphere (see the discussion of Pover above).

Further, LRTP and Pover of the pollutants depend strongly on the environmental parameters. To illustrate this dependence, calculations of the transport of PCN-47 from two conventional emission sources with one and the same power but with different locations: in North America and China are considered. According to the model results, the values of the half-life in the atmosphere $T_{1/2}^{air}$ are about 8 days for the transport from American source and about 6 days for transport from Chinese source.

Spatial distributions of concentrations originated from the considered two sources are displayed in Fig. 1.6. The value of transport distance of PCN-47 in the case of the transport from American emission source is 2450 km, whereas the transport distance in the case of the Chinese source is 1410 km. The difference between LRTP of PCN-47 calculated for the two selected regions is mainly conditioned by degradation process (from overall emissions of 1000 kg degraded mass for Chinese source is about 760 kg, and for North American source – about 580 kg only). The degradation process is governed mostly by air temperature and OH radical concentrations and their variations. The results of LRTP and Pover evaluation depend essentially on the geographical location of the emission source.

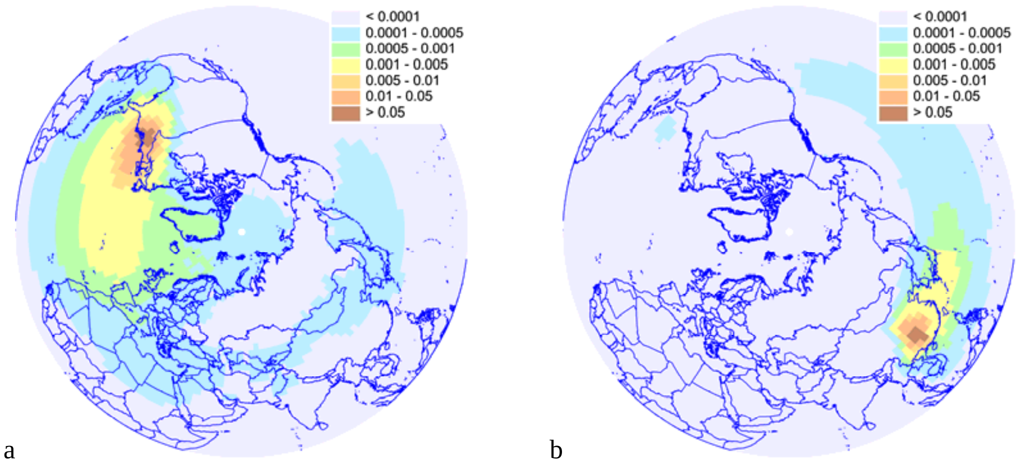


Fig. 1.6. *Spatial distribution of air concentrations for PCN-47: (a) – transport from a conventional point source in North America, (b) – transport from a conventional point source in China (relative units)*

Same reasons lead to the difference in half-lives in the environment calculated for the transport from emission sources of different geographical location. Namely, half-life in the environment for PCN-47 evaluated for the North American source is 70 days, and for Chinese source – 50 days.

LRTP parameters (half-life in the atmosphere and transport distance) depend on the meteorological conditions and thus vary with seasons. For example, seasonal variations of the half-life in the atmosphere and transport distance for PCP are shown in Fig. 1.7.

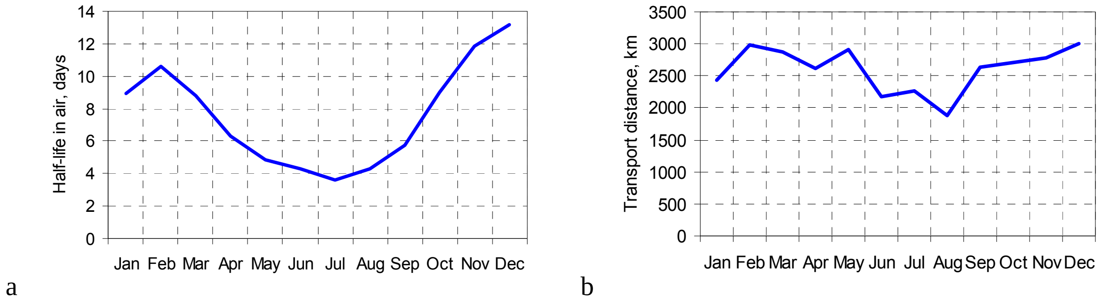


Fig. 1.7. *Seasonal variations of half-life in the atmosphere (a) and transport distance (b) for PCP*

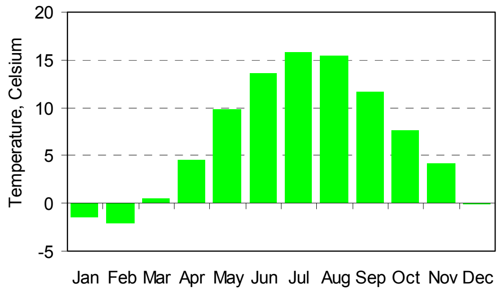


Fig. 1.8. *Seasonal variations of the temperature in the European region*

It is seen that seasonal variations of the half-life in the atmosphere is significantly anti-correlated with temperature (Fig. 1.8). The transport distance depends both on temperature and a number of other factors (in particular, wind patterns).

More detailed analysis of the dependence of LRTP and Pover parameters on pollutant-dependent, environmental and meteorological parameters is presented in [*Gusev et al.*, 2009].

The results of calculation of LRTP parameters (half-life in the atmosphere $T_{1/2}^{air}$ and transport distance $TD_{0.001}$) are summarized in the plots in Fig. 1.9. Due to differences in physical-chemical properties of the considered substances, their ranking with respect to $T_{1/2}^{air}$ and $TD_{0.001}$ is slightly different.

However, both rankings allow splitting the considered pollutants into groups of pollutants of regional or hemispheric/global concern.

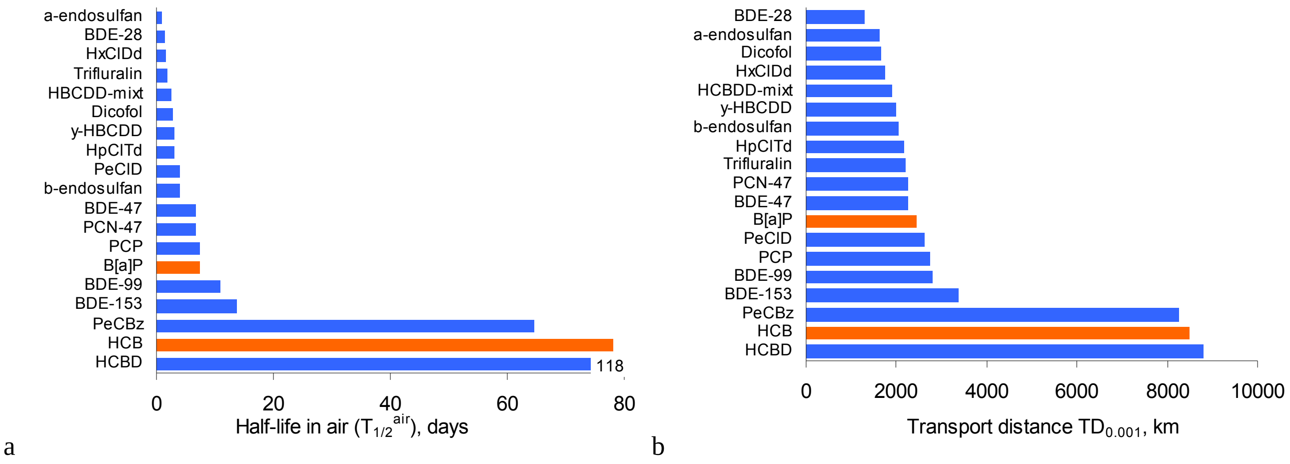


Fig. 1.9. *Results on LRTP evaluation: (a) – half-life in air, (b) – transport distance*

Namely, half-life in air and transport distance for pentachlorobenzene and hexachorobutadiene are close to those for HCB which is a known to be a pollutant of the hemispheric/global concern. The rest of the pollutants are likely to be of regional concern since their characteristics are of the same order as for B[a]P (especially the transport distance).

The values of half-lives in the environment obtained on the basis of model simulations are presented on the plot in Fig. 1.10. This characteristic shows the time during which environmental content of a given pollutant will be diminished twice due to main environmental processes (degradation in particular environmental compartments and exchange between these compartments).

Fig.1.11 shows the characteristics of LRTP and Pover for the substances which were considered this year by the Task Force on POPs. MSC-E reported the results of evaluation of LRTP and Pover for these substances to the Task Force. The Task Force welcomed the results of MSC-E modelling assessment of the proposed substances and used them in the technical review of the Protocol.

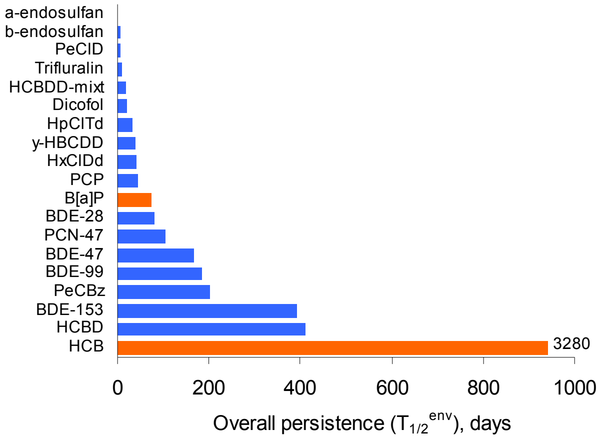


Fig. 1.10. *Results on Pover evaluation: half-life in the environment*

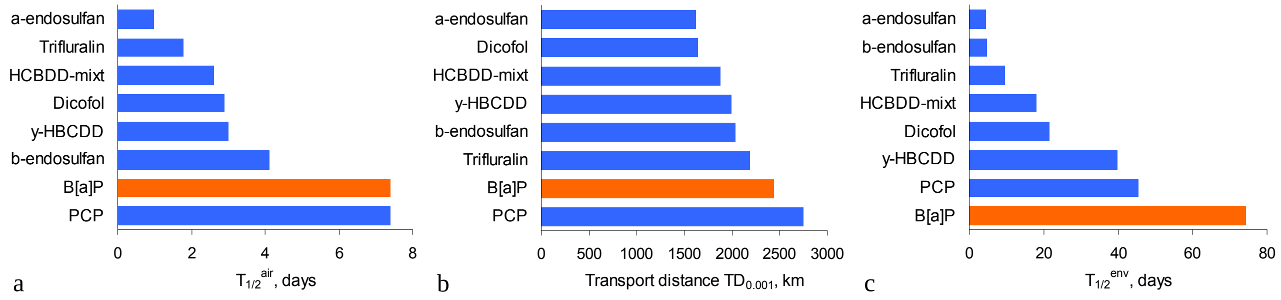


Fig. 1.11. *Ranking of substances-candidates with respect to* $T_{1/2}^{air}$ *(a), TD (b) and* $T_{1/2}^{env}$*(c)*

Conclusions

- In accordance with the recommendation of the Steering Body to EMEP, MSC-E has contributed to the preparatory work for the review of the Protocol on POPs to the Convention since 2004. The elaboration of supporting information on POP candidate substances with respect to evaluation of their long-range transport potential (LRTP) and persistence was performed. Technical notes on 18 substances proposed under CLRTAP as POP-candidates were prepared and submitted to the Task Force on POPs. Among them Technical notes on the five newly proposed substances (endosulfan, dicofol, trifluralin, hexabromocyclododecane and pentaclorophenol) were made available to the Task Force on POPs in 2009 at the invitation of the Executive Body for the Convention.
- Specific methodology of the evaluation of LRTP and persistence of substances on the basis of model simulations was elaborated. Application of spatially resolved models for the evaluation of LRTP and persistence of substances allows taking into account the variability of these characteristics due to geographical location of emission source, environmental conditions and types of the underlying surface.
- Model calculations of overall persistence and transport distance with allowance of various processes in the main environmental compartments (air, soil, water) and intermedia exchange, provide a relevant characterization of a substance persistence and LRTP in the environment.
- Numerical values of transport distance strongly depend on the evaluation methodology and model design. However, this parameter is highly illustrative and can be used in ranking substances with respect to their LRTP.
- It makes sense to take geographical location of emission source into account while interpreting the data on long-range transport potential and persistence of POP-like substances.
- Sources on physical-chemical properties of POP candidates such as data from the Stockholm Convention and European Chemical Agency are useful as additional information to the dossiers prepared by countries.

2. MONITORING OF POPs IN EMEP

2.1. Measurement network and implementation of the monitoring strategy

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 (see *http://ebas.nilu.no/*). A number of countries have been reporting POPs within the EMEP area in connection with different national and international programmes such as HELCOM, AMAP and OSPARCOM. Data from the open scientific literature are also used for model validation and complements the EMEP data. Detailed information about the sites and the measurement methods are found in EMEP/CCC's data report on heavy metals and POPs [*Aas and Breivik*, 2009]

In the EMEP monitoring strategy for 2004-2009 [*UN-ECE*, 2004] it is stated that parties should measure POPs in precipitation and air at their level 2 super sites. There should be at least one EMEP level 2 site per country with size larger than 50.000 km^2, and about 25-30 sites across Europe. Co-located and concurrent monitoring of relevant species is highlighted as a priority for the Parties, i.e. both air and precipitation measurements should be done at the same site. How is the status of implementing the strategy by 2007, now two years from the implementation stage? In Table 3.1, the measurement program in 2003 and 2007 is compared. It's been a distinct increase with seventeen sites in 2007 compared to twelve in 2003, furthermore only six sites with co-located air and precipitation measurements in 2003 compared to eleven in 2007. Germany has increased their number of sites considerably and has started measuring POPs in air. Spain, the United Kingdom and Latvia have started with POP measurement after 2003 while Ireland has stopped. Particularly noteworthy is the increase in reported PAH measurements, which is probably caused by the EU Directive on PAH (EU, 2004).

Even though the spatial coverage has improved, there is still a need for more monitoring sites, especially in south – southeast of Europe. There are, however, some positive developments in this region. At the EMEP sites in Moldova and Kazakhstan there will be one year of air and aerosol measurements of key POPs (PAHs, PCBs, pesticides, HCB, HCHs) from June 2009, a campaign financed by the Norwegian Ministry of Foreign Affairs. Furthermore, a one year POP passive measurements campaign was initiated in April 2009 by RECETOX (the Czech Republic) which aims to collect monthly samples at a number of EMEP sites to support relevant efforts under the Stockholm Convention on POPs, both also in support of EMEP.

Benzo-*a*-pyrene (BaP) which is a by-product of incomplete combustion processes is the most frequently measured POP component in EMEP. These results are therefore highlighted herein, whereas additional results for other compounds can be found in the data report [*Aas et al.*, 2009]. The spatial pattern of the average annual concentration level of BaP is shown in Fig. 2.1, and the concentrations seem to decrease when moving towards more remote areas in Europe. Notable differences in air concentrations can be seen between some adjacent sites (e.g. LV10 vs LV16), suggesting that some EMEP sites may be influenced by local emissions of PAHs. In general, elevated concentrations of POPs are often seen in central parts of Europe [*Aas and Breivik*, 2009] reflecting proximity to major sources areas in Europe [*Breivik et al.*, 1999; *Breivik et al.*, 2007].

Table 2.1. *Measurement sites and programs for POPs in 2007 and 2003. Bold means 2007 only while Italic only in 2003*

	POPs in air and aerosol	POPs in precipitation
BE04		Pesticides, HCHs
CZ03	PAHs, PCBs, pesticides, HCHs, HCB	PAHs, PCBs, pesticides, HCHs
DE01	**PAHs**	PAHs, PCBs, pesticides, HCB, HCHs
DE03	**PAHs**	**PAHs, PCBs, pesticides, HCB, HCHs**
DE08	**PAHs**	**PAHs, PCBs, pesticides, HCB, HCHs**
DE09	**PAHs**	PAHs, PCBs, pesticides, HCB, HCHs
ES08	**PAHs**	**PAHs, PCBs, pesticides, HCB, HCHs**
FI96	PAHs, PCBs, pesticides, HCHs	PAHs, PCBs, HCHs
GB14	**PAHs, PCBs**	
IE02		*PCBs, pesticides, HCB, HCHs*
IS91	PCBs, pesticides, HCB, HCHs	PCBs, pesticides, HCB, HCHs
LV10	**PAH (benzo-a-pyrene)**	
LV16	**PAH (benzo-a-pyrene)**	
NL91		γ-HCH
NO01/NO99	**PCBs,** HCB, HCHs	**PCBs,** HCB, HCHs
NO42	PAHs, PCBs, pesticides, HCHs, HCB	
SE12	PAHs, PCBs, pesticides, HCHs	PAHs, PCBs, HCHs
SE14	PAHs, PCBs, pesticides, HCHs	PAHs, PCBs, HCHs

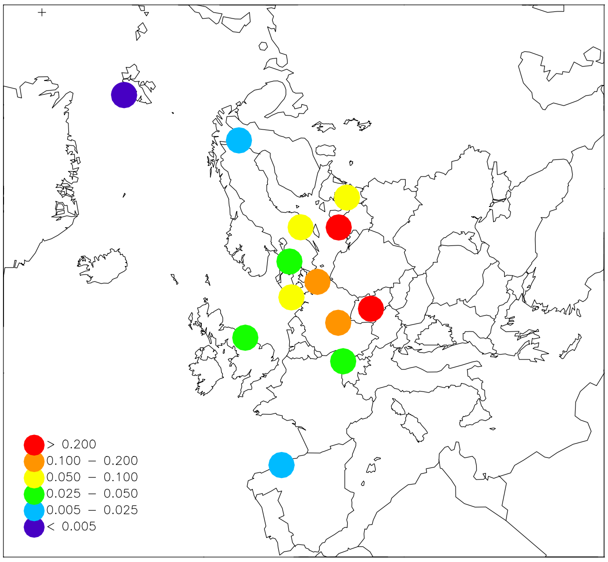


Fig. 2.1. *Spatial distribution of the annual average concentrations of Benzo[a]pyrene (B[a]P) in 2007, ng/m^3*

2.2. Passive air sampling of POPs

Even though the situation has slightly improved, the EMEP network is still limited in terms of spatial coverage for POPs. In response, a passive air sampling (PAS) campaign using polyurethane foam disks (PUF) [*Jaward et a*l., 2004; *Shoeib and Harner,* 2002] was carried out in various European countries during late summer 2006. The campaign was organized by EMEP/CCC in close collaboration with the Lancaster University (U.K.) and the GAPS initiative (which carries out passive air sampling of POPs on a global scale in support of the Stockholm Convention on POPs) [*Harner et al.*, 2006b; *Pozo et al.,* 2009; *Pozo et al.*, 2006]. 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.

The study regions included thirty three countries and eighty five 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 eighty five background sites, seventy two were EMEP sites. Duplicate samples were furthermore deployed at six EMEP sites where POPs in air are measured on a regular basis. The PAS results from these sites was compared with measured air concentrations, corresponding to the actual PAS deployment period, see Fig. 2.2.

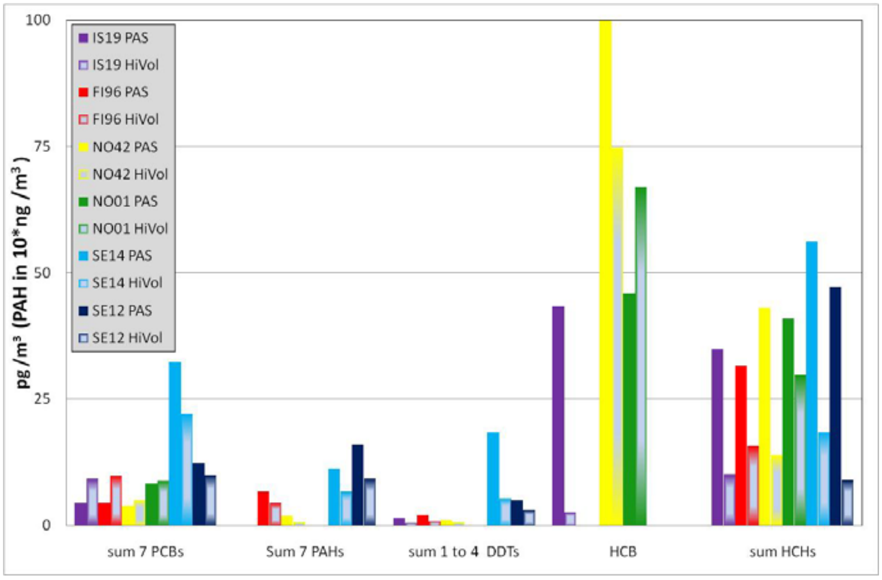


Fig. 2.2. *Comparison of results from active and passive samplers at selected EMEP sites, July - October 2006. Sum 7 PCBs = PCBs 28,52,101,118,138,153,180, Sum 7 PAHs = Phenanthrene, Anthracene, Fluoranthene, pyrene, Benzo-a-pyrene, Benz-a-anthracene, crysene, DDTs include from 1 up to 4 DDTs (p,p'-DDE, p,p'-DDD, o,p'-DDT, p,p'-DDT) while sum HCHs =* α*- and* γ*-HCH. Note that sum PAH is given in ng/m*^{3} *multiplied by 10, while the other POPs are in pg/m*^{3}.

There is typically not more than a factor two in differences between the active air samplers (AAS) and the PAS. This is an encouraging result since the same order of uncertainty can be observed by just comparing two labs measuring POPs [*Manø and Schaug*, 2003]. These are two very different sampling strategies and there are many factors that may cause differences in results:

- Whereas PAS integrate results over the entire exposure period, many sites using AAS do not measure POPs in air on a continuous basis. Results based on AAS are thus not directly comparable to PAS unless AAS is used on a continuous basis. For the high volume sampler it can be a problem with breakthrough, meaning that not all the volatile POPs are captured.

- PAS mainly collects the gaseous fraction only, whereas an active air sample collects both the gaseous fraction and the fraction which is sorbed to aerosols. For the AAS, the size cut off is usually about PM_{10}. Significant differences between PAS and AAS are thus expected for those chemicals that are extensively sorbed to atmospheric particles.

- Except for the results from Norwegian sites, the comparison of analytical results between AAS and PAS in Fig. 2.2 originate from different chemical laboratories.

- Uncertainties remain in methods used to back-calculate air concentrations derived on the basis of PAS as compared to AAS [*Gouin et al*., 2005; *Harner et al.*, 2006a; *Moeckel et al.*, 2009].

Taken into account all these sources of uncertainty the comparison between the samplers is quite satisfactory.

2.3. Recommendations for future monitoring

The Stockholm Convention on POPs has helped to gain an increased focus on air monitoring. A POP monitoring workshop was held in St. Petersburg, Russia 31. March, 2009 with representatives from regional and global monitoring networks, and the aim was to come up with recommendations for future monitoring of POPs. This workshop was held back to back to the Task Force of Hemispheric Transport of Air Pollutants (TF HTAP). The most central conclusions are repeated here:

1) **Data comparability.** It is important to improve the comparability between programmes as well as within each programme. To address this it is necessary with further laboratory- as well as field intercomparisons. Co-location of measurements serving several programmes to the same site(s) should further be encouraged.

2) **Particle-bound compounds.** Difficulties exist in interpreting passive sampler data for chemicals that partition between gas and particles. At present monitoring of such chemicals requires active air sampling techniques.

3) **New POPs.** It was recognized that in the near future new POPs maybe added to the existing POPs listed under the Stockholm Convention and CLRTAP. It is recommended that Parties include these new POPs and relevant precursors so that baselines can be established

4) **Long range transport, climate and meteorological variability.** To better understand source contribution etc, is essential to incorporate information of transport, and influences associated with variability in climate and meteorology. It is important to develop tools (e.g. back trajectory techniques, multimedia and transport models and investigations of meteorological and climate variability) to better interpret monitoring data.

5) **Data availability.** Existing as well as new programs are strongly encouraged to incorporate data management in their programs, i.e. utilize sustainable international databases that already exists to make use of their existing tools regarding e.g. dissemination of data and quality assurance

3. EVALUATION OF POP TRANSPORT AND POLLUTION LEVELS

This Chapter is devoted to the analysis of pollution levels and transboundary transport of selected POPs in the European and the Central Asian countries. Model simulations were performed using the most recent hemispheric and regional versions of MSCE-POP model based on official emission data and unofficial expert estimates. Levels of concentrations of selected POPs over the European and the Central Asian countries were evaluated and estimates of transboundary fluxes were obtained. This year POP pollution levels in the European region were analyzed linking the information from regular EMEP observations, measurement data of passive sampling campaigns, and modelling results. Computed concentrations were considered together with monitoring data to provide more realistic description of contamination and to characterise the level of agreement between measurements and modelling results.

3.1. Emission data for model assessment

The new EMEP Centre on Emission Inventories and Projections (CEIP), established in 2008, has the responsibility for providing the EMEP modelling Centres with the emission datasets for modelling purposes. This year, taking into account the transition period in CEIP, emission datasets for model evaluation of the European and the Central Asian countries pollution by POPs were prepared by MSC-E with the financial support of the Russian Federation. In particular, annual POP emissions were compiled on the basis of officially submitted information by EMEP countries and unofficial expert estimates for the following POPs: 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. Gridded information for these POPs was prepared for the EMEP domain with spatial resolution 50x50 km^2. For the evaluation of intercontinental transport the spatial distribution of PCDD/Fs, PCB-153, HCB, and γ-HCH emissions within the Northern Hemisphere with resolution 2.5°x2.5° was constructed.

Detailed information on POP emissions changes in the period 1990-2007 for each EMEP country and spatial distribution of annual emissions for 2007 can be found in Internet on the MSC-E web site [http://www.msceast.org/]. Officially submitted information on POP emissions is available at the web site of the CEIP [http://www.emep-emissions.at/ceip/].

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Gridded emissions for selected PAHs (B[a]P, B[b]F, B[k]F, and I_P) within the EMEP domain for 2007 were prepared using officially submitted PAH emissions. For the European countries, which did not report their emissions, unofficial data of TNO emission inventory [*Denier van der Gon et al.*, 2005; *MEPA*, 2007] 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 of the European and the 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 *Y.Zhang and S.Tao* [2009] and used for modelling of pollution levels in 2007. 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 2007 is illustrated in Fig. 3.1 by the example of B[a]P. Elevated levels of B[a]P emissions (20 – 200 g/km^2/y) can be noted for the Central, Southern and Eastern parts of Europe. The countries of Northern and Western Europe, Russia, and the Central Asian countries are characterised by relatively low emission fluxes (1 - 20 g/km^2/y).

The total emission of B[a]P within the EMEP grid in 2007 used for model calculation is estimated as 479 tonnes. Maximum contribution to the total B[a]P emission within the EMEP region in 2007 was made by Ukraine (21%) followed by Italy (10%), Poland (9%), and Turkey (8%).

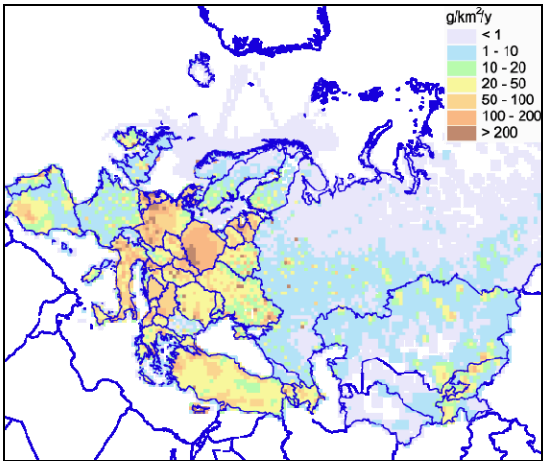


Fig. 3.1. *Spatial distribution of B[a]P emissions in 2007 over the EMEP grid with resolution 50x50 km^2, g/km^2/y*

POLYCHLORINATED DIBENZO(P)DIOXINS AND DIBENZOFURANS (PCDD/Fs)

Preparation of emission data on PCDD/Fs for modelling within the EMEP region was carried out on the basis of officially submitted information. In absence of officially reported information unofficial data of emission inventories [*Denier van der Gon et al*., 2005; *Pulles et al.,* 2006] were applied.

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 2007 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].

The spatial distribution of PCDD/F emissions in the EMEP domain for 2007 is shown in Fig. 3.2. Significant levels of PCDD/F emissions (0.5 - 5 ng TEQ/m^2/y) can be seen in countries of Central, Southern, and Eastern Europe. Other parts of Europe, in particular, Northern and Western Europe, are characterised by lower emission fluxes varying from 0.001 - 0.5 ng TEQ/m^2/y.

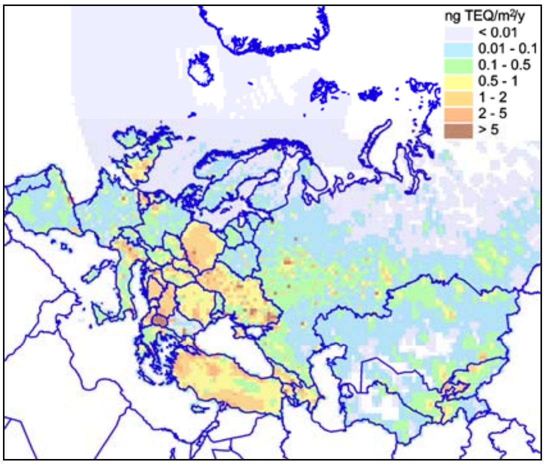


Fig. 3.2. *Spatial distribution of PCDD/F emissions in 2007 over the EMEP grid with resolution 50x50 km^2, ng TEQ/m^2/y*

The total emissions of PCDD/Fs in 2007 used for model calculation within the Northern Hemisphere is estimated to 9.6 kg TEQ, including 6.8 kg TEQ/y within the EMEP grid and 2.8 kg TEQ/y in North America. The most significant contributions to the total annual emission within the EMEP region were made by the Russian Federation (11%), Turkey (11%), Ukraine (11%), and Poland (5%).

HEXACHLOROBENZENE (HCB)

Datasets of HCB emission for modelling purposes were compiled on the basis of officially submitted data on HCB emission and unofficial information from [*Pacyna et al.*, 1999]. The HCB emission values for Tajikistan, Turkmenistan and Uzbekistan were estimated on the basis of the gross domestic product of these countries. Relationship between the gross domestic product and HCB emissions for these countries was obtained on the basis of the information from the emission inventory [*Pacyna et al.*, 1999].

To compile the distribution of HCB emission outside the EMEP region national data for Canada and the USA were used. The HCB emission for Japan was taken from the emission inventory of *E.Toda* [2005] for 2002. The HCB emission values for China, Pakistan and the Republic of Korea were estimated on the basis of the relationship of the gross domestic product and official HCB emission data for countries with similar economic indexes. The HCB emission value in India was taken from the previous studies of HCB pollution levels presented in the EMEP Technical Report 7/2005 [*Shatalov et al.*, 2005].

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 were implemented.

The spatial distributions of HCB emissions for 2007 within the EMEP domain and the Northern Hemisphere are shown in Figs. 3.3 and 3.4, 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, Ukraine, and the United Kingdom. Levels of emissions in other European countries are considerably lower.

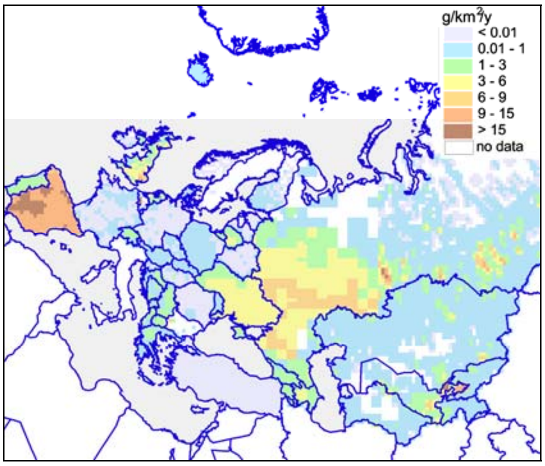


Fig. 3.3. *Spatial distribution of HCB emissions over the EMEP grid in 2007 with resolution 50x50 km^2, g/km^2/y*

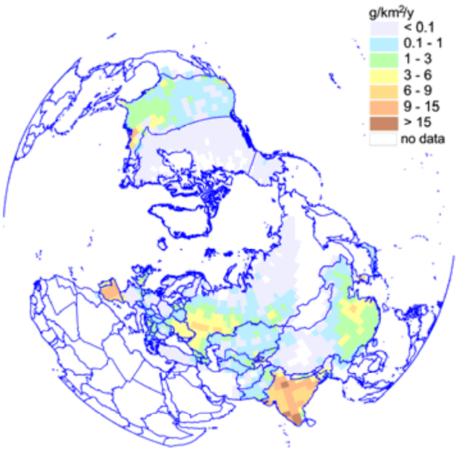


Fig. 3.4. *Spatial distribution of HCB emissions within the Northern Hemisphere in 2007 with resolution 2.5°x2.5°, g/km^2/y*

The total emissions of HCB in the Northern Hemisphere according to compiled information amounted to 78 tonnes in 2007, including 27 tonnes within the EMEP region and 51 tonnes in other regions. Maximum contributions to the total annual HCB emission within the EMEP grid in 2007 were made by the Russian Federation (48%), Spain (25%), and Ukraine (8%).

POLYCHLORINATED BIPHENYLS (PCBs)

Emission data for modelling of PCB long-range transport and deposition were prepared on the basis of unofficial global inventory of PCB usage and emission [*Breivik et al*., 2007] taking into account also officially submitted information on PCB emissions.

The inventory of *Breivik et al*. (2007) provides consistent set of historical and future emissions of 22 individual PCB congeners from 1930 up to 2100. The spatial distribution of annual PCB emissions on global scale with resolution 1°x1° was prepared. Three 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 the three emission scenarios allowed evaluating 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 deposition.

The indicator congener PCB-153 was selected for the evaluation of pollution levels for 2007 on regional and hemispheric scales. The spatial distribution of PCB-153 emissions within the European region was prepared using the data of emission inventory of *Breivik et al*. (2007) and spatial distribution of PCB emission officially submitted by the EMEP countries (Fig. 3.5). For the evaluation of PCB-153 long-range transport within the Northern Hemisphere gridded emissions with resolution 2.5°x2.5° were arranged (Fig. 3.6).

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.

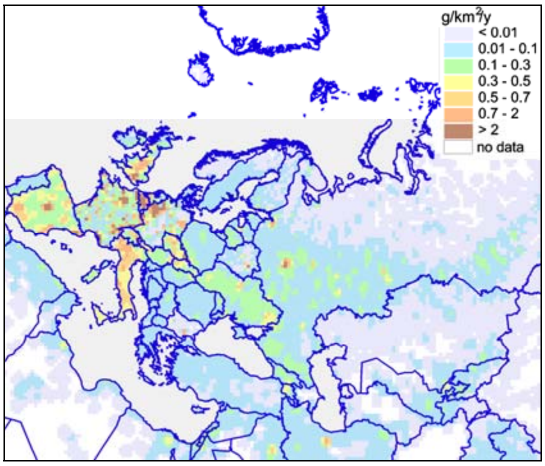


Fig. 3.5. *Spatial distribution of PCB-153 emissions over the EMEP grid in 2007 with resolution 50x50 km^2, g/km^2/y*

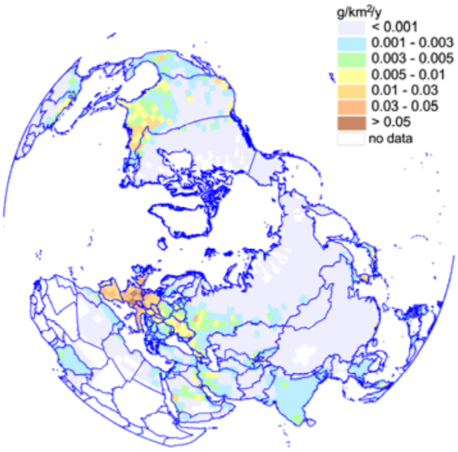


Fig. 3.6. *Spatial distribution of PCB-153 emissions within the Northern Hemisphere in 2007 with resolution 2.5°x2.5°, g/km^2/y*

LINDANE (γ-HCH)

The compilation of emission data for lindane (γ-HCH) within the EMEP region was based on the official emission data complemented by unofficial expert estimates. Data on emissions or usage of γ-HCH outside the EMEP region for the period 1990-2007 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 the European region official information on emissions was complemented by unofficial estimates on γ-HCH usage in the 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 [*Li et al.*, 1996; *Macdonald et al.*, 2000; *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]. Spatial distribution of γ-HCH emission in China was produced using the cropland area data available in the Canadian Global Emissions Interpretation Centre [http://www.ortech.ca/cgeic].

The spatial distribution of γ-HCH emissions within the Northern Hemisphere and over the EMEP grid for 2007 used for model simulations is presented in Fig. 3.8 and Fig. 3.7, respectively. Taking into account that the usage of lindane (γ-HCH) is severely restricted in Europe and that 25 countries reported no application of lindane, no emission of γ-HCH in 2007 was assumed for these countries in the model simulations.

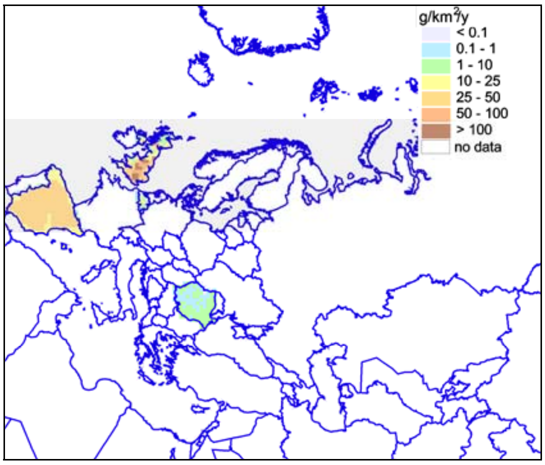


Fig. 3.7. *Spatial distribution of γ-HCH emissions over the EMEP grid in 2007 with resolution 50x50 km^2, g/km^2/y*

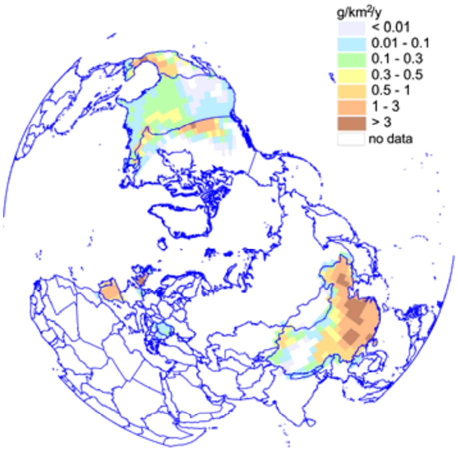


Fig. 3.8. *Spatial distribution of γ-HCH emissions within the Northern Hemisphere in 2007 with resolution 2.5°x2.5°, g/km^2/y*

3.2. Assessment of POP pollution levels in Europe

This section of the report presents the analysis of POP pollution levels within the EMEP region on the basis of modelling results and measurements of the EMEP monitoring network. The spatial distributions of modelled POP concentrations for 2007 is presented and complemented by available observations. Though the coverage of the EMEP domain by POP monitoring sites is currently limited to the north-western part of Europe it is possible to analyse the levels of pollution using the combined information on computed and observed concentrations and to determine the regions where additional efforts are needed to improve the description of POP concentrations and deposition.

Combined analysis of the pollution levels on the basis of the modelling results and measurements was carried out for air concentrations of selected POPs due to relatively bigger amount of regular measurements and availability of data of passive sampling campaigns. The comparison of modelled and observed POP concentrations in precipitation is provided to indicate the level of agreement of the model estimates of POP content in precipitation with measurements. Level of agreement between the computed and observed concentrations of selected POPs is characterised. To study the discrepancies between modelling results and measurements backward trajectories analysis was applied.

The analysis is complemented by the use of the results of passive sampling campaign performed by EMEP monitoring network in 2006 (Chapter 2). Monitoring campaigns on the basis of passive samplers provide valuable information for further refinement of description of POP pollution levels in the European and Central Asian countries due to their wider spatial coverage and cost efficiency. In combination with modelled estimates of POP concentrations, they can provide more complete description of pollution levels.

In this report brief information on measured and modelled pollution levels and their analysis is presented for selected POPs, namely, benzo[a]pyrene, PCB-153, HCB, and γ-HCH. Detailed description of pollution levels and the comparison of modelling results with measurements including the information on additional POPs can be found in the Technical report of MSC-E [*Gusev et al.*, 2009].

BENZO[A]PYRENE

Monitoring of B[a]P concentrations in air and precipitation was carried out at 13 sites of EMEP monitoring network. Available measurements cover central and western parts of Europe, in particular, the United Kingdom (GB14), Germany (DE1, DE3, DE8, DE9), the Czech Republic (CZ3), Latvia (LV10, LV16), and Sweden (SE12, SE14). Measurements in northern part of the EMEP domain are available in northern Finland (FI96) and in the Arctic region at Spitsbergen (NO42). In southern Europe monitoring of B[a]P concentrations is performed in Spain (ES8). It should be noted that B[a]P measurements of additional three Spanish sites (ES13, ES14, and ES16) were reported, but only for a short period of the year and therefore not included into the analysis.

The spatial distribution of modelled B[a]P annual mean air concentrations for 2007 is shown in Fig. 3.9. Along with the computed values the figure presents observed levels of B[a]P air concentrations at the EMEP monitoring sites. It is seen that the pattern of annual mean air concentrations calculated by the MSCE-POP model is close to the observed values. In spite of limited number of monitoring sites essential spatial correlation between the observations and the model results is noted. The model predicted low B[a]P concentrations for remote areas (about 0.001 – 0.02 ng/m^3), in particular, for the site NO42 and FI96. Moderate values of concentrations (0.02 – 0.08 ng/m^3) were obtained for the

United Kingdom, Sweden, Finland, France, Spain, and the Russian Federation, which is partly confirmed by available measurements of the sites GB14, SE12, SE14, and ES8. Elevated levels of B[a]P air concentrations were obtained in the central, eastern, and southern parts of Europe (about 0.08 – 1 ng/m^3). The most significant concentrations (more than 1 ng/m^3) can be seen in eastern part of Ukraine, in some regions of Italy, Romania, and Latvia.

For most of the monitoring sites computed values of B[a]P air concentrations are in a reasonable agreement with the measured ones (Fig. 3.10). In particular, for almost 80% of the sites the deviations between computed and observed annual mean air concentrations are about or less than a factor of two. At the same time, essential overestimation of observed concentrations, accounting for about a factor of 4, is seen for the sites ES8, LV16, and DE3.

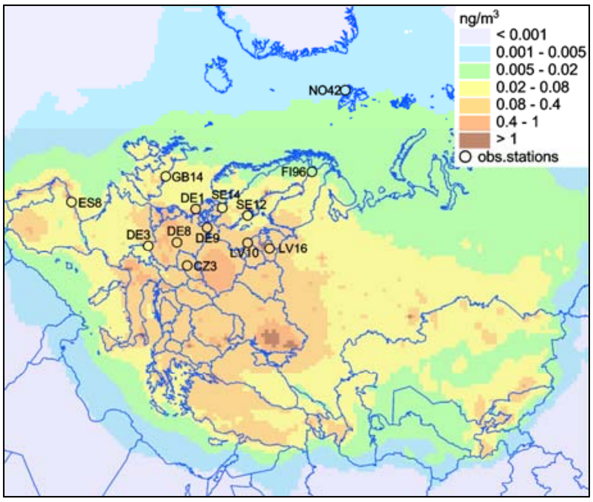


Fig. 3.9. *Spatial distribution of modelled B[a]P concentrations in air complemented by observed B[a]P air concentrations measured at the EMEP monitoring sites in 2007, ng/m^3*

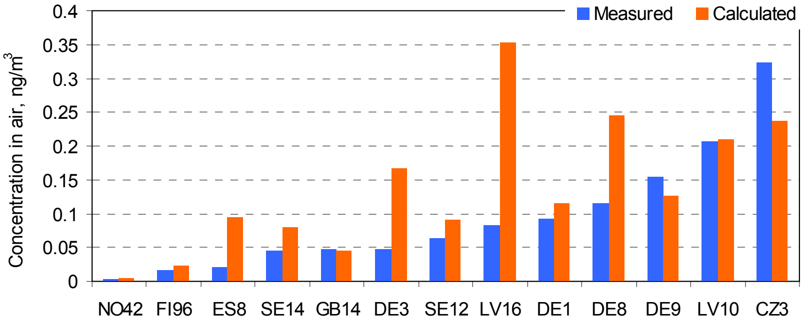


Fig. 3.10. *Computed and observed annual mean B[a]P concentrations in air for 2007, ng/m^3*

Essential discrepancies between the modelled and measured B[a]P air concentrations can be caused by several reasons. In particular, in all of these cases monitoring sites are located in or close to the grid cells with the essential anthropogenic emissions. Possibly the overestimation of observed concentrations can be conditioned by the spatial resolution used for model simulations, namely, 50x50 km^2, and representativeness of monitoring site for this spatial resolution. Another possible reason can be connected with the uncertainties of spatial distribution of emissions.

One of the possible ways to improve the agreement between observed and calculated concentrations for these sites can be application of fine resolution modelling for such regions. These cases require additional investigations on the basis of co-operation of experts in several areas, like emissions, monitoring, and modelling.

Levels of B[a]P air concentrations observed at most of monitoring sites are characterized by significant seasonal variations. In particular, winter time concentrations of B[a]P in air can be several times higher compared to the summer time concentrations. The comparison of modelled and measured air concentrations showed that the model was capable of providing reasonable predictions of seasonal variation of B[a]P concentrations. The Fig. 3.11 illustrates the comparison of seasonal variations of computed and observed B[a]P concentrations in air for the site SE14. It can be seen that modelled concentrations generally follow the observed variations of concentrations. However, there is a tendency to overestimate measured B[a]P concentrations, especially in warm period of the year, which may be caused by the uncertainties of the description of B[a]P emission seasonal variations in model simulations. Improvement of agreement is connected with the availability of more realistic information on temporal variations of B[a]P emission in the European countries.

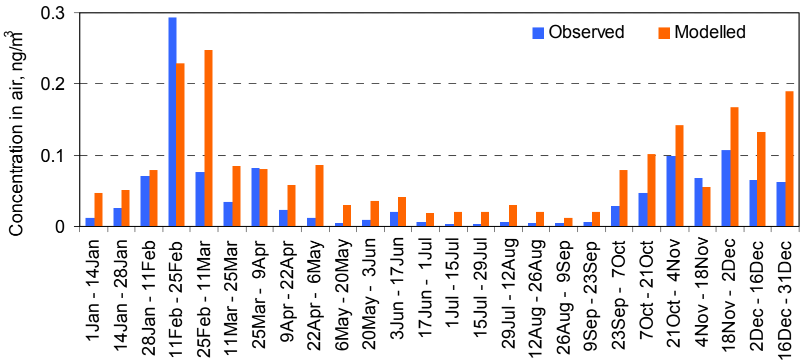


Fig. 3.11. *Comparison of observed and computed monthly mean B[a]P concentrations in air for 2007 for SE14, ng/m^3*

In comparison with a number of measurements of B[a]P air concentrations less information is available for its concentrations in precipitation. Computed concentrations of B[a]P in precipitation were compared with available measurements of four EMEP monitoring sites, namely, DE3, DE8, DE9, and CZ3. For all the sites except for CZ3 measured and calculated values of B[a]P concentrations in precipitation agree within a factor of 2. The model tends to predict higher values of concentrations in comparison to measured ones. For DE3 and DE8 sites similar tendency can be mentioned also for air concentrations of B[a]P. At the same time for the two sites, DE9 and CZ3, relation between the measured and modelled concentrations in precipitation is opposite (Fig. 3.12).

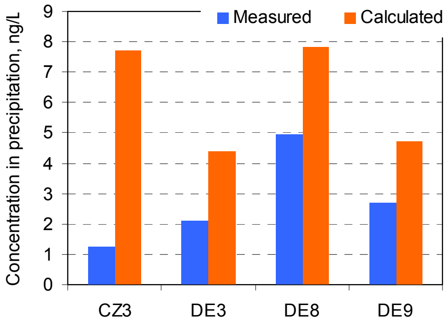


Fig. 3.12. *Comparison of computed and observed B[a]P concentration in precipitation for 2007, ng/L*

Considering the disagreement between the computed and observed B[a]P in precipitation at CZ3, it can be mentioned that measured concentrations of B[a]P in air at this site are the highest ones (Fig. 3.10). At the same time measured concentration in precipitation is essentially lower comparing to other measurements and the model prediction. To explain these differences further analysis of modelled and observed B[a]P concentrations at the CZ3 in co-operation with national experts is required.

Below the preliminary comparison of the modelling results with B[a]P measurements obtained in the framework of EMEP passive sampling campaign (Chapter 2) is described. As it was written above in the Chapter 2, the passive samplers mainly collect the gaseous fraction of a pollutant. Taking this into account, the comparison of modelling results with measurements of this campaign was performed for the computed B[a]P concentrations in gaseous phase.

Spatial distribution of measured B[a]P air concentrations is shown in Fig. 3.13 along with the modelling results for 2006. Modelling results agree with measurements mostly within a factor of 5 [*Gusev et al.*, 2009]. The lowest levels of concentrations (0.1 – 1 pg/m^3) are both measured and obtained by the model for the remote areas of Iceland, Norway, Sweden, and Finland. The highest concentrations of B[a]P (10 – 50 pg/m^3 and above) take place in central and eastern parts of Europe. Comparatively low concentrations of B[a]P in air can be seen in United Kingdom, France, and the European part of Russia (about 1 – 10 pg/m^3). In general, close character in distribution of computed and observed air concentrations of B[a]P can be noted.

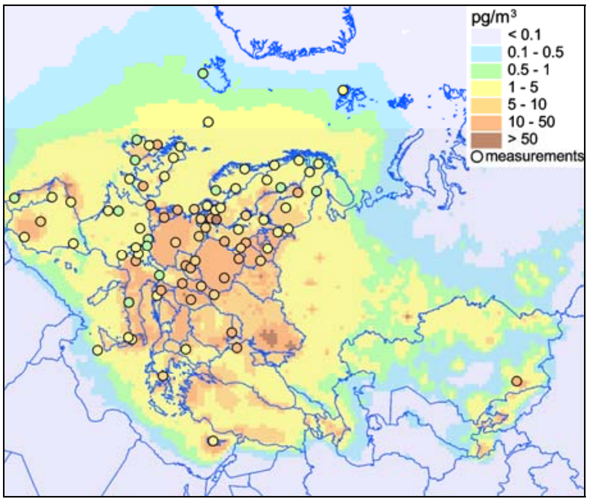


Fig. 3.13. *Spatial distribution of modelled air concentrations of B[a]P in gaseous phase and measurement data of passive sampling campaign of EMEP carried out in 2006, pg/m^3*

POLYCHLORINATED BIPHENYLS (PCB-153)

Investigation of PCB intercontinental transport and pollution levels for 2007 was carried out on the hemispheric scale with resolution 2.5°x2.5° and for the EMEP region with resolution 50x50 km^2 using the nesting of the hemispheric and regional MSCE-POP models. Due to essential persistence of PCBs in the environment and their accumulation in seawater and soil compartments hemispheric model simulations were performed for a sufficiently long period preceding the year 2007. Modelling was made for one indicator congener PCB-153 on the basis of the global emission inventory of PCBs prepared by *K. Breivik et al.* [2007]. During the hemispheric model run initial and boundary conditions for regional modelling of PCB-153 were prepared for 2007.

Monitoring of PCB-153 concentrations in air and precipitation was carried out at eight sites of EMEP network. Measurements of PCB-153 for 2007 are available for several countries in central and western parts of Europe, in particular, in the United Kingdom (GB14), Germany (DE1, DE3, DE8, DE9), the Czech Republic (CZ3), Sweden (SE12, SE14), Finland (FI96), and Norway (NO1, NO42).

Annual mean observed and computed air concentrations of PCB-153 for 2007 are shown in Fig. 3.14. It can be seen that the model closely reflects observed levels of PCB-153 air concentrations at the EMEP monitoring sites. In particular, low air concentrations (0.1 - 0.7 pg/m^3) were obtained for the Northern Atlantic and remote parts of Europe by the model and observed at the sites IS91, NO42, FI96, NO1, and SE12. Higher values (1 – 2.5 pg/m^3) were

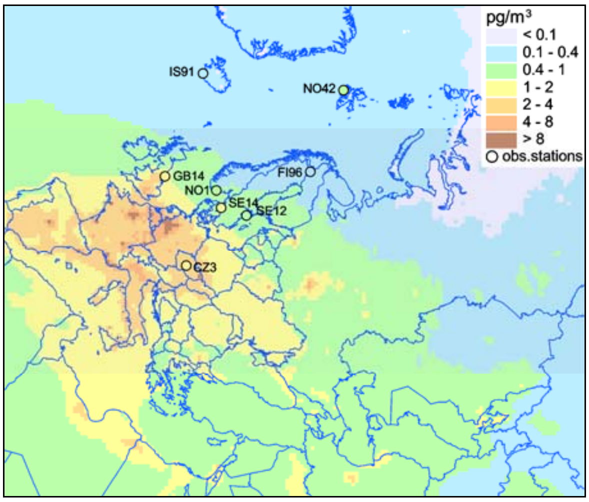


Fig. 3.14. *Spatial distribution of modelled PCB-153 concentrations in air complemented by observed PCB-153 air concentrations measured at the EMEP monitoring sites in 2007, pg/m^3*

measured at the sites GB14, SE14, and CZ3 situated in the United Kingdom, southern Sweden, and the Czech Republic. It should be noted that the model predicted comparable values of concentrations for these sites.

Comparison of computed and observed PCB-153 air concentrations is shown in Fig. 3.15. Reasonable agreement is noted between modelled PCB-153 air concentrations and measurements. In particular, for most of the sites the difference between the computed and observed annual mean air concentrations is about a factor of two or lower.

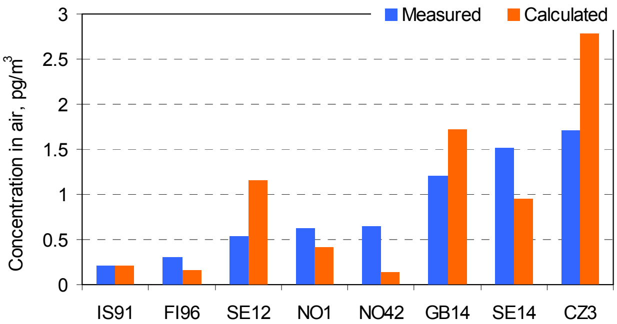
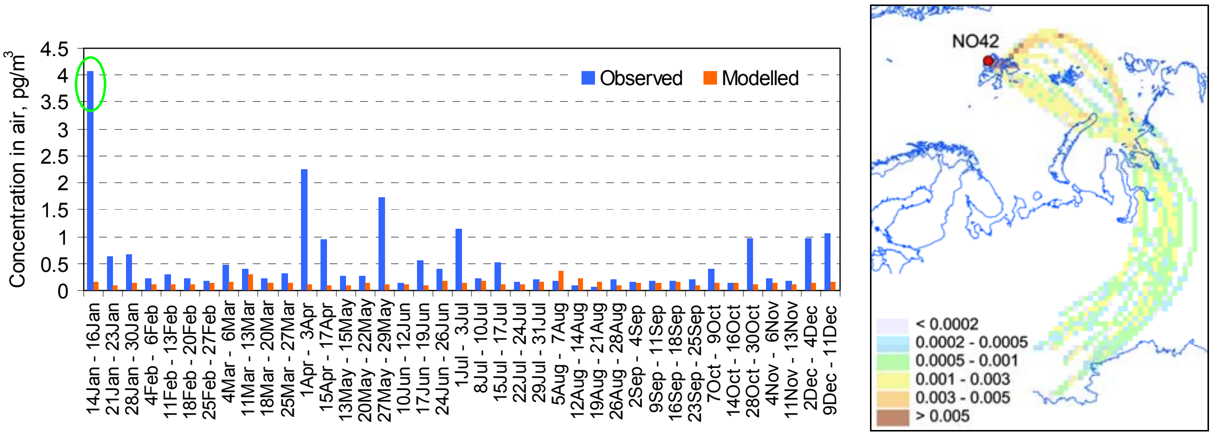


Fig. 3.15. *Comparison of observed and computed annual mean PCB-153 concentrations in air for 2007, pg/m^3*

More essential discrepancies were obtained for the site NO42 where the model underestimates observed air concentrations about a factor of 5. This underestimation can be caused by the influence of underestimated emission of remote sources within or beyond the EMEP domain. In particular, several sharp peaks of PCB concentrations measured at NO42 in 2007 can be caused by the episodic transport from emission sources of the Russian Federation. One of the episodes is presented in Fig. 3.16a and 3.16b where the backward trajectories for several days in January 2007 are shown. This map illustrates possible atmospheric transport of pollution from industrial regions of the Asian part of Russia which corresponds to the most essential peak of measured concentrations (Fig. 3.16a). For the improvement of the agreement between the modelled and observed concentrations at this site further refinement of PCB emission and its spatial distribution is required.



a b

Fig. 3.16. *Comparison of computed and observed PCB-153 air concentrations at the site NO42 in 2007, pg/m^3, (a) and density of backward trajectories of air masses for NO42 for the period 14-16 January 2007 (b)*

Computed concentrations of PCB-153 in precipitation were compared with available measurements of seven EMEP monitoring sites, namely, IS91, NO1, DE1, DE3, DE8, DE9, and CZ3. The model reasonably reproduced spatial distribution of annual mean PCB-153 concentrations in the remote regions and in the vicinity of major emission sources. In particular, elevated concentrations (about 0.2 - 0.3 ng/L) were measured at CZ3, DE8, and DE9 (the Czech Republic and Germany). Relatively lower levels of concentrations were observed at DE1, DE3, and NO1 (about 0.1 ng/L). Measured concentration of PCB-153 in precipitation obtained in the remote region at IS91 was almost an order of magnitude lower (about 0.01 ng/L).

Values of annual mean concentrations agree with measured ones for most of these sites within a factor of 2 (Fig. 3.17). Larger differences are seen for the sites DE3 and DE8 where the model overestimates observed PCB-153 concentrations in precipitation by a factor of 2 - 4. The most likely reason of the overestimation can be connected with uncertainties of spatial distribution of PCB emission used for modelling.

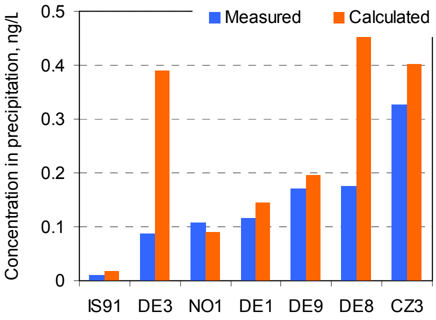


***Fig. 3.17**. Comparison of observed and computed annual mean PCB-153 concentrations in precipitation, ng/L*

The analysis of PCB pollution levels was complemented by the use of the results of EMEP passive sampling campaign carried out in 2006. The spatial variation of PCB-153 air concentrations is shown in Fig. 3.18 along with the modelling results for 2006. In general, the patterns of computed and observed PCB-153 concentrations in air are rather close. The agreement between modelling results and measurements is mostly within a factor of 2 – 3 [*Gusev et al.*, 2009]. The lowest levels of concentrations (0.1 – 1 pg/m^3) were obtained for rural and remote areas of Greenland, Iceland, Norway, Sweden, Finland, Ireland, and Cyprus. The highest concentrations (about 4 – 8 pg/m^3 and above) occurred at some regions of Denmark, Slovakia, Belgium, Netherlands, Germany, Switzerland, France, Hungary, the Czech Republic, Italy, and Sweden. Computed concentrations for these countries are somewhat lower (about 2 – 8 pg/m^3). It can be seen also that some of the measurements from the sites around the Baltic Sea are essentially higher than modelled values. The discrepancies for these sites might be conditioned by the influence of PCB emission sources not included into emission inventory. As noted earlier, the uncertainty in the passive sampling method may also contribute to the difference (Chapter 2).

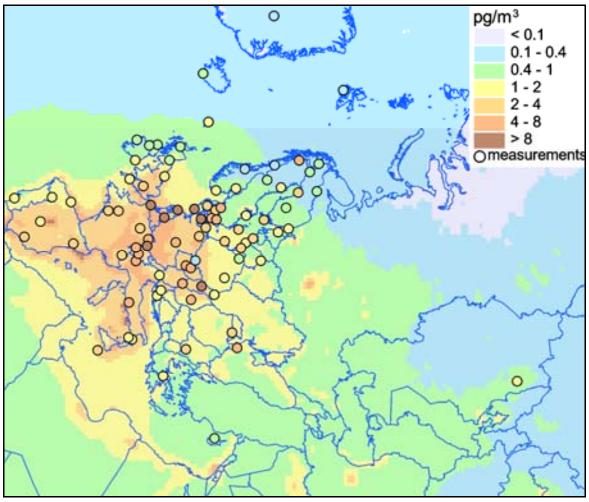


***Fig. 3.18.** Spatial distribution of modelled PCB-153 concentrations in air and measurement data of passive sampling campaign of EMEP carried out in 2006, pg/m^3*

HEXACHLOROBENZENE (HCB)

Evaluation of HCB pollution levels for 2007 was performed on the basis of regional modelling with resolution 50x50 km^2 for the EMEP domain along with the hemispheric scale modelling with resolution 2.5°x2.5° for estimation of HCB intercontinental transport. The hemispheric MSCE-POP model was applied to estimate the distribution of HCB from several groups of emission sources within the Northern Hemisphere for the period 1970-2006.

As it was mentioned in previous Status Report on POPs [*Gusev et al.*, 2008] available information on HCB emissions within the EMEP domain and on the global scale is subject of essential uncertainties. To continue the analysis of HCB pollution levels in the European and Central Asian countries modelling of HCB long-range transport was carried out using two different scenarios of emissions for

2007. One of scenarios was constructed on the basis of available official emission data for 2007 complemented by unofficial estimates of HCB emission. The second scenario was based on the TNO inventory of HCB emission for the year 2000 to illustrate possible underestimation of HCB emission in the officially reported information. According to this emission inventory the HCB emissions in the western and central parts of Europe are comparatively higher than that in previous scenario.

Modelling results obtained on the basis of two emission scenarios for 2007 were compared with measurements of 8 sites of EMEP monitoring network. In particular, monitoring of HCB concentrations was carried out in Germany (DE1, DE3, DE8, DE9), the Czech Republic (CZ3), Iceland (IS91), and Norway (NO1, NO42).

Spatial distribution of the observed and modelled annual mean HCB air concentrations within the EMEP domain for 2007 obtained on the basis of official HCB emissions complemented by unofficial emission estimates is shown in Fig. 3.19a. Essential variations of HCB content in air are seen both in measured and computed distribution of air concentrations. In particular, observed HCB air concentrations in Germany and southern Norway (60 – 70 pg/m^3) are essentially higher than the concentrations measured in Iceland and the Czech Republic (5 – 10 pg/m^3). High HCB concentrations, compared to the values measured in Germany, are noted for the Arctic station NO42.

Compared with the measured HCB concentrations in air modelling results obtained on the basis of official emission data are significantly lower, especially for monitoring sites located in Germany and Norway (Fig. 3.19a).

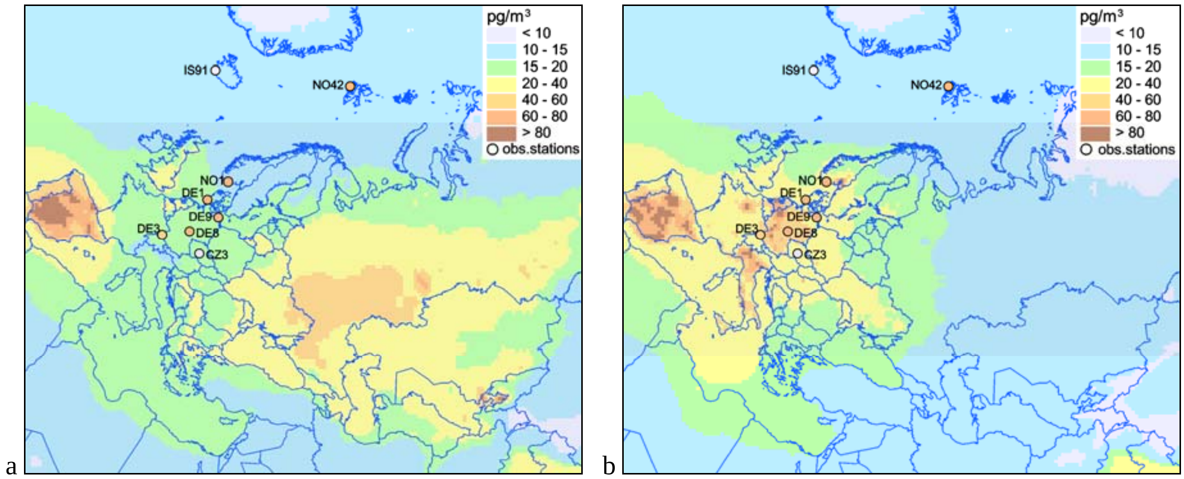


Fig. 3.19. *Comparison of HCB air concentrations measured at the EMEP monitoring sites with spatial distribution of modelled HCB concentrations in air for 2007 obtained on the basis of official HCB emissions complemented by unofficial emission estimates (a) and modelled HCB concentrations in air for 2007 obtained on the basis of unofficial emission estimates of TNO for 2000 (b), pg/m^3*

The underestimation of observed HCB concentrations can be caused by the incomplete information on HCB emission officially reported by countries. Spatial distribution of HCB air concentrations obtained on the basis of emission inventory of TNO for 2000 is shown in Fig. 3.19b along with the measured concentrations of HCB. It can be seen from the Fig. 3.20 that the use of higher emissions resulted in noticeable improvement of agreement between the computed and observed HCB concentrations for the sites in Germany (DE1, DE3, DE8, DE9) and in Norway (NO1). At the same time it can be noted that the model still underestimates observed levels of HCB air concentrations.

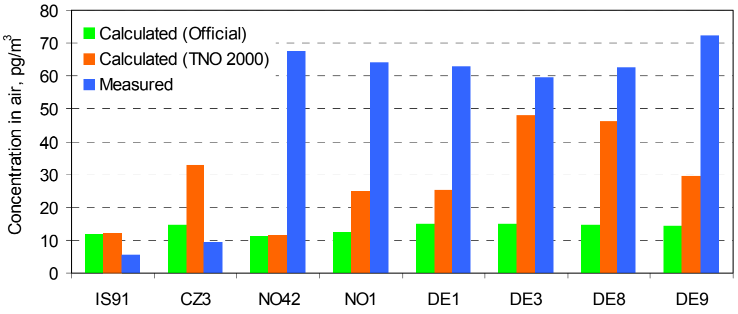


Fig. 3.20. *Comparison of HCB air concentrations measured at the EMEP monitoring sites (pg/m^3) with modelled HCB air concentrations for 2007 obtained on the basis of official HCB emissions complemented by TNO unofficial emission estimates for 2007 and on the basis of unofficial emission estimates of TNO for 2000*

Similar tendency to underestimate measured levels of HCB is seen in Fig. 3.21 where the comparison of computed and observed HCB concentrations in precipitation for 2007 is presented. Measured levels of HCB concentrations are essentially higher than the model predictions for the sites NO1, DE1, DE3, DE8, and DE9. Model simulations with unofficial emission estimates of TNO provided better agreement between the computed and measured HCB concentrations in precipitation.

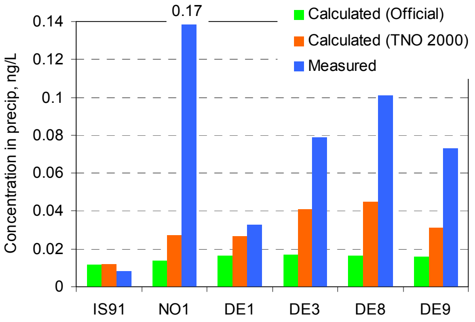


Fig. 3.21. *Comparison of observed and computed annual mean HCB concentrations in precipitation for 2007, pg/m^3*

The use of HCB measurements obtained by EMEP passive sampling campaign permitted to evaluate the level of agreement between the computed and observed HCB concentrations for significantly wider region. The distribution of computed HCB air concentrations within the EMEP region along with the data of passive sampling campaign for 2006 is shown in Fig. 3.22.

It is seen that the highest levels of measured HCB air concentrations (more than 80 pg/m^3) took place in remote and mountainous areas, in particular, Greenland, Spitsbergen, and in Switzerland which can be the effect of 'cold condensation' of HCB in colder regions. Model predictions for these regions are essentially lower which might be conditioned by the underestimation of the influence of global HCB emissions.

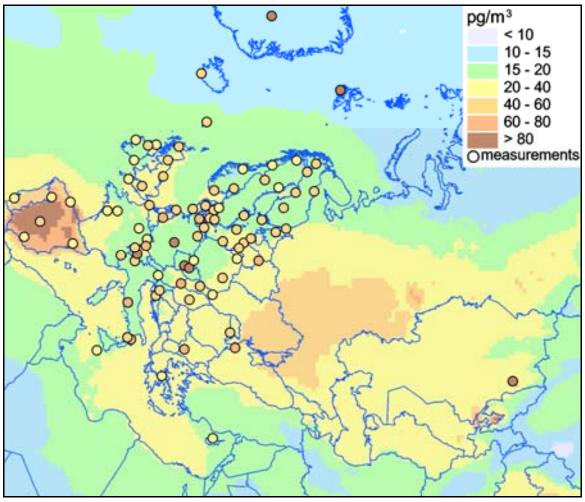


Fig. 3.22. *Spatial distribution of modelled HCB concentrations in air obtained for 2006 and measurement data of passive sampling campaign of EMEP carried out in 2006, pg/m^3*

Elevated values of measured HCB concentrations (40 – 80 pg/m^3) are noted for most of the European countries (the Czech Republic, Germany, etc.) and for the Central Asian countries (Kazakhstan). Relatively lower concentrations of HCB in air (20 - 40 pg/m^3) were observed in France, Spain, Ireland, Norway, Greece, and Cyprus.

Comparing the measurements of passive sampling campaign with modelling results the same tendency to underestimate observed levels of HCB concentrations, as it was mentioned above, is noted. In particular, model predictions of HCB air concentrations for Italy, Germany, the Czech Republic, Poland, Sweden, and Finland underestimate measured ones by a factor of 3 – 4. Slightly lower differences, about a factor of 2 – 3, can be noted for the United Kingdom and countries of Eastern Europe. At the same time the overestimation of observed HCB concentrations by the model was obtained for Spain.

The analysis of computed and observed HCB concentrations indicates that the levels of HCB emission in Europe are likely more significant than that officially reported by the European countries. The results obtained in model simulations using different emission scenarios showed that the use of higher HCB emission essentially improves the agreement between the measurements and model estimates. As an indirect confirmation of incompleteness of official data on HCB emissions in some countries can be significant difference between the values of emissions reported by different countries, for instance, between emission of Spain (6.9 tonnes) and emission of France (0.013 tonnes) or Germany (0.002 tonnes).

LINDANE (γ-HCH)

The environmental levels of lindane (γ-HCH) have been significantly decreased within the European region during two recent decades due to reduction of its application. In particular, the information on lindane emissions for the period 2000 – 2007 was provided only by the United Kingdom, Spain, Belgium, Croatia, and Romania. In other European countries according to the officially reported information there was no application of lindane or its emission was insignificant.

Model simulation of γ-HCH long-range transport and accumulation in the environmental compartments within the Northern Hemisphere was performed with the hemispheric MSCE-POP model for the period 1985-2007. Modelling of γ-HCH distribution in the European region for 2007 was carried out using nesting of hemispheric and regional modelling.

Spatial distributions of annual mean γ-HCH air concentrations within the EMEP region and data of regular EMEP measurements for 2007 are presented in Fig. 3.23. Elevated γ-HCH air concentrations (40 pg/m^3 and above) in 2007 are characteristic of the United Kingdom and Spain. 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 (about 5 pg/m^3), which is mainly connected with the absence of information on the emissions for these regions. Similar pattern of air concentrations is provided by measurements of γ-HCH in air. Elevated γ-HCH air concentrations were obtained at CZ3 and DE1 sites while low level of concentrations was observed at other sites in Norway, Sweden, Finland, and Iceland.

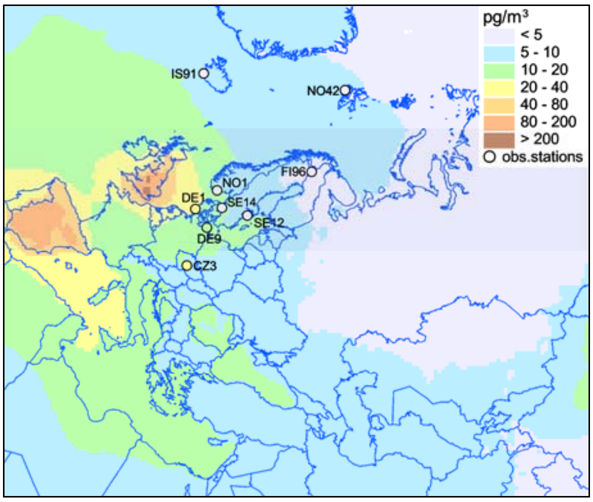


Fig. 3.23. *Spatial distribution of modelled γ-HCH concentrations in air complemented by observed air concentrations measured at the EMEP monitoring sites in 2007, pg/m^3*

It can be seen that the model predictions of γ-HCH air concentrations for 2007 are somewhat lower for CZ3, DE1, and DE9 (Fig. 3.24). At the same time, measurements of the sites in Scandinavian countries are overestimated by the model. The most significant differences in air concentrations accounting for a factor of 3 - 5 are encountered for the sites IS91, NO42, SE14, and SE12. The reason of the overestimation can be connected with the uncertainties of lindane emissions, its spatial distribution, and seasonal variations. Additional source of differences can be uncertainties in γ-HCH physical-chemical properties and their temperature dependence. For other monitoring sites the differences are about a factor of two.

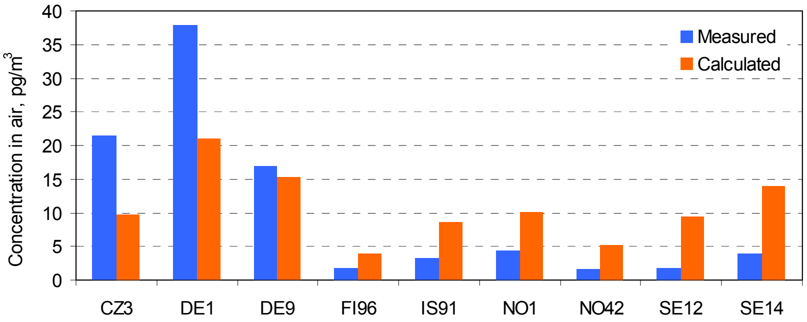


Fig. 3.24. *Comparison of observed and computed annual mean γ-HCH concentrations in air for 2007, pg/m^3*

In case of γ-HCH concentrations in precipitation the model tends to underestimate measured levels at most of the sites (Fig. 3.25) by a factor of 2.6 on the average. The most essential underestimation, about a factor of 3 - 4, takes place for the sites DE3 and NL91. In other cases computed concentrations agree with measurements nearly within a factor of two. Essential overestimation of observed γ-HCH concentrations, both in air and in precipitation, was obtained for the site IS91. This difference might be caused by the overestimation of the boundary conditions provided by the hemispheric model simulation due to uncertainties of emission estimates for the regions outside the EMEP grid.

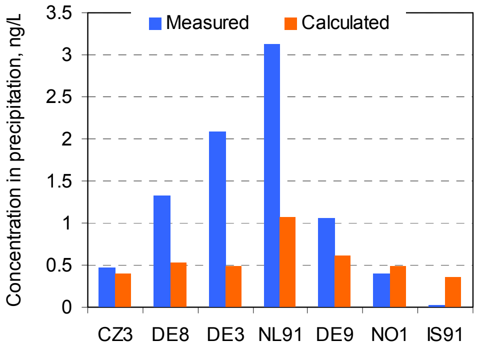


Fig. 3.25. *Comparison of observed and computed annual mean γ-HCH concentrations in precipitation, ng/L*

Measurements of γ-HCH air concentrations obtained by EMEP passive sampling campaign combined with spatial distribution of computed γ-HCH air concentrations within the EMEP region for 2006 are shown in Fig. 3.26. The geographical distribution of γ-HCH air concentrations obtained by measurements of passive samplers reflects possible pattern of γ-HCH emission which is most likely underestimated by officially reported information.

Elevated γ-HCH air concentrations (about 40 - 80 pg/m^3 and above) were measured in most of countries of Western, Central, and Eastern Europe, namely, in France, Germany, eastern part of the United Kingdom, Belgium, the Netherlands, Spain, Portugal, the Czech Republic, Austria, Hungary, Ukraine, and Moldova. Lower levels of concentrations (5 – 40 pg/m^3) were provided by measurements in areas surrounding southern part of the Baltic Sea and in Ireland, Greece, and Italy. Lowest γ-HCH air concentrations (1 – 5 pg/m^3) were observed in remote regions, in northern parts of Norway, Sweden, Finland, Iceland, and Greenland.

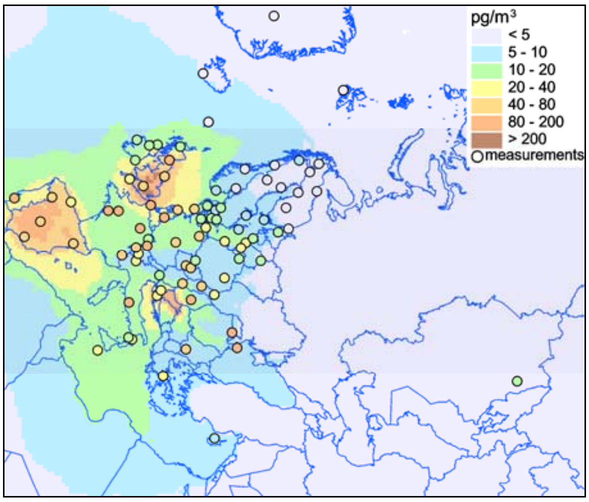


***Fig. 3.26**. Spatial distribution of modelled γ-HCH concentrations in air and measurement data of passive sampling campaign of EMEP carried out in 2006, pg/m^3*

It can be seen that the model predicted close levels of concentrations for the United Kingdom, Spain, and Scandinavian countries along with the remote areas. At the same time the measurements of sites in other regions of Europe are essentially underestimated by the model mostly due to the underestimation of γ-HCH emissions. Similar tendency to underestimate observed concentrations can be noted for Poland, Lithuania, Estonia, and Greece.

Considering available measurements and modelling results on γ-HCH it can be noted that the current levels of its emissions in a number of European countries, possibly connected with ongoing application or past usage, are more significant than available official emission data. Therefore the improvement of description of γ-HCH pollution levels in the European and the Central Asian countries requires further refinement of information on γ-HCH emissions.

3.3. POP Transboundary Pollution

Transboundary transport of POPs within the EMEP region in 2007 was evaluated for PAHs and PCDD/Fs. The calculations were made with the regional MSCE-POP model at the EMEP domain with resolution 50x50 km^2. Emission data used for the modelling purposes are described in Section 3.1. Officially reported emission data on PAHs and PCDD/Fs are more complete compared to other POPs considered in these report. That is why these POPs were selected for the evaluation of transboundary transport. Estimates of deposition due to transboundary transport of pollution include contributions of emission sources of European countries, distant sources outside the EMEP grid, and re-emission. Modelling approach implemented in the MSCE-POP model for the evaluation of transboundary transport of POPs is described in the Technical report [*Gusev et al.*, 2009]. Detailed information on the calculated source-receptor relationships for 2007 is presented in the Annex B.

POLYCHLORINATED DIBENZO(P)DIOXINS AND DIBENZOFURANS (PCDD/F$_S$)

Evaluation of transboundary transport of PCDD/Fs for 2007 was carried out for the mixture of 17 toxic PCDD/F congeners. To take into account the influence of 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 for the period 1970-2007 was performed. Based on the results of this model run the initial and boundary concentrations for the regional MSCE-POP model were prepared. Model simulations were based on the physical-chemical properties of PCDD/F “indicator congener” 2,3,4,7,8-PeCDF. Differences between the modelling results based on the physical-chemical properties of indicator congener and the results of simulations using the properties of all 17 toxic congeners did not exceed 20%. In case of evaluation of country to country deposition matrix the differences were within a 5% range [*Dutchak et al.,* 2004].

Evaluation of PCDD/F transboundary transport considers the contributions of anthropogenic emission sources of the European and Central Asian countries, distant emission sources outside the EMEP domain, and re-emission. On hemispheric scale the influence of PCDD/F emission sources of the USA and Canada was taken into account. For other regions outside the EMEP domain emissions of PCDD/F are currently not available. Therefore the contribution of non-EMEP emission sources of PCDD/F in this model simulation can be underestimated. PCDD/F anthropogenic emission within the EMEP domain for 2007 was accounted for 6 kg TEQ. In comparison to the emission used for model evaluation of pollution for 2006 [*Gusev et al.*, 2008] this value of emission is about 4% lower.

Total deposition of PCDD/Fs to the European and Central Asian countries from anthropogenic and non-EMEP emissions, and re-emission made up 15.2 kg TEQ. The contribution of anthropogenic and non-EMEP emission sources amounted to 5.6 kg TEQ and 0.9 kg TEQ, respectively. Significant fraction in total deposition of PCDD/Fs belongs to re-emission accounting for 57% of total deposition. In comparison to the modelling results obtained for 2006 [*Gusev et al.*, 2008], PCDD/F deposition to the European and Central Asian countries in 2007 did not change significantly. The difference between the total PCDD/F deposition within the EMEP domain computed for 2006 and 2007 is about 1%.

Spatial distribution of calculated annual PCDD/F deposition fluxes within the EMEP domain in 2007 is presented in Fig. 3.27. It can be noted that deposition fluxes over the European and Central Asian countries ranged from 0.1 ng TEQ/m^2/y to about 5 ng TEQ/m^2/y. Elevated values of deposition fluxes (1.5 – 5 ng TEQ/m^2/y) were obtained for the Central, Southern, and Eastern Europe. In other regions of Europe (Scandinavian Peninsula, France, Spain, Portugal and the United Kingdom) and in Central Asian countries the deposition fluxes vary from 0.1 – 1.5 ng TEQ/m^2/y which reflects the proximity of major emission sources.

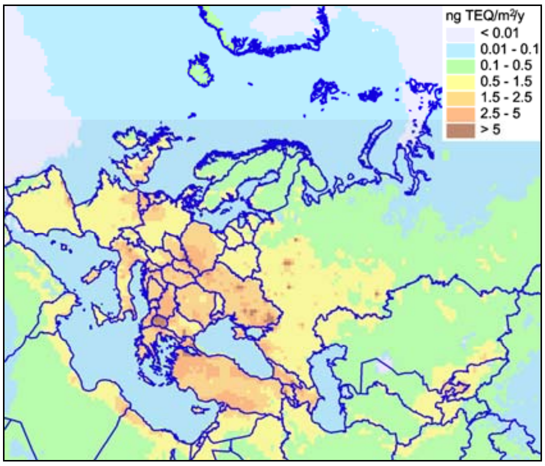


Fig. 3.27. *Spatial distribution of annual deposition flux of PCDD/Fs calculated for 2007, ng TEQ/m^2/y*

Transboundary transport and deposition of PCDD/Fs within the EMEP region was carried out taking into account the contributions of national emission sources of the European and Central Asian countries, non-EMEP emission sources (USA and Canada), and re-emission. Figure 3.28 presents the total annual deposition of PCDD/Fs over the EMEP region for 2007 divided into the contributions of different groups of emission sources. Transboundary transport and its contribution to total deposition depends on a number of factors like the size of a country territory, peculiarities of meteorological conditions, and magnitude of domestic emission of a given country.

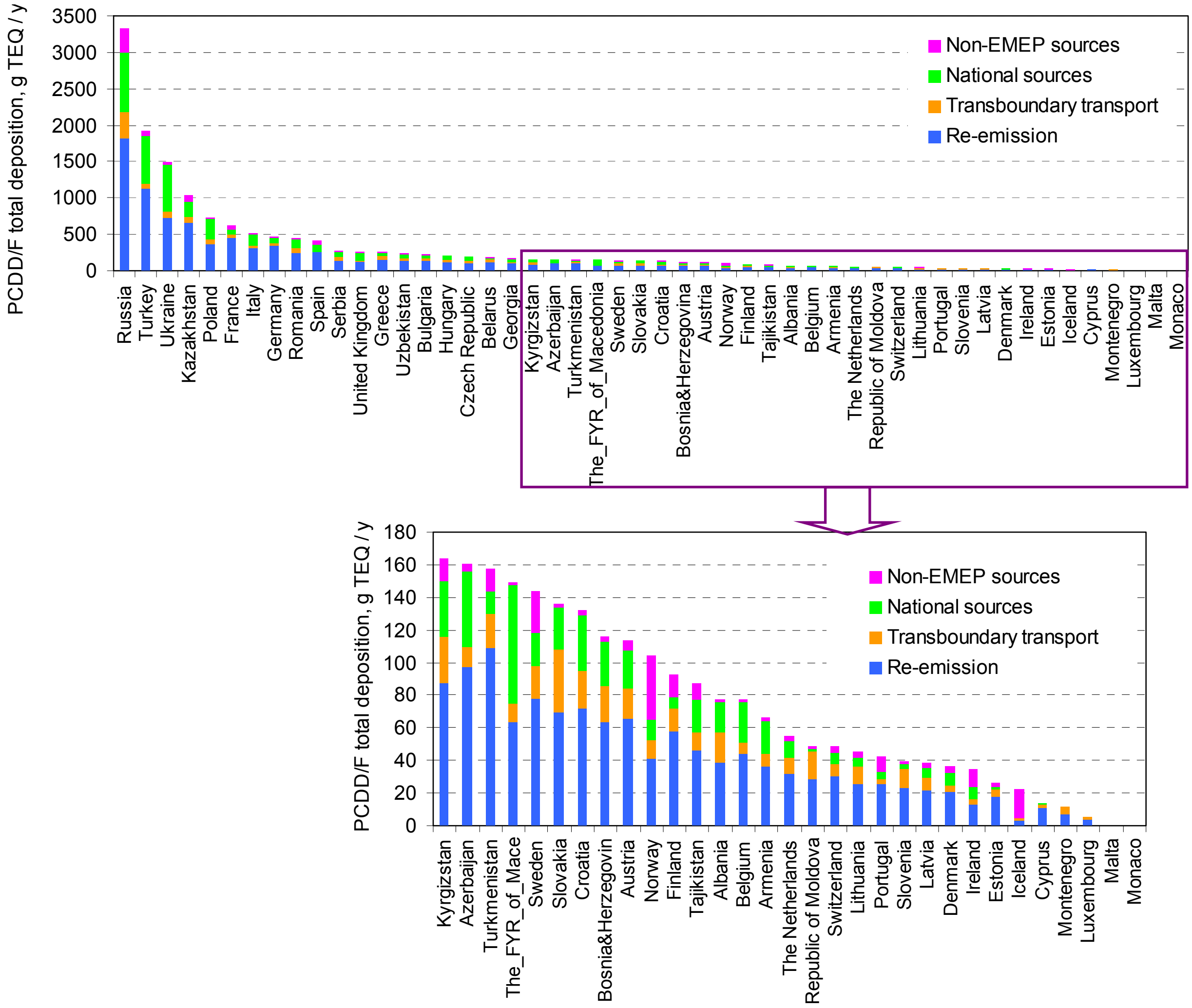


Fig. 3.28. *Total annual deposition of PCDD/Fs over the European and the Central Asian countries in 2007 and contributions of national emission sources, transboundary transport within the EMEP region, and re-emission, g TEQ/y*

Relative importance of PCDD/F transboundary transport from anthropogenic emission sources of the European and Central Asian countries comparing to the contribution of national sources is shown in Fig. 3.29. Contribution of transboundary transport to the deposition varies from almost 100% for Montenegro to about 9% for the United Kingdom. For 18 countries the contribution of PCDD/F transboundary transport exceeds 50%, and for 5 countries – 75%. The contribution of transboundary transport for the countries with significant national emissions of PCDD/Fs (Turkey, Ukraine) and countries situated upwind to the major emission sources (the United Kingdom, Spain) is comparatively low being about 9%-13%.

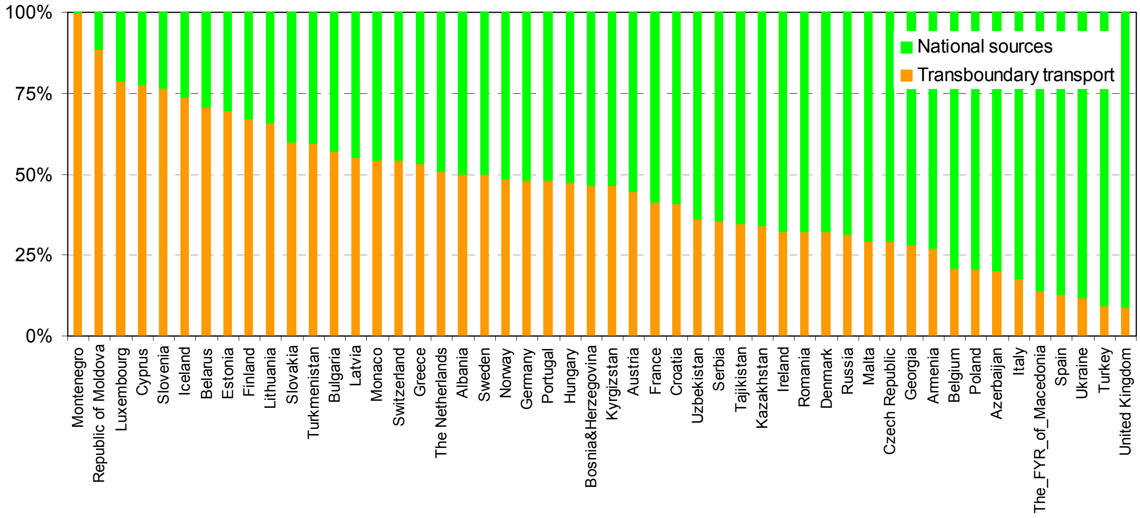


Fig. 3.29. *Relative contribution of transboundary transport and national emission sources to total deposition of PCDD/Fs in the European and the Central Asian countries for 2007 (excluding contribution of re-emission).*

The contribution of a particular country to the transboundary transport of pollution and the fraction of total deposition originated from its national emission sources and deposited outside its territory are shown in Fig. 3.30 and Fig. 3.31. Essential part of the emitted PCDD/Fs from the sources of the European and Central Asian countries is transported outside their boundaries. The most essential contribution to the transboundary transport of PCDD/Fs in 2007 is made by emission sources of Ukraine (about 270 g TEQ) followed by Poland (126 g TEQ) and the Russian Federation (120 g TEQ). The fraction of total deposition occurred outside a country territory vary from almost 100% for Monaco and Montenegro to about 13% for Turkey. For 13 countries the fraction of total deposition from national emission sources deposited outside their territory exceeds 50%.

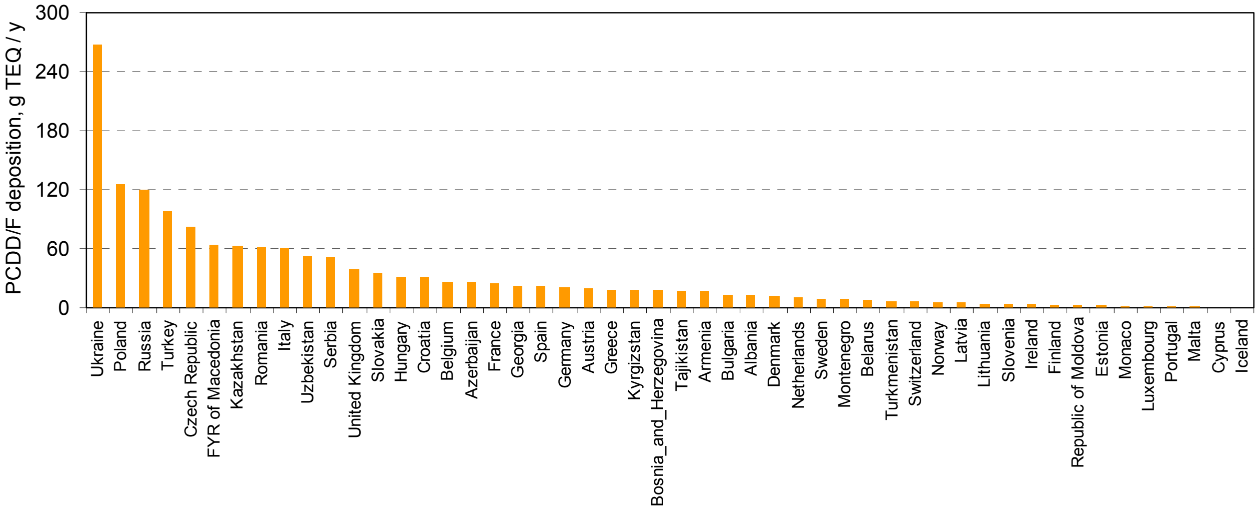


Fig. 3.30. *PCDD/F deposition originated from countries emission sources and occurred outside their territories in 2007, g TEQ/y*

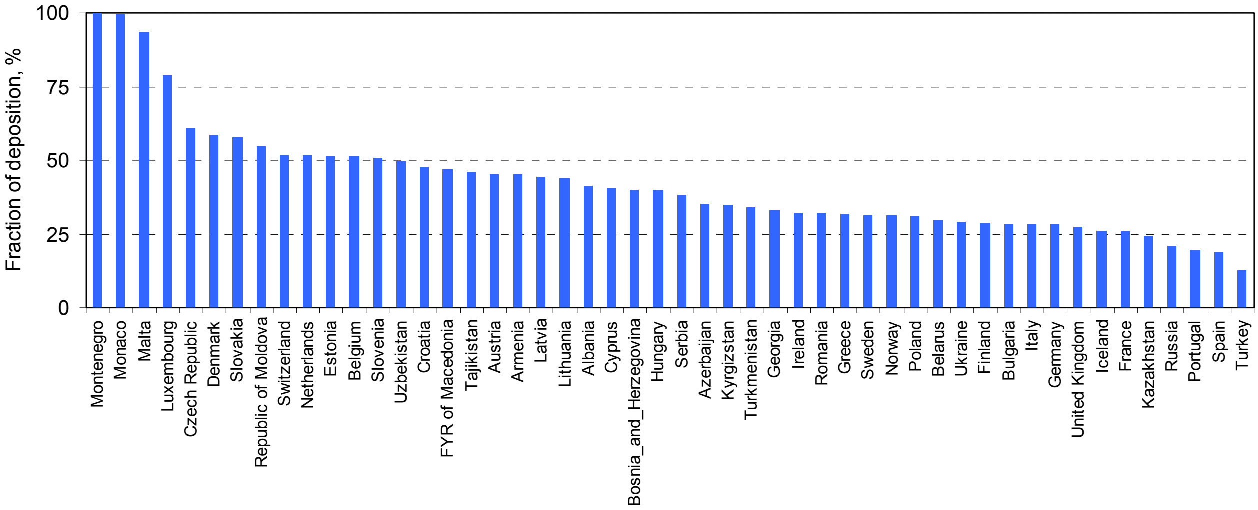


Fig. 3.31. *Fractions of PCDD/F deposition originated from countries emission sources and occurred outside their territories in 2007, %*

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

Evaluation of PAH transboundary transport within the EMEP grid was carried out on the example of indicator compound benzo[a]pyrene (B[a]P). Due to its physical-chemical properties B[a]P is present in the atmosphere mostly in the particle-bound form. Taking this into account the contribution of B[a]P intercontinental transport to the pollution of the European region is comparatively small. For this reason only the sources of emissions within the EMEP domain were considered in model simulations of B[a]P transboundary transport. Anthropogenic emission of B[a]P within the EMEP domain for 2007 was accounted for 479 tonnes. This value of emission is about 3% lower comparing to the B[a]P emission used for model simulations for 2006 [*Gusev et al.*, 2008].

Total deposition of B[a]P to the European and Central Asian countries in 2007 from anthropogenic emission sources amounted to 175 tonnes. In comparison to the results obtained for 2006 [*Gusev et al.*, 2008], the deposition to the European and Central Asian countries decreased by 24%. These changes can be attributed to the interannual variability of meteorological parameters, decrease of B[a]P emissions, and the refinement of model parameterization. Total deposition to the EMEP domain from all sources (anthropogenic and re-emission) made up 193 tonnes. The contribution of re-emission sources in 2007 is accounted for 9%.

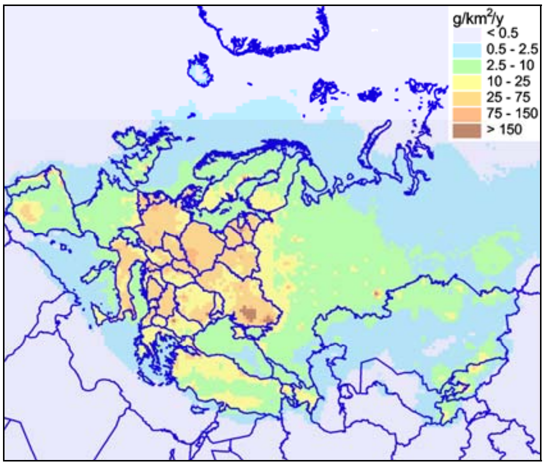


Fig. 3.32. *Spatial distribution of annual deposition flux of B[a]P calculated for 2007, g/km^2/y*

Spatial distribution of calculated annual B[a]P deposition fluxes within the EMEP domain in 2007 is given in Fig. 3.32. It is seen that B[a]P deposition fluxes over the European countries varied from 2.5 g/km^2/y to about 150 g/km^2/y. Essential values of deposition fluxes (25 – 150 g/km^2/y) were characteristic of the Central, Southern, and Eastern Europe. In other parts of Europe (Scandinavian Peninsula, France, Spain, Portugal and the United Kingdom) deposition fluxes typically did not exceed 25 g/km^2/y. Deposition fluxes of B[a]P calculated for the Central Asian countries were comparatively lower (about 0.5 – 10 g/km^2/y).

Modelling of long-range transport and deposition of B[a]P within the EMEP domain using MSCE-POP model allows evaluating the contributions of national emission sources, transboundary transport, and re-emission to the total deposition. In Figure 3.33 estimates of total annual deposition of B[a]P over the European and Central Asian countries in 2007 are presented along with contributions of different emission sources. It can be seen that transboundary transport of B[a]P is a significant source of pollution for the European countries. Its contribution can vary from almost 100% for Monaco and Montenegro to about 5% for Spain (Fig. 3.34). For 22 countries the contribution of B[a]P transboundary transport exceeds 50%, and for 8 countries – 75%. Transboundary transport and its contribution to total deposition depends on a number of factors like the size of a country territory, peculiarities of meteorological conditions, and magnitude of domestic emission of a given country. In particular, for countries with significant national emission, in comparison with the emissions of surrounding countries, the contribution of transboundary transport is typically low, like for instance, for Ukraine (11%), Poland (17%), and Germany (19%). At the same time for countries with relatively small territory or low emission the contribution of transboundary transport can be essential (Montenegro – 91%, Switzerland – 86%, Malta – 82%).

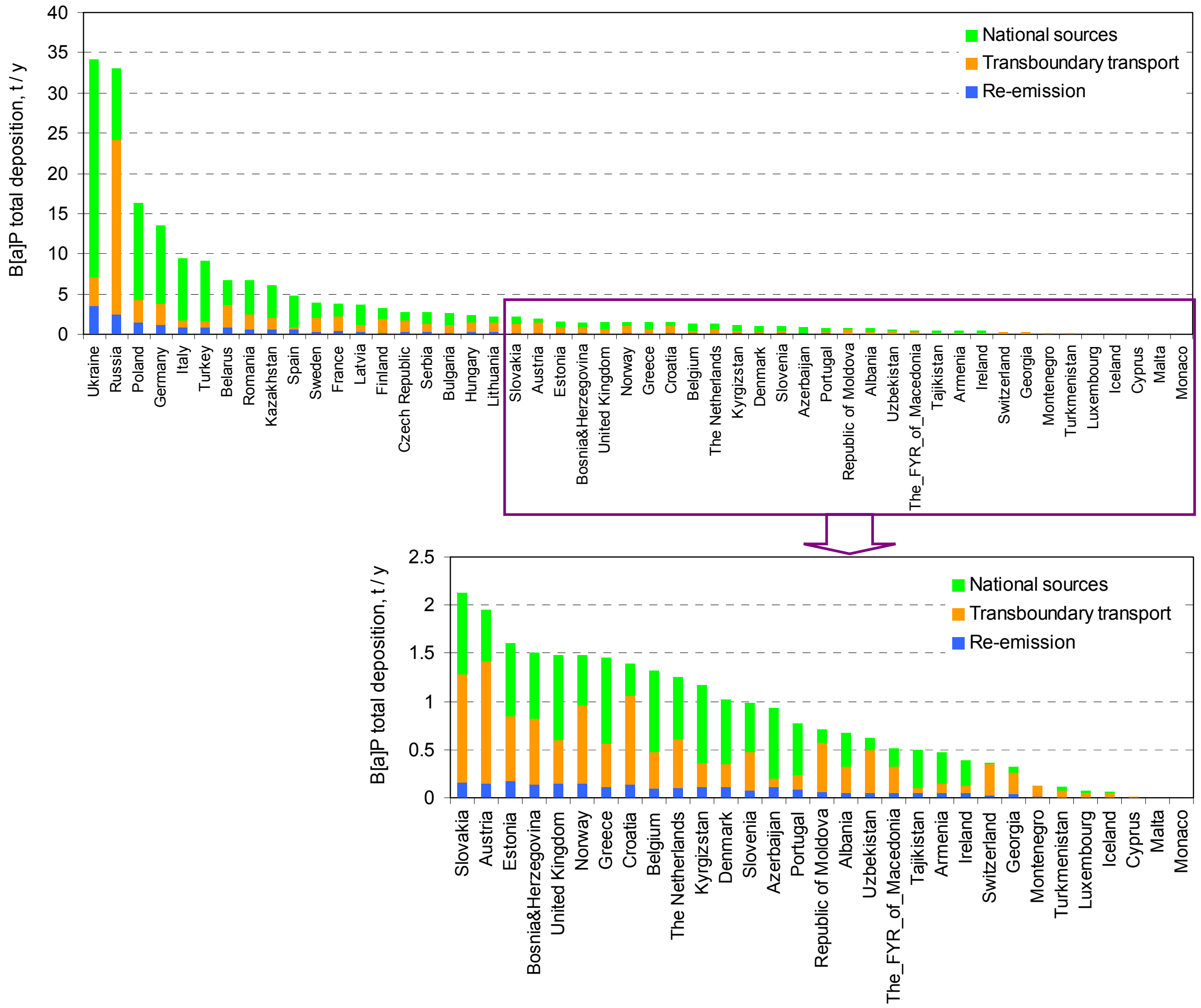


Fig. 3.33. *Total annual deposition of B[a]P over the European and the Central Asian countries in 2007 and contributions of national emission sources, transboundary transport within the EMEP region, and re-emission, t/y*

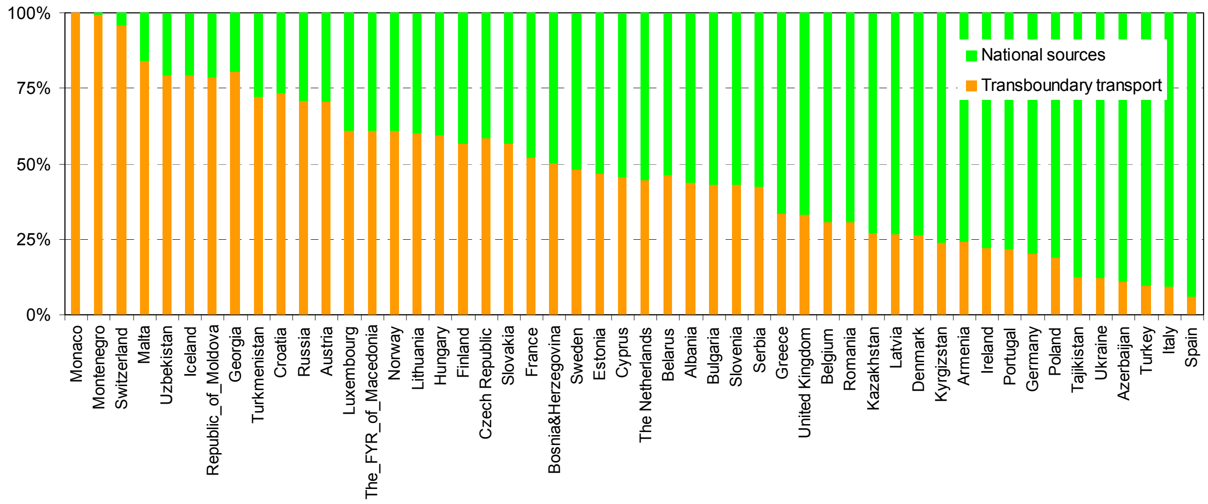


Fig. 3.34. *Relative contribution of transboundary transport and national emission sources to total deposition of B[a]P in the European and the Central Asian countries for 2007 (excluding contribution of re-emission).*

The contribution of a particular country to the transboundary transport of pollution can be characterised by the fraction of total deposition originated from its national emission sources and deposited outside its territory. This information is shown for each EMEP country as B[a]P deposition in tonnes per year and as a fraction of total deposition from national emission sources in 2007 in Fig. 3.35 and Fig. 3.36, respectively. It is seen that essential part of pollutant emitted from the sources of the European and Central Asian countries is transported outside their boundaries. In particular, this fraction varies from almost 100% for Monaco and Montenegro to about 13% for Turkey. For 18 countries the fraction of deposition occurred outside their boundaries exceeds 50% of total deposition from anthropogenic sources. The most essential contribution to the transboundary transport of B[a]P in 2007 is made by emission sources of Ukraine (about 13 tonnes) followed by Poland (9 tonnes) and Germany (5 tonnes).

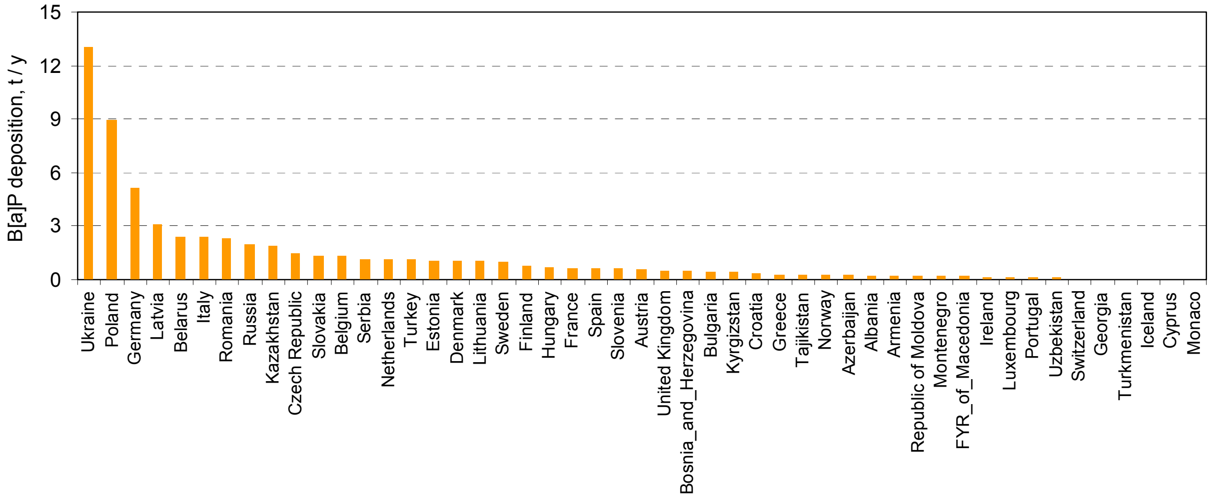


Fig. 3.35. *B[a]P deposition originated from countries emission sources and occurred outside their territories in 2007, t/y*

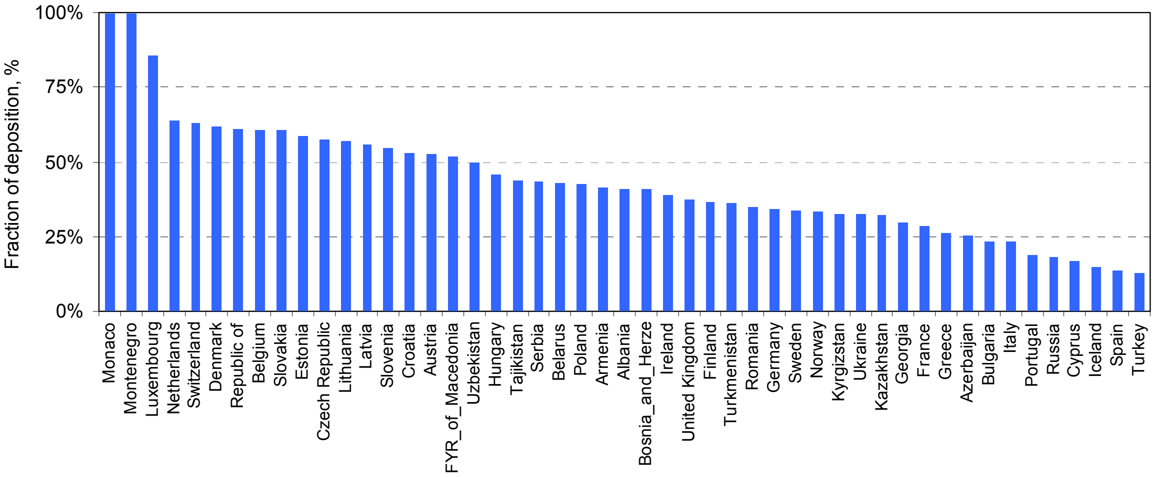


Fig. 3.36. *Fractions of B[a]P deposition (in %) originated from countries emission sources and occurred outside their territories in 2007*

4. POP MODEL DEVELOPMENT

In 2009 the work on further development of the multicompartment POP transport model MSCE-POP was continued. This year main attention was paid to the refinement of model parameterization of main aerosol-related processes and preparation of the model input data. In particular, global-scale data on atmospheric constituents important for POP modelling based on GEMAQ-EC model simulations as well as CMAQ data on aerosol specific surface, particulate matter composition, and OH-radical concentrations were analyzed. Besides, dependence of dry deposition of particulate POPs on particle size distribution was investigated.

4.1. Input data on aerosols and OH-radical for the modelling of POP long-range transport

Simulation of transboundary atmospheric transport of POPs requires input data on air concentrations of different compounds. In particular, to describe gas-particle partitioning data on specific aerosol surface or organic carbon content in aerosol particles are needed. Besides the degradation rates of POPs in the atmosphere depend on OH-radical air content. Evaluation of pollution levels of POPs for the European region is currently performed on both hemispheric and regional scale, therefore two types of the input data, global and regional scale data, are used in model simulations.

Global data

The information on global distribution of various atmospheric constituents important for POP modelling was provided by the Environment Canada (K. Puckett and S. Gong) to the MSC-E for the application in the experimental modelling of POPs on global scale using the common EMEP global modelling framework. These data were obtained from GEMAQ-EC model and include three-dimensional daily fields of OH-radical, natural black carbon, anthropogenic black carbon, natural organic carbon, anthropogenic organic carbon, sea salt, soil dust and sulphate with spatial resolution 1°x1°.

The global scale information on aerosol content in the atmosphere generated by GEMAQ-EC is being processed and analyzed at the MSC-E. Fig. 4.1 illustrates the spatial distribution of annual mean air concentration of total particulate matter in the lowest model layer. The highest concentrations (> 100 $\mu g/m^3$) take place over the Sahara desert. The level of PM air concentrations over the most part of Europe varies from 5 to 10 $\mu g/m^3$.

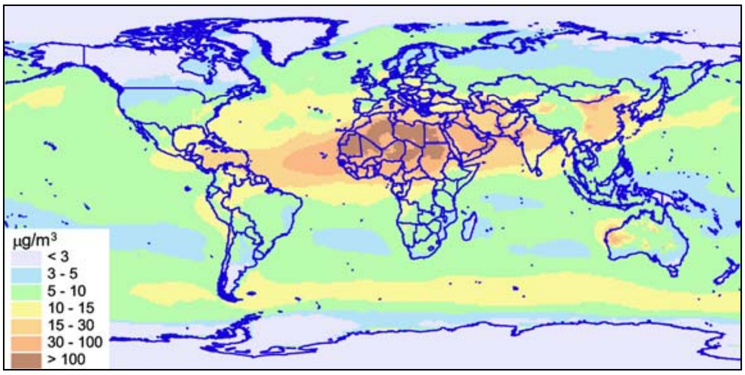
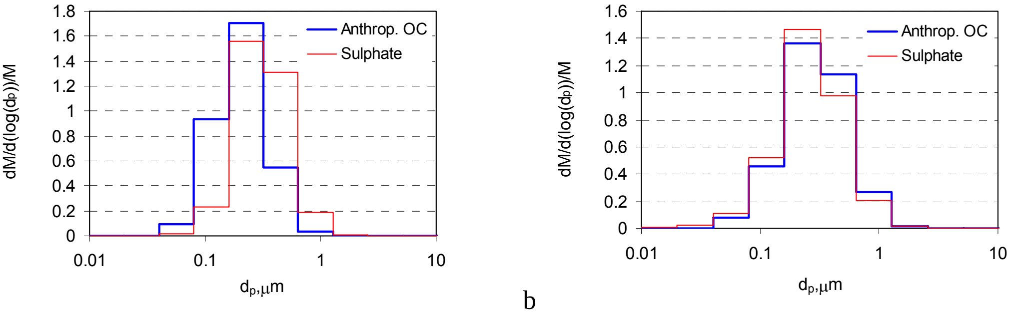


Fig. 4.1. *Global spatial distribution of aerosol particles in the surface air layer in 2001 (annual average), $\mu g/m^3$*

Calculated size distributions of two particulate species (organic carbon and sulphate) for two grid cells located in different geographical regions (Brazil and Russia) are given in Fig. 4.2. It is seen that the form of size distribution of aerosol mass depends on geographical location and aerosol component substantially.



a b

Fig. 4.2. *Particle size distributions of anthropogenic organic carbon mass and sulphate mass in different cells of the GEMAQ-EC global grid: a – cell (124,104) – Brazil; b – cell (273,28) - Russia*

Regional data

To calculate concentrations of aerosols and OH-radical in air the Community Multiscale Air Quality modelling system (CMAQ) model has been used [*Byun and Ching,* 1999]. Input meteorological data were calculated by the MM5 model on the basis of operational meteorological analysis data of ECMWF. The data on anthropogenic and natural emission of SO_2, NO_X, NH_3, NMVOC, CO, elemental carbon, organic carbon, dimethyl sulfide, and dust have been compiled using the following sources: **EMEP** (*webdab.emep.int),* **EDGAR** (*www.mnp.nl/edgar),* **GEIA** (*www.geiacenter.org),* **AEROCOM** (*nansen.ipsl.jussieu.fr/AEROCOM)* and **University of Illinois** (*cee.uiuc.edu).*

Calculated spatial distributions of PM10 and PM2.5 annual mean concentrations in the surface air layer for 2007 are shown in Fig 4.3. Maximum levels of particulate matter content in the air (up to 100 µg/m^3) take place over arid areas of Central Asia and the north of Africa. Annual averages of PM10 concentrations over the most part of Europe normally range from 10 to 20 µg/m^3. PM10 field differs from that of PM2.5 by high concentration of sea salt appearing in the atmosphere mainly in the form of coarse particles.

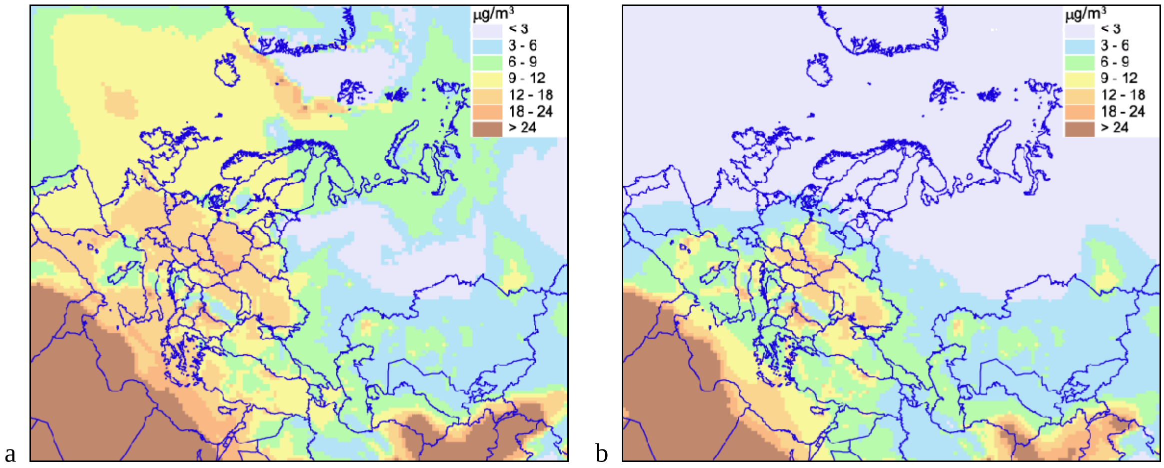


Fig. 4.3. *Spatial distributions of PM10 (a) and PM2.5 (b) concentrations in the surface air layer in 2007 (annual averages), µg/m^3*

Calculated annual averages of PM10 and PM2.5 concentrations in air are shown in Fig. 4.4 in comparison with the data of measurements at EMEP sites currently available in the AIRBASE database (http://dataservice.eea.europa.eu). The model underestimates PM10 and PM2.5 concentrations on the average by 30% and 8%, respectively. Coefficient of correlation R_{corr} between calculated and measured air concentration equals 0.76 for PM10 and 0.59 for PM2.5.

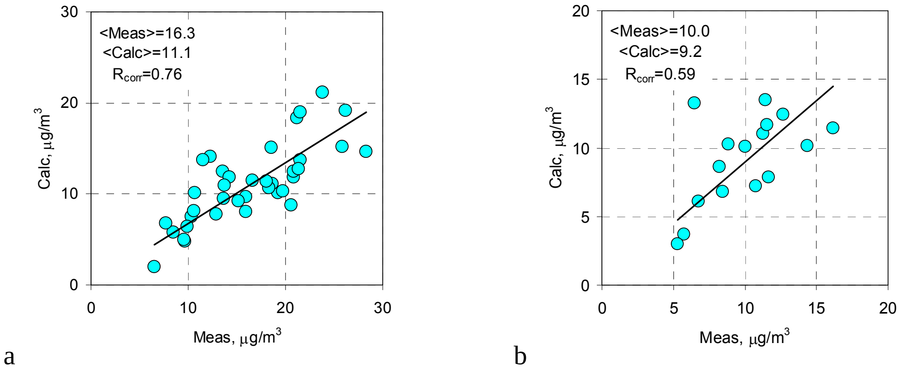


Fig. 4.4. *Comparison of calculated annual averages of PM10(a) and PM2.5(b) concentrations in the air with measurement data (EMEP sites) available in AIRBASE, µg/m^3*

CMAQ model is capable of reproducing aerosol composition. Especially important for POP modelling is that CMAQ can generate fraction of organic matter in aerosol particles. Examples of calculated aerosol composition at three EMEP monitoring stations located in different parts of Europe are given in Fig. 4.5. As seen, the fraction of organic matter differs largely depending on site location and particle size.

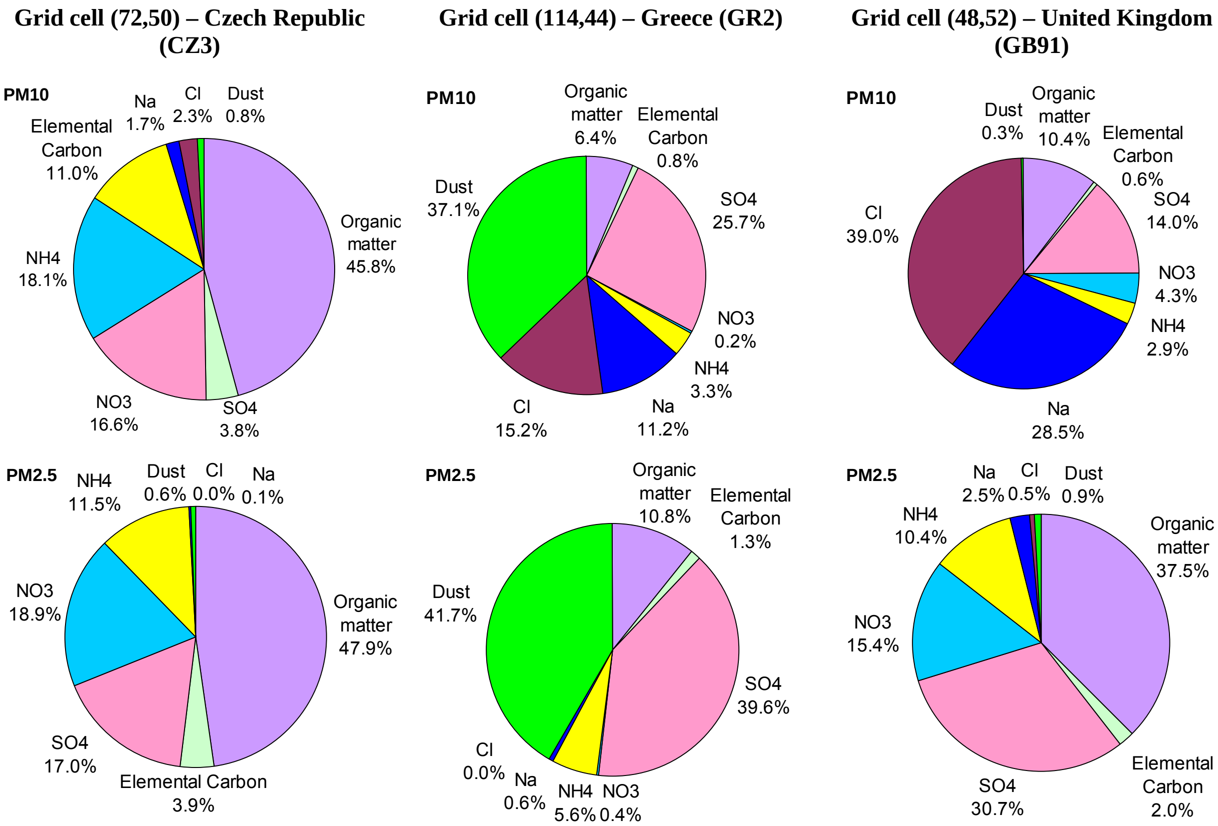


Fig. 4.5. *Composition of PM10 and PM2.5 calculated by CMAQ in percentage shares of annual averaged dry mass in the lowest model layer*

Fig.4.6 and Fig.4.7 present spatial distributions of annual mean concentrations of the two parameters used for evaluation of POPs atmospheric transboundary transport for 2007, namely, specific aerosol surface and OH-radical concentrations. The spatial distribution of aerosol surface is similar to that of PM (Fig. 4.3), but slightly differs due to the difference in particle size distribution in various parts of the model domain. It is seen that concentrations of OH-radical in the air strongly depend on geographical latitude.

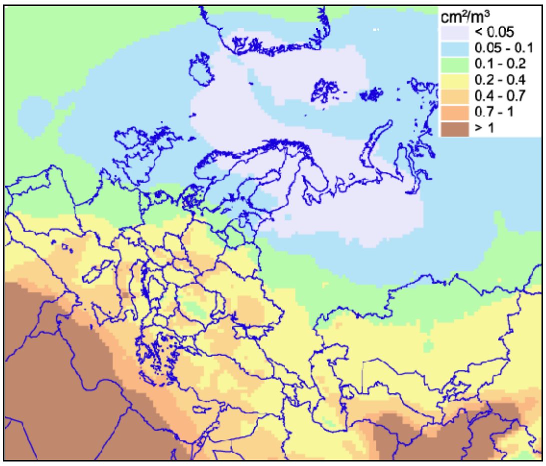


Fig. 4.6. *Spatial distribution of specific aerosol surface in surface air layer (annual averages for 2007), cm^2/m^3*

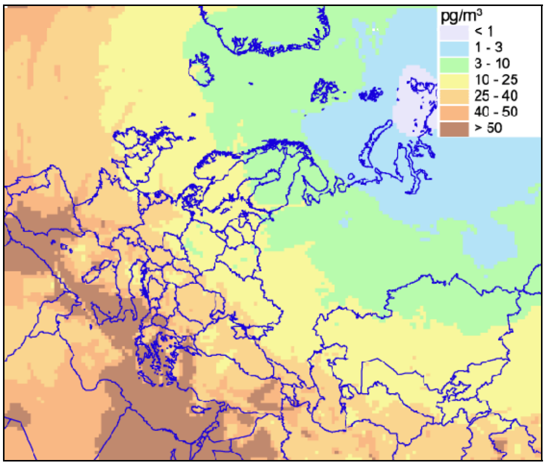


Fig. 4.7*. Spatial distribution of OH-radical concentrations in the surface air layer (averages for 2007), pg/m^3*

4.2. Refinement of parameterization of gas-particle partitioning

Data on atmospheric aerosols such as its specific aerosol surface and its spatial and temporal variations are essentially important for calculations of POP gas-particle partitioning. For regional-scale modelling of POP long-range transport the data generated by CMAQ model are used.

For verification of the data on aerosol specific surface generated by CMAQ information on measurements of this parameter was collected from literature sources. The following values of specific aerosol surface characteristic for Europe can be found in literature sources (e.g. [*Bidleman*, 1988; *Falconer*, 1994; *Lohman and Lammel*, 2004]): 11· cm^2/m^3 for urban regions, 3.5·cm^2/m^3 for suburban regions, 0.4· – 1.5· cm^2/m^3 for background regions and 0.1· cm^2/m^3 for remote regions. According to CMAQ simulations, the specific aerosol area is typically below 0.1 cm^2/m^3 in remote area and 0.2 – 1 cm^2/m^3 over major part of Europe and Central Asia (Fig. 4.6). This short comparison shows that the CMAQ data are several times lower than the observed ones. Therefore, the use of current CMAQ-generated data on specific aerosol surface could lead to underestimated particle-bound fraction of POPs and overestimated gas-phase fraction. It, in turn, increases the uncertainty of the results of transboundary transport modelling.

Though the computed specific aerosol surface is underestimated the spatial pattern of this parameter is described quite reasonably. In particular, high values are noted over deserts, moderate levels occur over central part of Europe and the lowest values take place over oceans and the Arctic. In order to use the CMAQ data in modelling, specially developed approach of adaptation of these data was developed. The details concerning this approach are described in MSC-E technical report in detail [*Gusev et al,* 2009].

For the testing purposes air concentrations of B[a]P and PCB-153 with corrected CMAQ-generated data were calculated for 2006 and compared with monitoring data from the EMEP sites (see Fig. 4.8, 4.9). As seen, the modelled and measured concentrations agree within a factor of two over most of stations. Besides, the spatial pattern was reproduced relatively well by the model: the correlation coefficients are almost 0.8 for B[a]P and PCB-153. Significant temporal correlation between modelled and measured monthly mean values was also found at most of stations.

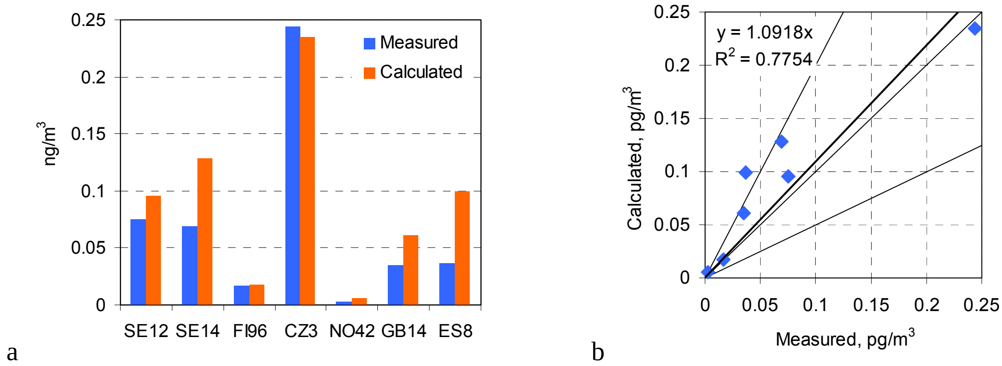


Fig. 4.8. *Comparison of calculated and measured air concentrations of B[a]P: (a) – individual stations, (b) – scatter plots*

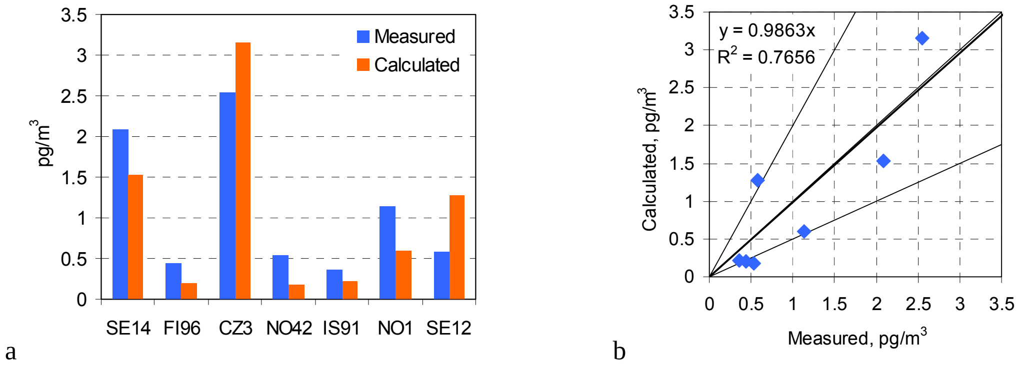


Fig. 4.9. *Comparison of calculated and measured air concentrations of B[a]P: (a) – individual stations, (b) – scatter plots*

4.3. Size-segregated modelling of particle-bound POP dry deposition

The parameterization of dry deposition of the particulate phase in the MSCE-POP regional model is based on the resistance analogy (see the description in [*Gusev et al.,* 2005]). Monodisperse distribution of mass of particles in assumed. The pilot numerical experiments on modelling of dry deposition of particle phase of POPs depending on particle size have been carried out. For test calculations dry deposition scheme has been changed to size-segregated one [*Travnikov and Ilyin,* 2005].

Fig. 4.10 illustrates the relation between the previous and new parameterizations. For the old parameterization pairs of points for two particle diameters (0.55 μm and 0.84 μm) are presented. As seen, the difference (either positive or negative) in the values of dry deposition velocity can reach several times or even orders of magnitude for different land-use types and meteorological conditions.

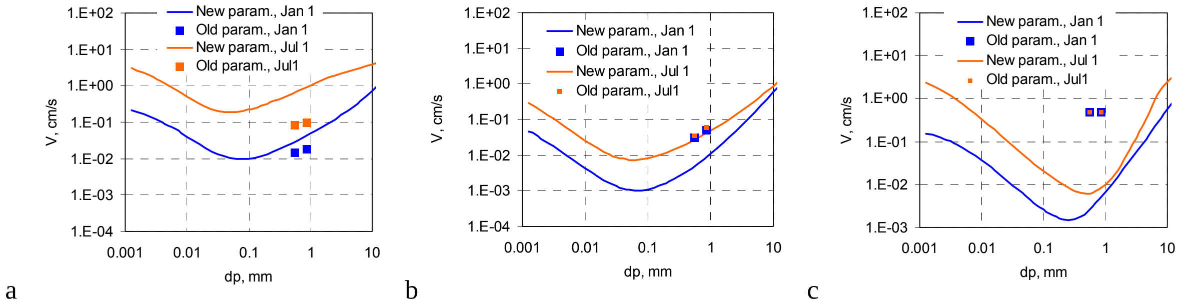


Fig.4.10. *Calculated dry deposition velocities to forest (a), grass (b), and urban areas(c) as functions of particle diameter in (72,50) EMEP grid cell for January 1 and July 1, 2006*

To examine the influence of particle size distribution on dry deposition process experimental calculations of the atmospheric transport of B[a]P within the EMEP domain have been carried out for 2006. Benzo[a]pyrene has been chosen for numerical investigations because of its considerable particle-bound fraction. Four runs of the MSCE-POP model with different parameterizations of dry deposition and different B[a]P particle phase size distributions have been done: two runs with monodisperse parameterization using previous and new description of dry deposition, and two runs with size-segregated parameterization using initial and corrected (see section 4.2) CMAQ data.

The use of the new parameterization of dry deposition changes calculated B[a]P mass balance (in particular, deposition fluxes and total mass in the atmosphere). Namely, dry deposition flux to the EMEP region as a whole rises (Fig. 4.11) because of the growth of the deposition velocities to the most of land-cover types. The use of size-segregated scheme increases deposition even more. On the contrary, total B[a]P mass in air inside the model grid and wet deposition flux of B[a]P to the EMEP region (Fig. 4.12) decrease with the change of dry deposition scheme (for details see [*Gusev et al.*, 2009]).

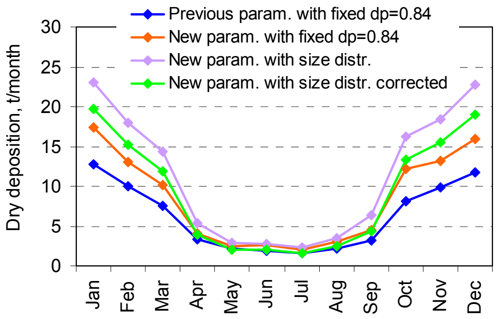


Fig. 4.11. *Calculated monthly dry deposition fluxes of particle B[a]P to the EMEP region as a whole for 2006*

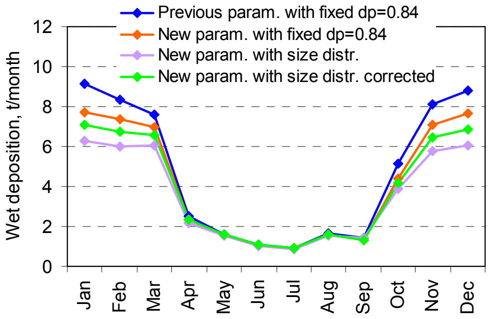


Fig. 4.12. *Calculated monthly wet deposition fluxes of B[a]P to the EMEP region as a whole for 2006*

Spatial distribution of annual dry deposition flux of B[a]P for the base model run (run with the previously used dry deposition scheme and fixed aerosol diameter d_p = 0.84 μm) and differences in the fluxes for different runs are presented in Fig. 4.13. Similar information on annual mean concentrations of B[a]P in near-surface air is given in Fig. 4.14.

The change of parameterization of dry deposition results in the increase of dry deposition flux over the major part of the EMEP domain as a consequence of the growth of the deposition velocities to the most types of land-cover. However, dry deposition velocity over urban areas decreases if new parameterization is used. Therefore, in regions with high fraction of urban area (e.g., the United Kingdom, east of Ukraine, Belgium) dry deposition flux decreased (Fig. 4.13). The inclusion of particle size distribution leads to the increase of dry deposition to the most part of the domain (compare Fig. 4.13b and Fig. 4.13c). Air concentrations (Fig. 4.14) as well as wet deposition flux [*Gusev et al.*, 2009] calculated in the experimental model runs decreased compared to the results of the base run over the most part of the model domain.

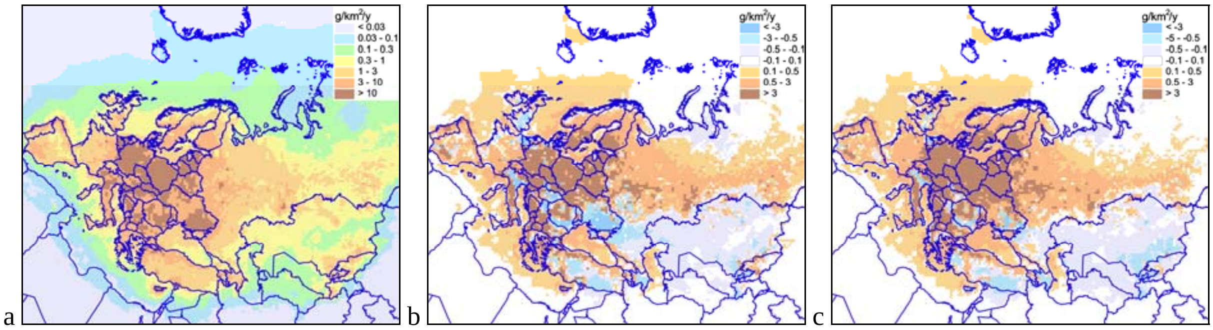


Fig. 4.13. *Spatial distribution of annual dry deposition flux of particle B[a]P over the EMEP domain: a – base model run results; b – difference between the run with new parameterization of dry deposition and the base run; c - – difference between the size segregated run with corrected particle size distribution and the base run*

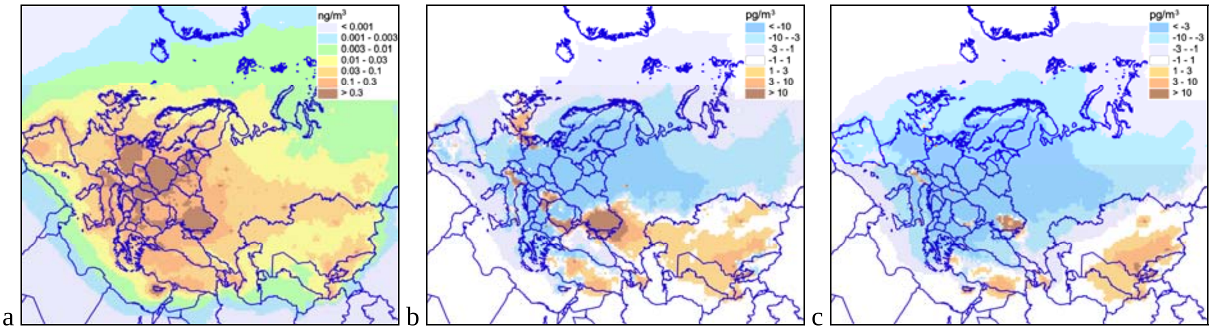


Fig 4.14. *Spatial distribution of annual air concentration of B[a]P over the EMEP domain: a – base model run results; b – difference between the run with new parameterization of dry deposition and the base run; c – difference between the size segregated run with corrected particle size distribution and the base run*

The comparison of the calculated results with the EMEP measurements of air concentrations (Fig. 4.15) and wet deposition (see [*Gusev et al.*, 2009]) of B[a]P has not shown clear advantage of the new size-segregated dry deposition scheme compared to the currently used one. However, the distinctions in the calculated levels of concentrations and deposition for some sites are essential. Pilot numerical experiments on size-resolved modelling of POPs dry deposition have shown high sensitivity of modelling results to deposition parameterization. Further improvement of the scheme of particle dry deposition in the MSCE-POP model and further investigations of the size distribution of aerosol particles carrying POPs are planned to be performed in the future.

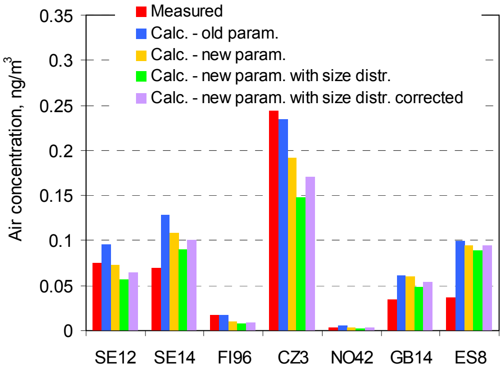


Fig. 4.15. *Annual mean air concentrations (a) and wet deposition (b) of B[a]P calculated by the MSCE-POP model and observed at the EMEP monitoring stations in 2006, ng/m^3*

5. COOPERATION

5.1. Task Force on POPs (Working Group on Strategies and Review)

This year at the invitation of the Executive Body for the Convention [ECE/EB.AIR/96] additional information for the review on the potential of long-range transboundary atmospheric transport (LRTP) and overall persistence of the five newly proposed substances (dicofol, endosulfan, HBCD, trifluralin, PCP) has been prepared by MSC-E. The results of model evaluation of LRTP (parameterized by residence time $T_{1/2}^{air}$ in the atmosphere and transport distance (TD)) and overall persistence (parameterized by half-life in the environment $T_{1/2}^{env.}$) of the considered substances were submitted to the Task Force on POPs (Plovdiv, Bulgaria, June 2009) as supporting information for preparation of technical elements for the track A review.

Task Force welcomed and took note of the results of the EMEP modelling assessment, and recognized that overall persistence and TD taking into account various processes in the main environmental compartments (air, soil, water) and intermedia exchange provided relevant characterization of substances LRTP and persistence. The obtained information was taken into consideration in the subsequent discussions particularly on pentachlorophenol having the higher persistence in the environment than in soil or in water according to model estimates. Some experts pointed out the necessity of the investigation of transformation products of PCP including PCAs (polychlorinated anisole) and dioxins and furans. Research work on the possibility of simultaneous modelling of the transport of this substance together with its transformation products is planned to be performed by MSC-E next year.

5.2. Task Force on Measurements and Modelling

In recent years a large amount of work on application of passive sampling for the evaluation of air pollution is performed both in the European region and over the entire globe. Measurements of this type, being cost-consuming, can essentially improve spatial coverage of the EMEP region by measurement sites. A complex analysis of the results of passive sampling campaigns and model results can give additional information not only on pollution levels, but also on model performance and on quality of emission data.

At present data on passive sampling campaigns in the European region (CCC, MONET-CEEC) and on the global scale (GAPS) are available at MSC-E.

Information on the inclusion of measurements of passive sampling campaigns (PAS) into the analysis of POP pollution levels over Europe and their use for model validation was presented by MSC-E at the tenth annual session of the TFMM (Paris, France, June 2009). Comparing to regular measurements of POPs carried out at the EMEP monitoring sites the passive sampling campaigns cover essentially wider area of Europe. Therefore complementary use of measurements of active and passive samplers is of importance for the evaluation of European countries pollution by POPs. The progress in the application of passive sampling measurements was demonstrated. It was shown that modelling results on selected POPs significantly correlated with PAS measurements. At the same time TFMM recognized that further work of monitoring and of modelling communities on joint analysis of POP pollution levels and elaboration of measurement-modelling approach was required. It was also stressed that additional data on POP concentrations in soils, seas, fresh waters and vegetation were highly needed for the improvement of model parameterizations of exchange processes in various environmental compartments and for the refinement of the description of the pollution levels.

5.3. Task Force on Hemispheric Transport of Air Pollution

This year MSC-E was actively involved in cooperation with TF HTAP. The main fields of activities were connected with POP model intercomparison exercises led by MSC-E, passive sampling campaigns, linking of local, regional and global scales modelling.

MSC-E contributed to the Workshop "Focusing on Eastern Europe, Central Asia, and the Arctic" (St. Petersburg, Russia, April 2009) and chaired a special POP session held in the framework of the Workshop. The session was focused on progress on the model intercomparison and evaluation work, and prospects directed for the preparation of the POP part of the TF HTAP Assessment Report 2010.

An overview of recent results on TF HTAP POP model itercomparison study was presented by MSC-E. Three models took part in the intercomparison for the time being: MSCE-POP (EMEP), SimpleBox (the Netherlands), and BETR-Global (Switzerland). Other experts in POP modelling were invited to join this study and to contribute to the TF HTAP Assessment Report.

The Workshop was also informed about availability of POP measurements at hemispheric/global scales including regular measurements and passive sampling campaigns. The methodology of using passive sampling results for the evaluation of POP contamination was considered. In particular, it was recognized that measurement-modelling approach was required for better understanding of pollution levels at regional and global scales.

MSC-E participated in the joint workshop of TF MM and TF HTAP on Regional-Global and Air Quality-Climate Linkages held in Paris, France in June 2009. The workshop included several sessions devoted to the discussion of methodological issues in linking of regional and global scale air quality modelling and impacts of climate change. The session on linking of regional and global scale models considered recent progress and challenges for the work in this direction. MSC-E contributed to the work of this session and presented the information on the on-going development of the EMEP global multi-scale modelling framework. In particular, basic features of the modelling framework including nesting capabilities were described. Preliminary modelling results on global and regional levels including application of one-way nesting were presented. Current limitations in linking of global modelling of POPs with regional within EMEP domain and local scale modelling were characterized and requirements for further progress were discussed. It was stressed that further progress in the multi-scale POP modelling significantly depended on the availability of fine resolution emission data and global POP emission inventories.

5.4. Marine Conventions

Helsinki Commission

In accordance with 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 Sea. MSC-E had the main responsibility for the evaluation of atmospheric transport and deposition of PCDD/Fs to the Baltic Sea. Officially reported emission data on PCDD/Fs to EMEP for 1990-2006 were used in simulations for the Helsinki Commission. Modelling results on the pollution of the Baltic Sea by PCDD/Fs and contributions of surrounding countries were described [*Bartnicki et al*., 2008].

Besides, the environmental indicator report with regard to temporal variations of PCDD/F emissions to the atmosphere and their deposition over the Baltic Sea in the period from 1990 to 2006 has been prepared. The indicator report is available in the Internet at the HELCOM web site [www.helcom.fi].

Annual emissions of dioxins and furans have decreased in HELCOM countries during the period from 1990 to 2006 by 22%. The most significant drop of PCDD/F emissions can be noted for Denmark (63%), Finland (60%), and Estonia (53%). Some decrease of emission can also be noted for Sweden (37%), Germany (26%), Russia (22%), and Poland (15%).

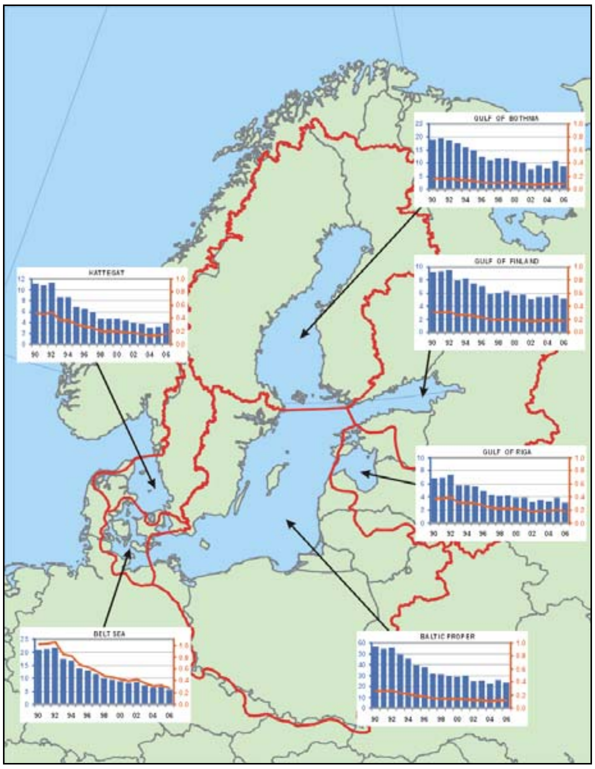


Fig. 5.1. *Computed net annual deposition of PCDD/Fs to six sub-basins of the Baltic Sea for the period 1990-2006 in t/y as bars (left axis) and deposition fluxes in μg TEQ/km^2/y as lines (right axis)*

Annual net deposition of PCDD/Fs to the Baltic Sea has decreased in the period 1990-2006 by 59%. On the level of individual sub-basins the most significant drop in PCDD/F deposition took place for the Belt Sea (73%) and the Kattegat (65%) (Fig. 5.1). For other sub-basins the decrease of deposition varies from 45% to 59%. The highest levels of PCDD/F deposition over the Baltic Sea (0.27 ng TEQ/m^2/y) can be noted for its southern-western part (the Belt Sea). Lowest level of PCDD/F deposition fluxes (0.07 ng TEQ/m^2/y) is obtained for the Gulf of Bothnia. Among the HELCOM countries the most significant contributions to deposition over the Baltic Sea in 2006 belonged to Poland, Russia, and Denmark (12%, 7%, and 7%).

OSPAR Commission

In the framework of cooperation programme between EMEP and the OSPAR Commission (Convention for the Protection of Marine Environment of the North-East Atlantic) MSC-E updated model assessment of atmospheric input of polychlorinated biphenyls (PCB-153) and lindane (γ-HCH) to the OSPAR maritime area. In accordance with the request of the OSPAR Commission time-series of emissions and deposition levels for the period 1990-2006 were prepared and estimates of the contributions of the OSPAR countries emissions to the deposition over the OSPAR Convention Waters were added.

Total annual emissions of selected POPs from the OSPAR countries did not change significantly from 2005 to 2006. In particular, emissions of PCB-153 and γ-HCH in the OSPAR countries decreased by 9% and 6% from 2005 to 2006.

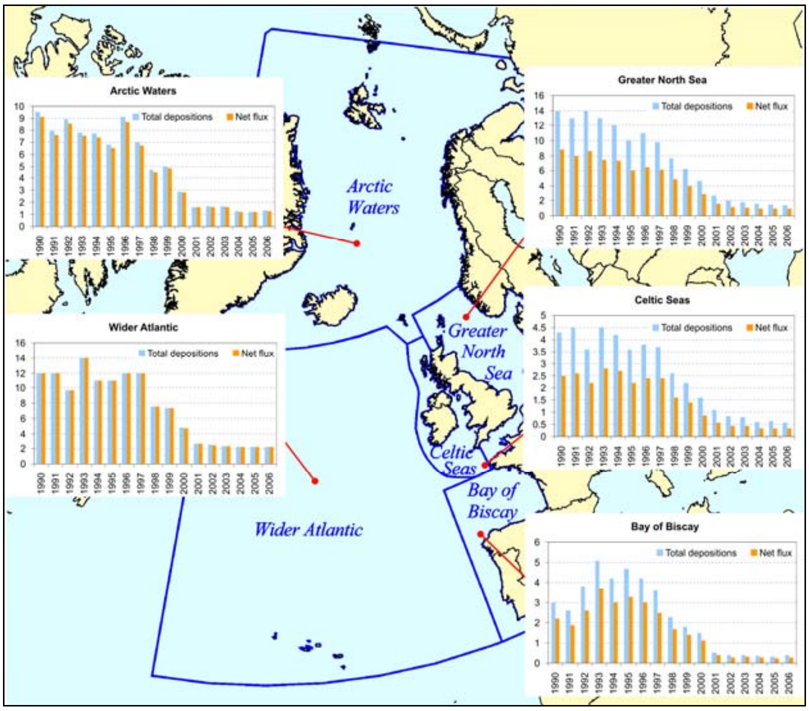


Fig. 5.2. Time series of modelled total annual deposition and net deposition flux of γ-HCH to the five main OSPAR regions in period 1990-2006, t/y

Time-series of modelled annual total and net deposition flux of γ-HCH to the five main OSPAR regions for the period 1990-2006 are shown in Fig. 5.2. Due to the decrease of emissions the values of total deposition of selected POPs in most of the OSPAR regions are lower in 2006 than that in 2005. The declining of PCB-153 deposition from 2005 to 2006 is more significant in comparison with γ-HCH due to more essential changes in its emissions. Certain influence can also have the changing of meteorological conditions in particular, air temperature and wind speed. For instance, the increase of net deposition fluxes of PCB-153 and γ-HCH in the Celtic Sea from 2005 to 2006 can be attributed to the interannual variation of meteorological parameters.

The information on contribution of individual countries to the annual deposition over the OSPAR maritime area was prepared for the 5 OSPAR regions and for both selected POPs. Major contributions to the PCB-153 deposition in 2006 (Fig. 5.3) over the Arctic Waters, the Greater North Sea, and the Celtic Sea were made by the United Kingdom and France. For the Bay of Biscay and the Wider Atlantic the most significant contributors were Spain and France. In case of γ-HCH the largest contribution to the deposition in 2006 over the Arctic Waters, the Greater North Sea, the Celtic Sea, and the Wider Atlantic was made by the United Kingdom and over the Bay of Biscay – by Spain. The second most significant contributor to the γ-HCH deposition over the Arctic Waters, the Greater North Sea, the Celtic Sea, and the Wider Atlantic was Spain, and for the Bay of Biscay – the United Kingdom.

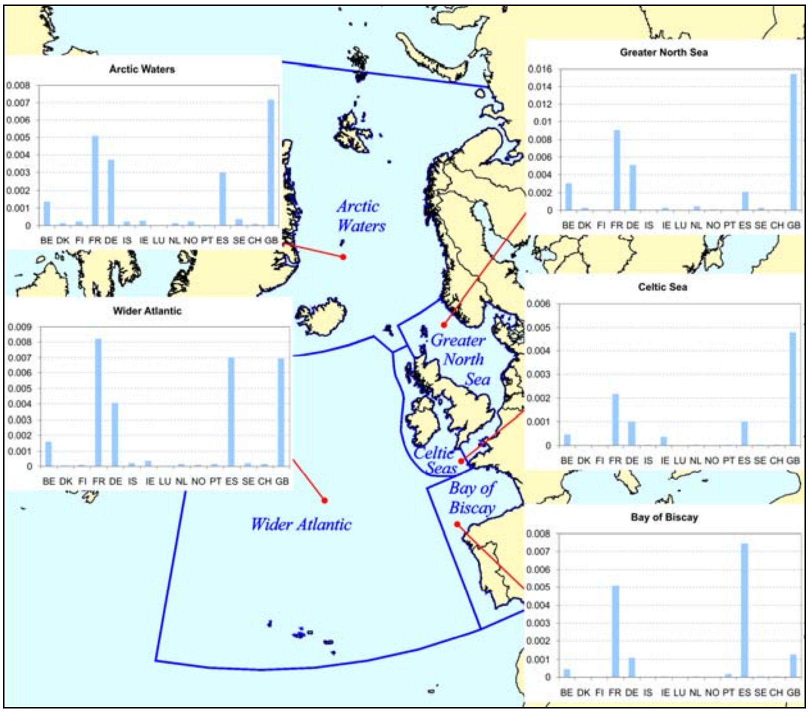


Fig. 5.3. *Contribution of individual countries to the annual deposition of PCB-153 to the 5 OSPAR regions for 2006, t/y*

Updated information on atmospheric input of PCB-153 and γ-HCH to the OSPAR maritime area was used in course of preparation of 2009 CAMP data assessment report.

5.5. Cooperation with EMEP countries and national experts

In 2009, the work on measurement-modelling assessment of POP levels in the environment, including the elaboration of the methodology of usage of passive sampling in line with modelling and development of a tool for evaluating POP pollution levels on the hemispheric/global scale, was performed in co-operation with experts from countries.

Usage of passive sampling for improving spatial coverage of the EMEP region and entire globe is one of promising directions of monitoring activities. A lot of national experts and institutions are involved in this activity. The peculiarities of involving passive sampling data for the description of POP contamination levels as well as a methodology of using of these data for monitoring-modelling evaluation of POP contamination were presented by MSC-E at the Workshop “Future of the air global monitoring” (St Petersburg, Russia, March 2009) organized by the Research Centre for Environmental Chemistry and Ecotoxicology (RECETOX), Masaryk University. National experts from Austria, Canada, the Czech Republic, Italy, the Russian Federation, Spain, the United Kingdom, and representatives from the Stockholm Convention, AMAP and EMEP took part in the discussion on this issue.

This year the systematic work on the comparison of passive sampling data with model simulations was initiated. The results of MONET-CEEC (the Czech Republic) and EMEP passive sampling campaigns were used for this purpose. The comparison of the data of these two campaigns with calculations for 2006 was performed in collaboration with Ivan Holoubek and Jana Klanova (the Czech Republic). The results of global passive campaign GAPS (Canada) were put at MSC-E disposal by Tom Harner, Canada. Canadian data are planned to be compared with results of hemispheric/global calculations next year.

One of the important directions of MSC-E work is model development. In particular, it includes preparation of input data on atmospheric reactants affecting POP atmospheric transport both at European and global scales. In the framework of this direction the one-year data on the atmospheric aerosol and OH radical with global coverage generated by GEMAQ-EC model was put at MSC-E disposal by Environment Canada (K. Puckett and S. Gong). Pilot calculations using these data are planned to be carried out by MSC-E in the next year.

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 2010:

I. CCC activities

1. Annual activities:

1.1. Publish 2008 data, including a quality assessment.

1.2. Review, store and make available 2009 monitoring data for the modelling centres and Parties.

1.3. Coordinate and carry out the intensive advanced measurements on the topics to be defined by TFMM.

1.4. Adoption of reference method for elementary carbon (EC)/organic carbon (OC). Define reference or guidance method for mineral dust and for passive sampling of POPs (harmonized with the Stockholm Convention on POPs). Incorporate these into the EMEP manual (in co-operation with TFMM).

1.5. Provide training/guidance to Parties to establish monitoring activities in compliance with the EMEP monitoring strategy, with a special focus on countries in EECCA.

1.6. Arrange laboratory intercomparisons for POPs and carry out field intercomparisons at selected sites.

1.7. Address integration of quality assessment/quality control (QA/QC) activities of regional monitoring programmes on the global scale, including standards for metadata provision, intercomparisons, etc..

1.8. Contribute to preparation, review and assessments of observations data presented in the series of EMEP reports.

1.9. Maintain close interaction with relevant organizations and bodies in relation to integration of observations. This includes monitoring efforts under other bodies under the Convention (e.g. the International Cooperative Programmes (ICPs)), national monitoring obligations to European Commission Directives, as well as activities undertaken by EEA, WMO, the OSPAR Commission, the Baltic Marine Environment Protection Commission (HELCOM), UNEP, AMAP, NinE (Nitrogen in Europe), Global Monitoring for the Environment and Security (GMES)/Global Earth Observation System of Systems (GEOSS) and others.

2. New developments:

2.1. Start implementing the new monitoring strategy for 2010–2019.

2.2. Improve the Web interface of the database to include more statistical opportunities for aggregated data, further develop the plotting routines, and develop improved export routines for data downloading for modellers.

2.3. Explore the use of passive POP measurements to validate the EMEP model and other transport models to evaluate source contribution.

2.4. Contribute to the development of standard methods and QA/QC procedures in relation to the new parameters included in the monitoring requirements of the 2010–2019 strategy.

II. MSC-E activities

1. Annual activities:

1.1. Preparation of meteorological data for operational modelling based on the European Centre for Medium-Range Weather Forecasts (ECMWF) analysis and meteorological driver update/development (global Weather Research and Forecasting Model (WRF)).

1.2. Processing of POPs emission data as input for operational modelling.

1.3. Preparation of measurement data on POPs in air and precipitation from national and international programmes including data of passive sampling campaigns for the purpose of MSCE-POP model validation (in co-operation with CCC).

1.4. Calculations of PAH, PCBs, PCDD/Fs, HCB and γ-HCH air concentrations and ecosystem-dependent depositions over the EMEP domain in 2008 with resolution 50x50km.

1.5. Computation of country-to-country deposition matrix for PAHs, PCBs, and PCDD/Fs.

1.6. Estimation of PAHs, PCBs, HCB, PCDD/Fs, and γ-HCH deposition on the regional seas.

1.7. Calculation of PCBs, PCDD/Fs, HCB, and γ-HCH dispersion at the hemispheric/global scale for the refinement of pollution of the EMEP domain.

1.8. Evaluation of modelling results against monitoring data.

1.9. Preparation of individual country status reports in English and Russian languages.

1.10. Contribution to the work of the subsidiary bodies to Convention and EMEP Task Forces:

1.10.1. WGSR – support the work of TF on POPs in the evaluation of new POP candidates;

1.10.2. TFHTAP – contribution to the TFHTAP 2010 Assessment report, leading the POP model intercomparison study, and evaluation of the intercontinental transport of POPs on global scale;

1.10.3. TFMM, TFHTAP - reporting on the results of research activities and developments regarding to POP modelling.

1.11. Co-operation with international bodies: UNEP, the Stockholm Convention, EU (in particular as regards the EU REACH), HELCOM, OSPAR and countries.

1.12. Dissemination of results (e.g. via status reports, technical notes, the website, publication in peer-reviewed journals).

1.13. Joint interpretation of measurement/modelling data together with national experts.

2. Research and development activities:

2.1. Investigate effects of climate change on POPs dispersion in the environment on the basis of analysis of inter- and intra-annual variability of POPs atmospheric transport, deposition, and concentrations during two recent decades;

2.2. Study the sensitivity of POPs model to the application of size-segregated data on aerosol and information on its chemical composition for the refinement of modelling of POPs atmospheric transport and removal from the atmosphere.

2.3. Analysis of the agreement between measured and modelled POPs pollution levels on the basis of inverse trajectory approach.

2.4. Review, collection and evaluation of global datasets on soil properties (soil texture, organic carbon content etc.).

2.5. Development and testing of POP modules within the global modelling framework.

2.6. Preparation of publications in scientific journals (particularly, special issue of ACP focused on the EMEP activity).

CONCLUSIONS

This Status Report presents the progress in the evaluation of the pollution levels and transboundary transport of POPs within the EMEP region and at the hemispheric scale achieved in 2009. The main conclusions of the work carried out by CCC and MSC-E in 2009 are summarized below.

EMEP Contribution to the Review of CLRTAP Protocol on POPs

- In accordance with the recommendation of the Steering Body to EMEP, MSC-E has contributed to the preparatory work for the review of the Protocol on POPs to the Convention since 2004. The elaboration of supporting information on POP candidate substances with respect to evaluation of their long-range transport potential (LRTP) and persistence was performed. Technical notes on 18 substances proposed under CLRTAP as POP-candidates were prepared and submitted to the Task Force on POPs. Among them Technical notes on the five newly proposed substances (endosulfan, dicofol, trifluralin, hexabromocyclododecane and pentaclorophenol) were made available to the Task Force on POPs in 2009 at the invitation of the Executive Body for the Convention.
- Specific methodology of the evaluation of LRTP and persistence of substances on the basis of model simulations was elaborated. Application of spatially resolved models for the evaluation of LRTP and persistence of substances allows taking into account the variability of these characteristics due to geographical location of emission source, environmental conditions and types of the underlying surface.
- Model calculations of overall persistence and transport distance with allowance of various processes in the main environmental compartments (air, soil, water) and intermedia exchange, provide a relevant characterization of a substance persistence and LRTP in the environment.
- Numerical values of transport distance strongly depend on the evaluation methodology and model design. However, this parameter is highly illustrative and can be used in ranking substances with respect to their LRTP.
- It makes sense to take geographical location of emission source into account while interpreting the data on long-range transport potential and persistence of POP-like substances.
- Sources on physical-chemical properties of POP candidates such as data from the Stockholm Convention and the European Chemical Agency are useful as additional information to the dossiers prepared by countries.

Monitoring of POPs in EMEP

- Monitoring of POP concentrations in 2007 was performed at seventeen monitoring sites among which eleven sites made parallel measurement of POP content in air and precipitation. The number of sites measuring POP concentrations distinctly increased in recent years. In particular, monitoring of POPs was started in Spain, the United Kingdom, and Latvia. The number of sites in Germany was considerably increased and measurements of POP air concentrations were initiated.
- In addition to the regular measurements, EMEP passive air sampling (PAS) campaign was carried out in thirty three European countries on eighty five background sites during late summer 2006. The campaign included measurements of PCBs, PAHs, HCB, HCHs, PBDEs, DDT, and various other organochlorine pesticides. Data of the passive sampling campaign along with the regular

EMEP measurements were applied for the analysis of POP pollution levels within the EMEP region.

- Parallel measurements of POP atmospheric concentrations using active and passive samplers showed that the typical differences between their results were within a factor of two. At the same time significant differences can be expected between the active and passive samplers for those chemicals that are extensively sorbed to atmospheric particles.

Assessment of POP Pollution Levels in Europe

- Evaluation of POP pollution levels and transboundary transport in the European and the Central Asian countries in 2007 was carried out on the basis of EMEP measurements, emission data, and modelling of POP long-range transport. Emission datasets for model assessment of POP long-range transport within the EMEP region were prepared by MSC-E on the basis of officially submitted emission data and unofficial expert estimates.
- The analysis of POP contamination in the European and the Central Asian countries was based on the combined consideration of results of model assessment of POP long-range transport and measurements of EMEP monitoring sites and passive sampling campaigns.
- Modelling results on spatial distribution of B[a]P concentrations along with regular measurements and data of the EMEP passive sampling campaign, showed that the highest levels of B[a]P concentrations were characteristic of the countries of Central and Eastern Europe. Lower concentrations were seen in Northern and Western Europe and in the Central Asian countries.
- Modelled concentrations of PCB-153 were the highest in the countries of Western and Central Europe while lower concentrations were obtained for the Scandinavian, eastern European, and Central Asia countries. Similar distribution of PCB-153 air concentrations was obtained by measurements of EMEP passive sampling campaign and by the MSCE-POP model.
- Comparison of modelling results on B[a]P and PCB-153 with regular measurements of the EMEP monitoring network showed reasonable agreement between the computed and observed concentrations. For most of monitoring sites the deviations between the modelled and measured annual mean concentrations in air and in precipitation were about or less than a factor of two.
- The overestimation of observed B[a]P and PCB-153 concentrations can be seen for the sites ES8, LV16, DE3, DE8, and CZ3 and underestimation of observed PCB-153 concentrations at NO42. The overestimation of measured concentrations can be caused by insufficient spatial resolution of the model, representativeness of these monitoring sites, or uncertainties of spatial distribution of emissions. The underestimation can be explained by the uncertainties of PCB emission data. Improvement of description of POP pollution levels for these sites requires additional investigations in a form of joint case studies with experts in emissions, monitoring, and modelling.
- Modelled HCB concentrations essentially underestimate the levels of HCB air concentrations observed at the sites in Germany and southern Norway. Results of the model simulations obtained using different HCB emission scenarios showed that higher HCB emissions can essentially improve the agreement between the measurements and the model estimates.
- Comparison of the model predictions of HCB concentrations with measurements of passive sampling campaign revealed the same tendency to underestimate observed levels of HCB concentrations, especially in the countries of Western, Central, and Northern Europe. This indicates that the levels of HCB emission in Europe are likely more significant than that officially reported by the European countries and further refinement of HCB emission is required.

- The application of lindane (γ-HCH) has been banned or severely restricted in the majority of the European countries during two recent decades. Only several countries, namely, the United Kingdom, Spain, Belgium, Croatia, and Romania provided information on their emission for the recent years, while other European countries reported no usage of lindane.
- Comparing the spatial distribution of measured and computed air concentrations of γ-HCH it can be seen that the model predictions are close to the observed levels of concentrations for the United Kingdom, Spain, and Scandinavian countries along with the remote areas. At the same time measurements of sites in a number of countries of eastern and southern Europe are essentially underestimated mostly due to incomplete information on γ-HCH emissions.
- Transboundary transport of POPs is a significant source of pollution for the European and the Central Asian countries. Evaluation of transboundary transport for B[a]P and PCDD/Fs showed that its contribution to deposition from anthropogenic emission sources exceeds 50% in 22 and 18 countries, respectively.

POP Model Development

- This year particular attention in the development of the EMEP multicompartment POP transport model MSCE-POP was paid to the refinement of parameterizations of POP gas-particle partitioning and deposition processes and input data on aerosol particles and OH-radical concentrations required for modelling of POP long-range transport.
- Detailed information on global distribution of aerosols and OH-radical air concentration for 2001 was provided by the Environment Canada (K. Puckett and S. Gong) to MSC-E for its application in the experimental modelling of POPs on global scale using the common EMEP global modelling framework.
- Regional-scale datasets on aerosol and OH-radical content in the atmosphere for 2007 were prepared using the CMAQ model. These data were analyzed, compared to the EMEP measurements, and adapted for use as the input information for the evaluation of POP pollution levels within the EMEP region. Experimental model simulations of B[a]P and PCB-153 long-range transport for 2006 using prepared CMAQ data show reasonable agreement of modelling results with measurement data.
- Development of size-segregated description of POP dry deposition for the MSCE-POP model was started. Numerical experiments showed essential sensitivity of modelling results to the inclusion of size resolved information on aerosol particles. Further development of size-segregated approach for modelling POPs is needed.

Co-operation

- The results of model evaluation of LRTP and persistence of the five newly proposed substances (dicofol, endosulfan, HBCD, trifluralin, PCP) were submitted to the Task Force on POPs (Plovdiv, Bulgaria, June 2009). It was recognized that evaluation of the overall persistence and transport distance, taking into account various processes in the main environmental compartments (air, soil, water) and intermedia exchange, provided relevant characterization of substances LRTP and persistence. EMEP contribution was welcomed and used as supporting information for the preparation of technical elements for the track A review.
- Information on the inclusion of measurements of passive sampling campaigns into the analysis of POP pollution levels over Europe and their use for the model validation was presented by MSC-E at the tenth annual TF MM meeting (Paris, France, June 2009). TF MM noted that further work of

monitoring and modelling communities on joint analysis of POP pollution levels and elaboration of measurement-modelling approach was required. It was stressed that complementary use of measurements of active and passive samplers was of importance for the evaluation of the European countries pollution by POPs. It was also pointed out that additional data on POP concentrations in soil, seawater, freshwater, and vegetation were highly needed for the evaluation of POP levels in the environment.

- MSC-E contributed to the Workshop “Focusing on Eastern Europe, Central Asia, and the Arctic” (St. Petersburg, Russia, April 2009) and chaired a special POP session held in the framework of the Workshop. An overview of recent results on TF HTAP POP model itercomparison study was presented and discussed at the meeting. Three models took part in the intercomparison for the time being: MSCE-POP (EMEP), SimpleBox (the Netherlands), and BETR-Global (Switzerland).
- MSC-E participated in the joint workshop of TF MM and TF HTAP on Regional-Global and Air Quality-Climate Linkages held in Paris, France in June 2009. The Workshop session on linking of regional and global scale models considered recent progress and challenges for the work in this direction. MSC-E contributed to the work of this session and presented the information on the on-going development of the EMEP global multi-scale modelling framework.
- In the framework of cooperation between EMEP and the OSPAR Commission MSC-E updated model assessment of atmospheric input of PCBs and lindane (γ-HCH) to the OSPAR maritime area. In particular, time-series of emissions and deposition levels for the period 1990-2006 were prepared. Additionally the estimates of the contributions of the OSPAR countries emissions to the deposition over the OSPAR Convention Waters for 2006 were evaluated.
- MSC-E contributed to the preparation of the EMEP Centres joint report on the evaluation of airborne pollution loads to the Baltic Sea for the Helsinki Commission. The information on the assessment of dioxins and furans deposition to the Baltic Sea for 2006 was provided and environmental indicator reports with regard to temporal variations of PCDD/F emissions of the HELCOM countries and deposition over the Baltic Sea in the period from 1990 to 2006 were updated.
- MSC-E took part in the Workshop “Future of the air global monitoring” (St. Petersburg, Russia, March 2009) organized by the Research Centre for Environmental Chemistry and Ecotoxicology (RECETOX), Masaryk University. One of the main objectives of the workshop was the discussion on the methodology of application of POP passive sampling for contamination assessment. In particular, it was concluded that:
    - it was important to improve the comparability of the data between programmes as well as within each programme;
    - in the near future new POPs might be added to the existing POPs listed under CLRTAP and the Stockholm Convention and the Workshop invited Parties to include new POPs to the national monitoring activities;
    - passive sampling data were requested to be reported as concentrations (as opposed to amount per sampler) according to a harmonized approach, which would facilitate the use of the data by modelers.
- During this year the systematic work on the comparison of modelling results with measurements of passive sampling campaigns (MONET_CEEC, EMEP, and GAPS) was initiated. It is planned to continue this activity in close collaboration with experts from the regional CEECs POPs Centre of the Stockholm Convention, CCC, and Environment Canada.

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ANNEX A

EMEP work-plan for POPs in 2009

2.1. Emissions

Description/objectives:

To further develop emission inventories; improve the quality, transparency, consistency, completeness and comparability of reported emission and projection data; support the review of compliance; and assist Parties with their emission reporting. TFEIP, led by Norway and co-chaired by Sweden and EEA, provides a technical forum for sharing information, harmonizing emission factors, establishing methodologies for the evaluation of emission data and projections, and identifying and resolving reporting problems, with a view to harmonizing as far as possible reporting requirements with UNFCCC and the European Union's National Emission Ceilings (NEC) directive.

Main activities by the EMEP Centres:

(d) Elaborate a data set of validated and complete emission data submitted during the 2009 reporting round by 15 April 2009 for use in the EMEP 2007 assessments. Increase the transparency in use of non-Party estimates for modelling (CEIP, MSC-W, MSC-E);

(e) Review sulphur oxides (SOx), nitrogen oxides (NOx), volatile organic compounds (VOCs), ammonia (NH3) and particulate matter (PM) emissions (MSC-W) and heavy metals and persistent organic pollutant (POP) emissions for modelling purposes (MSC-E);

Main activities by TFEIP

(b) Consider and propose further actions to close the gap between official emission data for heavy metals and POPs and modelling results in close collaboration with the modelling community (TFEIP, TFMM, MSC-E);

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 by the EMEP Centres:

(c) Provide validated data on concentrations, depositions and transboundary fluxes of heavy metals (mercury (Hg), lead (Pb) and cadmium (Cd)) and POPs for 2007 over the extended (eastward) EMEP domain, and update source-allocation calculation, including EECCA countries (MSC-E, CCC);

(d) Prepare individual country status reports; update web access to electronic source-allocation information with validated data for the main pollutants and PM and for heavy metals and POPs (MSC-W, MSC-E);

(e) Review, store and make available the 2008 monitoring data; assess uncertainties in, and the representativeness of, monitoring data required by the EMEP monitoring strategy (CCC, MSC-E and MSC-W);

(f) Provide access to validated databases with EMEP measurement data in 2008 by 31 December 2009 (CCC), after joint revision with MSC-E and MSC-W and bilateral discussions with Parties experts;

(j) Continue support and training in EECCA countries (CCC, MSC-East and MSC-W).

Main activities and time schedule for atmospheric modelling for POPs:

(a) New developments in POP gas/particle partitioning: Further refine the description of POP gas/particle partitioning (MSC-E);

(b) New developments in POP deposition processes: Improve the model description of depositions of POPs in the particulate phase on the basis of information on spatial and temporal aerosol distribution and chemical composition (MSC-E);

(c) New developments with inverse modelling: Continue to develop the inverse modelling approach for the analysis of differences between measurements and modelling results (MSC-E);

(d) New developments in the study of climate effects on POPs: Further investigate possible approaches to the evaluation of the influence of climate change on the fate and behaviour of POPs (MSC-E);

(e) New developments with POP monitoring: Continue to evaluate the POPs passive measurements campaign on the hemispheric level and compare with modelling results; evaluate the EMEP monitoring strategy in relation to the outcome of the campaign as well as with the UNEP global monitoring strategy, and report conclusions to TFMM (MSC-East, CCC).

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 ECE/EB.AIR/2008/8 ECE/EB.AIR/GE.1/2008/9/Rev.1 Page 12

Community, coordinates activities, including collaboration with other international bodies, programmes and networks, both within and outside the UNECE region, with related interests.

Main activities by the EMEP Centres:

(a) Participate in the TFHTAP model inter-comparison for O3, PM compounds POPs and heavy metals with the two EMEP global models (MSC-W, MSC-East);

(b) Contribute to the TFHTAP 2010 assessment report on intercontinental transport of air pollution (MSC-E, MSC-W, CIAM, CCC);

(c) New development - integrated EMEP global system: Evaluate the effect of using different geophysical and emission data in the existing global models used at the two meteorological synthesizing centres (MSC-E, MSC-W);

(d) New development - integrated EMEP global system: Evaluate means for the flexible introduction of different meteorological drivers to be used in the common EMEP global model (MSC-E, MSC-W);

(e) New development - integrated EMEP global system: Identify the changes in existing model routines that are necessary to facilitate common modules for global modelling in EMEP (MSC-W, MSC-E);

(f) New developments for global emission data: Evaluate the new EDGAR THTAP global emission data in comparison with other available expert estimates (CEIP, MSC-W, MSC-E).

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	Monaco	MC
Armenia	AM	Montenegro	ME
Austria	AT	Netherlands	NL
Azerbaijan	AZ	Norway	NO
Belarus	BY	Poland	PL
Belgium	BE	Portugal	PT
Bosnia and Herzegovina	BA	Republic of Moldova	MD
Bulgaria	BG	Romania	RO
Croatia	HR	Russian Federation (European part)	RU
Cyprus	CY	Russian Federation (Asian part)	RUA
Czech Republic	CZ	Serbia	RS
Denmark	DK	Slovakia	SK
Estonia	EE	Slovenia	SI
Finland	FI	Spain	ES
France	FR	Sweden	SE
Georgia	GE	Switzerland	CH
Germany	DE	The Former Yugoslav Republic of Macedonia	MK
Greece	GR	Tajikistan	TJ
Hungary	HU	Turkey	TR
Iceland	IS	Turkmenistan	TM
Ireland	IE	Ukraine	UA
Italy	IT	United Kingdom	GB
Kazakhstan	KZ	Uzbekistan	UZ
Kyrgyzstan	KY	Baltic Sea	BAS
Latvia	LV	Black Sea	BLS
Lithuania	LT	Caspian Sea	CAS
Luxembourg	LU	North Sea	NOS
Malta	MT	Mediterranean Sea	MDT

***Table B.2**. Matrix of B[a]P country-to-country deposition in 2007, kg/y*

Receptors↓ Emitters ⟶

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	
AL	**350.3**	0.01	0.52	0.01	2.80	0.29	12.67	0.39	0.01	0.00	0.86	2.80	0.25	AL
AM	0.01	**316.4**	0.03	71.27	0.02	0.03	0.12	0.31	0.00	0.02	0.08	0.31	0.09	AM
AT	0.86	0.04	**537.9**	0.14	7.01	18.04	1.77	12.42	1.65	0.002	136.1	495.9	5.87	AT
AZ	0.04	47.15	0.08	**736.5**	0.06	0.11	0.32	1.38	0.002	0.01	0.22	0.94	0.25	AZ
BA	22.39	0.02	10.86	0.06	**687.5**	2.39	12.59	3.21	0.08	0.001	14.77	32.36	2.18	BA
BE	0.03	0.01	0.88	0.02	0.08	**846.1**	0.07	1.02	0.09	0.00	2.20	154.0	3.80	BE
BG	12.12	0.10	3.42	0.21	8.10	1.65	**1373**	5.84	0.04	0.03	7.86	20.86	2.49	BG
BY	1.24	0.17	13.76	0.34	5.23	12.50	4.41	**3167**	0.28	0.002	53.68	149.8	38.23	BY
CH	0.09	0.01	8.64	0.01	0.56	8.20	0.17	0.99	**14.51**	0.00	2.94	99.79	1.48	CH
CY	0.01	0.01	0.01	0.003	0.01	0.01	0.04	0.02	0.00	**7.10**	0.02	0.05	0.01	CY
CZ	0.68	0.02	70.41	0.07	3.51	19.48	1.75	13.47	0.66	0.00	**1085**	503.3	12.55	CZ
DE	0.75	0.07	99.37	0.19	2.76	413.7	2.01	28.97	9.38	0.002	183.9	**9874**	132.5	DE
DK	0.04	0.005	1.29	0.01	0.14	13.97	0.12	3.71	0.05	0.00	4.97	86.71	**665.3**	DK
EE	0.15	0.02	1.41	0.04	0.53	5.98	0.54	34.47	0.04	0.00	5.78	42.28	16.35	EE
ES	0.59	0.03	1.48	0.07	1.38	4.34	0.77	2.46	0.15	0.001	1.71	20.78	1.65	ES
FI	0.39	0.13	5.10	0.32	1.67	23.62	1.23	86.32	0.14	0.001	21.17	144.0	58.76	FI
FR	1.07	0.07	12.40	0.20	3.93	227.4	1.85	9.60	5.72	0.001	18.74	555.9	16.19	FR
GB	0.12	0.02	1.77	0.06	0.30	39.80	0.25	4.72	0.13	0.00	5.64	102.8	14.54	GB
GE	0.09	50.14	0.19	57.62	0.17	0.23	0.79	1.56	0.003	0.05	0.57	2.13	0.51	GE
GR	34.28	0.05	1.22	0.11	2.97	0.66	56.59	2.74	0.02	0.01	2.77	7.55	0.98	GR
HR	9.35	0.03	24.66	0.08	158.1	2.30	6.06	4.32	0.13	0.001	20.32	37.34	1.75	HR
HU	3.90	0.05	61.99	0.14	31.30	5.12	10.18	7.99	0.23	0.004	55.64	84.11	5.40	HU
IE	0.03	0.005	0.21	0.02	0.07	4.02	0.06	0.55	0.02	0.00	0.66	10.78	1.14	IE
IS	0.05	0.02	0.50	0.07	0.10	1.25	0.11	1.54	0.03	0.00	1.15	7.40	1.34	IS
IT	19.11	0.08	57.08	0.23	45.71	8.87	14.35	9.45	2.50	0.01	26.16	125.8	3.40	IT
KY	0.00	0.05	0.004	0.17	0.003	0.01	0.01	0.07	0.00	0.00	0.01	0.07	0.01	KY
KZ	0.28	2.00	0.97	10.72	0.65	2.68	1.59	22.35	0.02	0.008	3.47	17.95	4.46	KZ
LT	0.18	0.01	2.97	0.04	0.71	5.61	0.60	133.3	0.08	0.00	12.80	61.95	18.05	LT
LU	0.00	0.001	0.13	0.002	0.01	7.80	0.01	0.11	0.01	0.00	0.27	19.08	0.23	LU
LV	0.17	0.02	2.31	0.04	0.70	7.21	0.58	81.45	0.07	0.00	9.34	62.09	17.44	LV
MC	0.00	0.00	0.002	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	MC
ME	0.71	0.002	0.29	0.005	1.04	0.11	10.19	0.22	0.003	0.00	0.61	1.48	0.14	ME
MD	0.43	0.04	0.64	0.08	0.71	0.45	2.56	5.74	0.009	0.002	2.01	5.25	1.16	MD
MK	37.96	0.01	0.47	0.02	1.64	0.25	45.56	0.55	0.01	0.001	1.09	2.77	0.31	MK
MT	0.00	0.00	0.002	0.00	0.005	0.001	0.002	0.001	0.00	0.00	0.003	0.007	0.001	MT
NL	0.02	0.003	0.53	0.01	0.06	237.0	0.05	1.11	0.05	0.00	1.94	198.7	5.58	NL
NO	0.19	0.05	2.41	0.16	0.54	24.99	0.68	21.15	0.10	0.00	8.67	105.8	76.86	NO
PL	1.66	0.06	36.95	0.17	6.65	41.28	4.91	210.0	0.70	0.003	415.8	655.6	108.9	PL
PT	0.01	0.001	0.08	0.003	0.04	0.36	0.02	0.18	0.01	0.00	0.13	1.76	0.17	PT
RO	9.72	0.15	14.23	0.36	27.60	6.37	62.86	21.45	0.16	0.02	33.41	81.53	10.56	RO
RS	66.83	0.02	8.23	0.06	98.89	2.56	76.59	3.10	0.07	0.001	14.42	33.25	2.57	RS
RU	5.60	15.56	37.93	64.86	19.86	69.59	27.74	1138	0.97	0.07	127.7	575.5	149.2	RU
RUA	1.47	2.61	8.04	11.42	5.04	17.49	6.86	120.0	0.18	0.02	26.06	124.9	35.90	RUA
SE	0.41	0.08	4.84	0.24	1.23	50.78	1.39	48.10	0.17	0.001	19.41	242.5	286.8	SE
SI	0.67	0.01	42.21	0.05	7.93	1.11	0.89	2.44	0.10	0.00	11.22	23.60	0.62	SI
SK	1.12	0.02	31.41	0.06	6.25	4.71	2.99	7.83	0.16	0.001	136.1	71.41	6.42	SK
TJ	0.00	0.02	0.001	0.08	0.001	0.003	0.003	0.02	0.00	0.00	0.004	0.02	0.004	TJ
TM	0.01	1.10	0.05	4.94	0.03	0.08	0.08	0.91	0.001	0.002	0.14	0.65	0.16	TM
TR	2.37	102.2	1.89	22.29	2.23	1.44	22.82	8.72	0.03	1.17	4.74	15.23	2.73	TR
UA	4.84	0.86	20.24	2.02	15.52	13.59	22.58	337.5	0.30	0.01	64.30	158.4	28.66	UA
UZ	0.01	0.44	0.06	1.91	0.03	0.13	0.08	1.41	0.002	0.001	0.19	0.94	0.24	UZ
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	

***Table B.2**. Matrix of B[a]P country-to-country deposition in 2007, kg/y (continued)*

Receptors↓ Emitters ⟶

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KY	
AL	0.09	0.85	0.06	0.55	0.19	0.002	38.07	0.97	1.27	0.04	0.00	91.10	0.001	**AL**
AM	0.06	0.02	0.05	0.02	0.04	3.20	0.09	0.02	0.07	0.01	0.00	0.17	0.001	**AM**
AT	1.30	4.07	0.96	16.09	6.88	0.02	0.87	13.21	44.46	1.24	0.02	150.3	0.01	**AT**
AZ	0.28	0.08	0.22	0.08	0.13	4.83	0.22	0.04	0.17	0.03	0.00	0.49	0.03	**AZ**
BA	0.60	2.48	0.41	2.59	1.25	0.01	12.03	84.00	33.97	0.26	0.01	163.1	0.01	**BA**
BE	0.43	5.62	0.40	56.82	19.76	0.002	0.05	0.09	0.24	2.20	0.02	3.87	0.001	**BE**
BG	0.86	0.96	0.54	1.29	1.08	0.06	61.66	3.70	10.77	0.23	0.01	51.09	0.01	**BG**
BY	39.33	6.17	15.01	8.63	9.60	0.07	1.77	5.19	21.24	1.98	0.04	36.25	0.03	**BY**
CH	0.31	6.57	0.24	35.74	4.12	0.002	0.09	0.90	0.81	1.04	0.01	118.8	0.001	**CH**
CY	0.003	0.00	0.00	0.01	0.01	0.00	0.17	0.01	0.02	0.00	0.00	0.18	0.00	**CY**
CZ	1.74	4.94	1.41	13.43	7.74	0.01	0.67	4.50	26.64	1.22	0.02	28.19	0.01	**CZ**
DE	11.06	41.17	7.78	206.9	85.11	0.02	1.02	3.23	10.94	12.71	0.15	107.3	0.01	**DE**
DK	1.87	2.63	1.49	6.24	14.37	0.002	0.05	0.18	0.97	2.34	0.04	3.05	0.001	**DK**
EE	**766.7**	1.50	28.82	3.05	4.35	0.01	0.21	0.52	1.81	0.80	0.02	4.71	0.003	**EE**
ES	0.61	**3950**	0.48	39.84	6.05	0.01	0.62	1.25	1.50	1.92	0.03	45.67	0.005	**ES**
FI	198.9	8.20	**1325**	12.84	21.70	0.04	0.50	1.70	7.16	4.51	0.16	13.73	0.03	**FI**
FR	3.03	254.6	2.38	**1641**	60.79	0.02	1.20	4.76	5.40	11.56	0.07	295.3	0.01	**FR**
GB	1.62	28.70	1.81	29.12	**885.9**	0.01	0.20	0.29	0.95	75.62	0.16	8.25	0.005	**GB**
GE	0.34	0.09	0.22	0.14	0.23	**55.95**	0.57	0.12	0.45	0.06	0.00	1.13	0.004	**GE**
GR	0.53	1.03	0.31	0.80	0.50	0.02	**890.2**	1.40	3.54	0.12	0.00	50.59	0.01	**GR**
HR	0.58	3.06	0.40	3.46	1.07	0.01	5.53	**335.4**	76.57	0.21	0.00	242.3	0.01	**HR**
HU	0.96	2.86	0.63	5.25	2.51	0.02	3.91	62.13	**872.6**	0.43	0.01	119.2	0.01	**HU**
IE	0.27	4.14	0.30	3.97	30.18	0.002	0.05	0.05	0.13	**265.5**	0.05	1.16	0.002	**IE**
IS	0.74	2.34	1.27	1.88	1.93	0.01	0.09	0.09	0.24	0.74	**12.64**	2.32	0.01	**IS**
IT	1.60	21.70	1.15	29.34	4.46	0.02	29.24	45.43	28.54	1.08	0.01	**7794**	0.01	**IT**
KY	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.04	**800.1**	**KY**
KZ	6.80	1.06	5.56	1.57	2.51	0.43	1.18	0.48	1.73	0.66	0.02	4.24	199.4	**KZ**
LT	14.78	2.11	4.60	3.65	3.54	0.005	0.22	0.76	2.98	0.70	0.01	7.12	0.004	**LT**
LU	0.04	0.52	0.03	6.38	0.57	0.00	0.01	0.01	0.03	0.08	0.00	0.63	0.00	**LU**
LV	93.36	1.97	11.08	3.97	4.19	0.01	0.24	0.72	2.62	0.81	0.01	6.43	0.005	**LV**
MC	0.00	0.001	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	**MC**
ME	0.03	0.05	0.02	0.08	0.07	0.001	0.70	0.41	1.15	0.01	0.00	3.13	0.00	**ME**
MD	0.53	0.16	0.28	0.28	0.33	0.02	1.07	0.44	1.75	0.07	0.00	4.08	0.01	**MD**
MK	0.12	0.32	0.08	0.26	0.16	0.003	43.67	0.64	1.56	0.03	0.00	23.85	0.001	**MK**
MT	0.00	0.003	0.00	0.003	0.001	0.00	0.01	0.003	0.003	0.00	0.00	0.13	0.00	**MT**
NL	0.46	4.06	0.41	20.36	14.96	0.001	0.03	0.07	0.20	1.64	0.01	2.92	0.001	**NL**
NO	15.01	6.75	32.97	11.75	53.52	0.02	0.32	0.55	2.60	11.15	0.34	6.87	0.04	**NO**
PL	12.79	10.84	7.47	22.51	21.50	0.03	1.75	7.95	44.03	3.83	0.06	49.60	0.02	**PL**
PT	0.05	138.72	0.04	1.35	0.45	0.00	0.01	0.05	0.06	0.15	0.00	1.98	0.001	**PT**
RO	2.53	2.67	1.50	4.74	3.98	0.09	12.86	14.87	85.29	0.78	0.02	95.37	0.04	**RO**
RS	0.67	1.56	0.42	2.06	1.55	0.01	24.26	26.54	43.67	0.31	0.01	123.8	0.01	**RS**
RU	545.5	33.76	438.1	47.77	57.52	9.91	13.13	17.07	56.84	12.49	0.38	142.0	2.33	**RU**
RUA	52.82	7.70	52.07	11.15	18.14	0.68	3.45	4.03	12.84	4.20	0.21	34.09	21.76	**RUA**
SE	55.55	10.20	124.33	22.51	44.34	0.03	0.56	1.17	5.58	8.32	0.23	13.35	0.04	**SE**
SI	0.26	1.28	0.17	1.94	0.46	0.004	0.52	45.25	19.24	0.08	0.00	156.3	0.004	**SI**
SK	0.97	1.80	0.65	3.72	2.31	0.01	1.00	8.99	97.49	0.39	0.01	37.24	0.01	**SK**
TJ	0.005	0.006	0.003	0.003	0.003	0.003	0.002	0.00	0.002	0.001	0.00	0.01	30.50	**TJ**
TM	0.23	0.06	0.17	0.06	0.09	0.13	0.05	0.03	0.09	0.03	0.00	0.23	0.77	**TM**
TR	1.34	0.72	0.79	0.97	1.24	3.38	38.20	1.39	4.77	0.29	0.01	22.36	0.02	**TR**
UA	17.57	4.99	9.46	9.07	9.69	0.42	10.39	13.73	71.82	1.94	0.04	87.47	0.24	**UA**
UZ	0.40	0.09	0.28	0.09	0.14	0.06	0.05	0.02	0.10	0.04	0.00	0.24	132.1	**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 deposition in 2007, kg/y (continued)*

Receptors ↓ Emitters ⟶

	KZ	LT	LU	LV	MC	ME	MD	MK	MT	NL	NO	PL	
AL	0.04	0.11	0.03	0.31	0.00	10.82	0.16	24.78	0.01	0.26	0.07	4.20	**AL**
AM	0.08	0.03	0.00	0.10	0.00	0.001	0.03	0.005	0.00	0.02	0.01	0.44	**AM**
AT	0.24	2.66	1.87	5.39	0.00	0.36	0.29	0.33	0.003	11.00	0.86	156.1	**AT**
AZ	1.11	0.16	0.00	0.47	0.00	0.004	0.07	0.01	0.00	0.06	0.04	1.29	**AZ**
BA	0.15	0.85	0.21	2.22	0.00	22.80	0.64	4.64	0.01	1.77	0.34	41.58	**BA**
BE	0.04	0.48	15.78	1.26	0.00	0.01	0.02	0.01	0.00	90.00	0.40	7.83	**BE**
BG	0.53	1.19	0.18	3.04	0.00	2.62	5.70	28.20	0.01	1.93	0.53	39.56	**BG**
BY	1.18	196.9	0.95	273.4	0.00	0.42	5.99	0.45	0.001	12.96	4.83	982.4	**BY**
CH	0.03	0.46	1.03	1.10	0.00	0.03	0.03	0.03	0.001	4.33	0.19	8.92	**CH**
CY	0.00	0.00	0.00	0.01	0.00	0.002	0.00	0.01	0.00	0.00	0.00	0.08	**CY**
CZ	0.21	4.82	1.75	8.95	0.00	0.34	0.36	0.41	0.001	14.82	1.47	586.7	**CZ**
DE	0.61	14.64	51.93	34.06	0.00	0.19	0.53	0.24	0.002	453.1	6.87	495.3	**DE**
DK	0.07	1.47	0.49	5.03	0.00	0.01	0.08	0.02	0.00	16.37	4.18	44.62	**DK**
EE	0.23	27.41	0.37	316.4	0.00	0.05	0.35	0.06	0.00	6.62	2.15	88.59	**EE**
ES	0.16	0.82	0.35	2.04	0.00	0.15	0.09	0.19	0.002	2.18	0.31	10.28	**ES**
FI	1.80	42.95	1.21	221.1	0.00	0.14	1.43	0.18	0.00	23.96	20.75	273.2	**FI**
FR	0.44	4.31	47.59	10.28	0.01	0.38	0.27	0.45	0.01	67.67	2.12	79.48	**FR**
GB	0.23	2.74	1.69	8.63	0.00	0.04	0.12	0.05	0.00	37.90	2.85	40.83	**GB**
GE	0.16	0.31	0.02	0.96	0.00	0.02	0.32	0.07	0.00	0.23	0.08	4.99	**GE**
GR	0.20	0.47	0.06	1.32	0.00	0.97	1.12	35.35	0.02	0.71	0.21	13.63	**GR**
HR	0.13	0.82	0.28	1.98	0.00	3.97	0.42	2.32	0.01	2.05	0.28	57.93	**HR**
HU	0.20	1.53	0.60	3.91	0.00	2.42	0.88	2.41	0.003	4.72	0.78	183.0	**HU**
IE	0.07	0.47	0.32	1.49	0.00	0.01	0.02	0.02	0.00	3.93	0.30	5.76	**IE**
IS	0.43	0.70	0.12	2.04	0.00	0.01	0.03	0.02	0.00	1.09	1.36	7.87	**IS**
IT	0.29	1.78	0.92	4.30	0.002	3.96	0.59	3.73	0.10	4.74	0.51	71.49	**IT**
KY	121.0	0.03	0.00	0.11	0.00	0.001	0.005	0.002	0.00	0.02	0.01	0.17	**KY**
KZ	**3999**	8.18	0.28	27.76	0.00	0.13	1.56	0.28	0.001	4.06	2.05	63.42	**KZ**
LT	0.23	**776.1**	0.70	361.4	0.00	0.10	0.72	0.14	0.001	9.37	3.79	412.0	**LT**
LU	0.00	0.05	**25.89**	0.13	0.00	0.001	0.003	0.002	0.00	2.11	0.03	0.98	**LU**
LV	0.36	186.7	0.84	**2455**	0.00	0.11	0.75	0.14	0.00	13.84	4.57	240.7	**LV**
MC	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.01	**MC**
ME	0.02	0.06	0.02	0.15	0.00	**0.65**	0.23	1.22	0.00	0.18	0.04	3.06	**ME**
MD	0.43	1.04	0.06	2.39	0.00	0.23	**136.6**	0.60	0.00	0.80	0.28	34.14	**MD**
MK	0.04	0.14	0.03	0.40	0.00	1.38	0.20	**179.1**	0.005	0.35	0.10	6.44	**MK**
MT	0.00	0.00	0.00	0.001	0.00	0.001	0.00	0.001	**0.05**	0.001	0.00	0.02	**MT**
NL	0.08	0.84	2.23	2.60	0.00	0.01	0.04	0.01	0.00	**643.2**	0.99	12.05	**NL**
NO	1.63	12.62	1.33	42.08	0.00	0.09	0.68	0.14	0.00	36.49	**520.0**	118.3	**NO**
PL	1.09	71.73	6.21	99.22	0.00	1.19	3.68	1.82	0.005	80.88	16.32	**12054**	**PL**
PT	0.02	0.10	0.05	0.22	0.00	0.00	0.01	0.004	0.00	0.40	0.05	1.02	**PT**
RO	1.44	4.70	0.96	11.37	0.00	7.70	52.82	13.92	0.01	8.76	2.14	236.3	**RO**
RS	0.22	1.14	0.45	3.03	0.00	125.5	1.97	53.68	0.02	3.92	0.77	59.79	**RS**
RU	300.9	309.3	6.02	1239	0.00	3.25	30.31	5.30	0.01	86.67	45.03	1902	**RU**
RUA	1327	45.08	1.52	167.8	0.00	0.74	6.11	1.15	0.003	25.05	15.99	375.1	**RUA**
SE	2.01	35.40	2.52	145.0	0.00	0.20	1.30	0.31	0.001	67.30	108.2	274.2	**SE**
SI	0.09	0.53	0.21	1.23	0.00	0.46	0.12	0.35	0.003	1.17	0.13	33.06	**SI**
SK	0.18	2.16	0.78	5.33	0.00	0.86	0.71	1.07	0.002	6.21	1.01	513.7	**SK**
TJ	7.43	0.01	0.00	0.03	0.00	0.00	0.003	0.001	0.00	0.004	0.002	0.06	**TJ**
TM	11.77	0.26	0.01	0.84	0.00	0.004	0.06	0.01	0.00	0.10	0.05	1.63	**TM**
TR	0.77	2.43	0.20	6.36	0.00	0.85	4.38	3.56	0.04	2.28	0.78	45.36	**TR**
UA	9.34	38.74	1.82	83.00	0.00	3.59	87.59	6.15	0.01	22.69	6.62	1381	**UA**
UZ	102.9	0.44	0.01	1.48	0.00	0.01	0.08	0.01	0.00	0.18	0.09	2.70	**UZ**
	KZ	**LT**	**LU**	**LV**	**MC**	**ME**	**MD**	**MK**	**MT**	**NL**	**NO**	**PL**	

***Table B.2**. Matrix of B[a]P country-to-country deposition in 2007, kg/y (continued)*

Receptors ↓ Emitters ⟶

	PT	**RO**	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total**	
AL	0.04	6.97	54.26	0.28	0.01	0.14	0.50	1.20	0.00	0.00	6.20	8.23	0.001	**622.7**	**AL**
AM	0.001	0.31	0.04	0.48	0.004	0.04	0.01	0.04	0.001	0.02	19.76	2.78	0.005	**416.7**	**AM**
AT	0.26	8.05	8.24	2.04	0.04	2.24	94.38	34.30	0.002	0.003	1.94	24.96	0.004	**1813**	**AT**
AZ	0.004	0.78	0.10	5.45	0.41	0.16	0.02	0.12	0.02	0.19	11.59	12.69	0.07	**828.5**	**AZ**
BA	0.13	37.71	118.2	0.97	0.01	0.72	10.77	12.68	0.002	0.003	4.63	26.72	0.004	**1377**	**BA**
BE	0.39	0.28	0.10	0.37	0.01	1.12	0.22	0.39	0.00	0.00	0.13	2.39	0.00	**1219**	**BE**
BG	0.06	345.5	109.2	4.44	0.05	1.33	3.41	9.74	0.01	0.01	90.40	193.2	0.02	**2409**	**BG**
BY	0.55	52.73	9.44	46.67	0.54	26.79	8.70	44.75	0.02	0.01	5.93	624.1	0.02	**5892**	**BY**
CH	0.41	0.69	0.44	0.31	0.01	0.61	2.60	0.69	0.00	0.00	0.24	2.42	0.00	**330.6**	**CH**
CY	0.00	0.09	0.03	0.01	0.00	0.01	0.00	0.01	0.00	0.00	4.82	0.26	0.00	**13.0**	**CY**
CZ	0.39	10.55	8.21	2.39	0.06	4.30	9.94	107.1	0.002	0.002	1.73	29.76	0.003	**2596**	**CZ**
DE	2.65	7.90	3.66	6.91	0.23	21.59	5.50	16.39	0.004	0.004	2.29	46.78	0.01	**12406**	**DE**
DK	0.15	0.97	0.27	0.89	0.04	9.86	0.42	2.10	0.00	0.00	0.17	5.63	0.00	**902.4**	**DK**
EE	0.15	3.83	0.96	15.20	0.10	20.81	0.90	3.90	0.001	0.001	0.66	28.95	0.002	**1438**	**EE**
ES	90.69	2.21	1.30	1.05	0.03	0.85	2.16	1.30	0.001	0.002	1.29	7.18	0.003	**4208**	**ES**
FI	0.66	15.34	3.45	81.88	0.91	237.3	3.05	15.70	0.01	0.01	2.75	167.9	0.02	**3053**	**FI**
FR	11.80	5.85	3.55	3.63	0.10	6.39	12.04	6.61	0.003	0.004	2.71	28.56	0.01	**3427**	**FR**
GB	1.53	1.58	0.44	2.20	0.09	4.95	0.64	2.25	0.002	0.002	0.87	11.48	0.003	**1324**	**GB**
GE	0.01	4.13	0.57	9.01	0.02	0.35	0.15	0.52	0.003	0.02	56.59	32.73	0.01	**284.6**	**GE**
GR	0.04	34.99	26.39	1.78	0.02	0.49	1.05	3.28	0.002	0.004	98.45	61.08	0.01	**1341**	**GR**
HR	0.22	23.41	63.18	1.04	0.01	0.78	120.1	20.69	0.001	0.002	3.12	23.42	0.003	**1259**	**HR**
HU	0.29	113.3	98.71	2.10	0.03	1.88	64.10	236.7	0.002	0.003	6.60	82.88	0.004	**2144**	**HU**
IE	0.21	0.33	0.12	0.42	0.02	0.83	0.12	0.31	0.001	0.001	0.29	2.35	0.001	**340.8**	**IE**
IS	0.21	0.55	0.17	1.59	0.24	2.22	0.23	0.54	0.004	0.002	0.46	3.75	0.004	**61.5**	**IS**
IT	0.56	22.54	28.43	2.10	0.04	1.57	99.53	15.98	0.003	0.005	11.32	33.90	0.01	**8577**	**IT**
KY	0.01	0.06	0.01	0.26	0.03	0.04	0.01	0.01	87.84	0.33	0.37	1.47	39.23	**1052**	**KY**
KZ	0.21	18.28	2.68	264.0	116.0	10.14	1.13	4.86	42.46	4.64	37.86	537.4	37.25	**5477**	**KZ**
LT	0.32	7.90	1.90	15.57	0.28	23.63	2.13	9.31	0.002	0.002	1.29	48.63	0.003	**1952**	**LT**
LU	0.11	0.05	0.02	0.04	0.001	0.11	0.05	0.06	0.00	0.00	0.02	0.26	0.00	**65.9**	**LU**
LV	0.39	8.32	2.02	17.44	0.20	37.19	1.90	8.38	0.002	0.003	1.85	57.43	0.004	**3345**	**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	**0.2**	**MC**
ME	0.01	27.87	47.70	0.15	0.003	0.09	0.45	0.96	0.00	0.00	1.66	8.66	0.00	**113.6**	**ME**
MD	0.03	172.5	4.45	2.70	0.03	0.91	1.12	4.25	0.01	0.01	11.15	238.7	0.01	**640.5**	**MD**
MK	0.05	10.66	73.39	0.32	0.01	0.21	0.53	1.88	0.00	0.001	9.62	10.03	0.00	**456.2**	**MK**
MT	0.00	0.004	0.004	0.00	0.00	0.00	0.003	0.003	0.00	0.00	0.02	0.01	0.00	**0.3**	**MT**
NL	0.84	0.48	0.12	0.60	0.04	2.11	0.22	0.54	0.00	0.00	0.15	3.43	0.001	**1160.7**	**NL**
NO	0.83	8.90	1.94	16.69	1.16	112.8	1.60	6.51	0.01	0.01	2.16	57.56	0.01	**1327.1**	**NO**
PL	2.44	72.95	25.34	25.00	1.57	52.12	25.73	297.3	0.01	0.01	9.53	315.2	0.01	**14828.8**	**PL**
PT	**541.6**	0.11	0.04	0.12	0.01	0.13	0.13	0.06	0.00	0.00	0.07	0.64	0.00	**690.4**	**PT**
RO	0.40	**4253**	246.8	10.92	0.16	5.45	23.44	62.93	0.02	0.03	81.44	605.2	0.04	**6123**	**RO**
RS	0.28	158.0	**1480**	1.77	0.03	1.44	11.77	23.52	0.002	0.004	23.77	78.75	0.01	**2561**	**RS**
RU	3.99	338.3	60.21	**6873**	81.97	279.0	37.47	133.5	1.03	1.54	336.8	7622	1.98	**23308**	**RU**
RUA	1.13	72.99	14.00	1037	**2130**	67.99	8.91	29.50	6.86	1.85	70.87	1376	5.44	**7372**	**RUA**
SE	1.18	16.49	4.09	32.89	1.14	**1912**	2.89	13.34	0.02	0.01	3.27	121.0	0.02	**3687**	**SE**
SI	0.17	5.00	7.56	0.68	0.01	0.49	**513.0**	10.78	0.001	0.001	0.95	9.64	0.002	**902.0**	**SI**
SK	0.38	38.05	20.71	1.99	0.04	2.49	24.24	**850.9**	0.002	0.002	4.10	69.39	0.003	**1967**	**SK**
TJ	0.001	0.04	0.01	0.08	0.005	0.01	0.002	0.01	**389.3**	0.54	0.32	0.41	15.10	**444.1**	**TJ**
TM	0.01	0.66	0.10	2.94	0.25	0.28	0.04	0.14	7.92	**27.96**	2.85	16.99	15.94	**100.9**	**TM**
TR	0.14	82.20	15.49	13.15	0.08	2.61	2.74	6.35	0.01	0.03	**7533**	335.5	0.02	**8322**	**TR**
UA	0.81	561.1	71.62	145.5	0.69	26.50	33.60	164.2	0.13	0.17	157.1	**26944**	0.25	**30652**	**UA**
UZ	0.01	0.91	0.13	5.09	0.64	0.48	0.05	0.23	155.6	6.34	2.67	28.71	**116.1**	**564.1**	**UZ**
	PT	**RO**	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total**	

***Table B.3**. Matrix of PCDD/F country-to-country deposition in 2007, g TEQ/y*

Receptors ↓ Emitters ⟶

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	
AL	**18.41**	0.003	0.04	0.01	0.23	0.01	0.25	0.002	0.01	0.001	0.08	0.03	0.01	**AL**
AM	0.01	**20.56**	0.00	3.10	0.01	0.003	0.01	0.002	0.001	0.004	0.01	0.004	0.002	**AM**
AT	0.05	0.01	**23.21**	0.02	0.21	0.32	0.05	0.02	0.49	0.001	3.26	1.37	0.06	**AT**
AZ	0.02	3.02	0.01	**46.94**	0.02	0.01	0.04	0.01	0.003	0.01	0.04	0.01	0.01	**AZ**
BA	0.68	0.004	0.35	0.01	**26.58**	0.06	0.16	0.01	0.03	0.001	0.62	0.13	0.03	**BA**
BE	0.004	0.001	0.03	0.002	0.01	**24.64**	0.004	0.002	0.02	0.00	0.05	1.18	0.03	**BE**
BG	0.51	0.02	0.16	0.04	0.33	0.05	**34.21**	0.02	0.02	0.004	0.48	0.10	0.04	**BG**
BY	0.04	0.02	0.18	0.04	0.08	0.13	0.08	**17.71**	0.03	0.001	1.41	0.28	0.27	**BY**
CH	0.02	0.001	0.40	0.003	0.05	0.15	0.02	0.003	**6.50**	0.00	0.10	0.40	0.01	**CH**
CY	0.01	0.01	0.002	0.003	0.01	0.00	0.01	0.00	0.001	**0.65**	0.005	0.002	0.00	**CY**
CZ	0.03	0.004	2.33	0.01	0.10	0.28	0.03	0.02	0.12	0.00	**52.86**	1.49	0.11	**CZ**
DE	0.06	0.01	3.28	0.03	0.11	6.39	0.06	0.05	2.25	0.001	3.62	**53.49**	1.21	**DE**
DK	0.004	0.001	0.02	0.002	0.01	0.17	0.004	0.01	0.01	0.00	0.13	0.24	**7.85**	**DK**
EE	0.01	0.002	0.01	0.004	0.01	0.05	0.01	0.06	0.004	0.00	0.10	0.08	0.10	**EE**
ES	0.19	0.01	0.15	0.02	0.22	0.26	0.10	0.01	0.13	0.002	0.21	0.24	0.04	**ES**
FI	0.03	0.01	0.06	0.02	0.04	0.20	0.03	0.11	0.02	0.001	0.40	0.26	0.33	**FI**
FR	0.23	0.01	0.55	0.04	0.34	6.57	0.13	0.03	2.02	0.002	0.71	4.01	0.19	**FR**
GB	0.02	0.01	0.08	0.02	0.03	1.13	0.02	0.02	0.04	0.00	0.29	0.70	0.28	**GB**
GE	0.03	3.32	0.02	4.58	0.03	0.01	0.08	0.01	0.005	0.01	0.07	0.02	0.01	**GE**
GR	2.07	0.02	0.11	0.04	0.31	0.04	3.25	0.02	0.02	0.01	0.27	0.08	0.02	**GR**
HR	0.37	0.004	0.84	0.01	5.50	0.06	0.11	0.01	0.04	0.001	0.98	0.15	0.03	**HR**
HU	0.10	0.01	1.97	0.01	0.79	0.09	0.12	0.02	0.04	0.001	3.10	0.26	0.07	**HU**
IE	0.01	0.002	0.02	0.01	0.01	0.14	0.01	0.003	0.01	0.00	0.05	0.10	0.03	**IE**
IS	0.01	0.004	0.01	0.01	0.01	0.04	0.005	0.003	0.01	0.00	0.03	0.03	0.02	**IS**
IT	1.49	0.02	1.97	0.04	2.01	0.26	0.40	0.02	0.82	0.005	1.16	0.53	0.06	**IT**
KY	0.01	0.06	0.01	0.15	0.01	0.004	0.01	0.003	0.003	0.002	0.02	0.01	0.00	**KY**
KZ	0.13	0.82	0.15	2.95	0.15	0.14	0.24	0.16	0.04	0.02	0.49	0.21	0.13	**KZ**
LT	0.01	0.002	0.05	0.01	0.02	0.08	0.01	0.45	0.01	0.00	0.35	0.16	0.22	**LT**
LV	0.01	0.002	0.03	0.01	0.01	0.08	0.01	0.23	0.01	0.00	0.22	0.16	0.19	**LV**
LU	0.00	0.00	0.005	0.00	0.001	0.22	0.00	0.00	0.004	0.00	0.01	0.16	0.00	**LU**
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	**MC**
ME	0.03	0.00	0.01	0.001	0.04	0.003	0.08	0.001	0.001	0.00	0.04	0.01	0.002	**ME**
MD	0.02	0.01	0.02	0.02	0.02	0.01	0.08	0.03	0.003	0.001	0.14	0.02	0.02	**MD**
MK	1.66	0.002	0.03	0.004	0.12	0.01	0.78	0.002	0.01	0.001	0.09	0.02	0.01	**MK**
MT	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**MT**
NL	0.004	0.001	0.02	0.003	0.005	5.44	0.004	0.003	0.01	0.00	0.07	1.83	0.07	**NL**
NO	0.03	0.01	0.08	0.03	0.04	0.35	0.03	0.04	0.03	0.001	0.32	0.35	0.59	**NO**
PL	0.09	0.01	0.97	0.03	0.23	0.63	0.09	0.67	0.12	0.001	35.58	2.30	1.31	**PL**
PT	0.01	0.001	0.01	0.002	0.02	0.03	0.01	0.001	0.01	0.00	0.02	0.02	0.005	**PT**
RO	0.38	0.04	0.47	0.08	0.87	0.12	1.54	0.08	0.05	0.004	2.10	0.30	0.13	**RO**
RS	2.88	0.01	0.33	0.01	3.66	0.07	0.77	0.01	0.03	0.002	0.84	0.15	0.04	**RS**
RU	0.45	1.86	0.72	8.10	0.62	0.86	1.08	3.30	0.18	0.03	3.60	1.37	1.18	**RU**
RUA	0.23	0.66	0.28	1.97	0.29	0.35	0.39	0.26	0.08	0.02	1.08	0.50	0.37	**RUA**
SE	0.04	0.01	0.09	0.03	0.06	0.51	0.04	0.09	0.03	0.001	0.51	0.59	3.42	**SE**
SI	0.04	0.002	1.44	0.01	0.24	0.03	0.02	0.005	0.03	0.00	0.44	0.07	0.01	**SI**
SK	0.04	0.004	0.98	0.01	0.18	0.07	0.05	0.02	0.03	0.00	14.50	0.22	0.07	**SK**
TJ	0.01	0.04	0.003	0.08	0.01	0.002	0.01	0.001	0.001	0.001	0.01	0.003	0.001	**TJ**
TM	0.02	0.35	0.02	1.31	0.03	0.01	0.04	0.01	0.01	0.01	0.06	0.02	0.01	**TM**
TR	0.59	6.16	0.24	1.80	0.37	0.11	2.64	0.09	0.05	0.28	0.71	0.20	0.09	**TR**
UA	0.21	0.19	0.50	0.43	0.40	0.23	0.69	1.51	0.07	0.01	3.49	0.50	0.34	**UA**
UZ	0.02	0.18	0.02	0.55	0.02	0.01	0.03	0.01	0.01	0.004	0.05	0.02	0.01	**UZ**
	AL	**AM**	**AT**	**AZ**	**BA**	**BE**	**BG**	**BY**	**CH**	**CY**	**CZ**	**DE**	**DK**	

***Table B.3**. Matrix of PCDD/F country-to-country deposition in 2007, g TEQ/y (continued)*

Receptors ↓ Emitters ⟶

	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KY	
AL	0.00	0.08	0.00	0.06	0.05	0.01	1.36	0.21	0.09	0.003	0.00	2.18	0.00	**AL**
AM	0.00	0.01	0.00	0.01	0.01	1.52	0.03	0.01	0.01	0.001	0.00	0.05	0.001	**AM**
AT	0.002	0.19	0.004	0.52	0.52	0.02	0.09	0.83	1.33	0.02	0.001	3.31	0.001	**AT**
AZ	0.001	0.02	0.001	0.02	0.03	3.59	0.08	0.02	0.03	0.002	0.00	0.12	0.007	**AZ**
BA	0.001	0.16	0.002	0.14	0.15	0.01	0.34	6.40	1.17	0.01	0.001	2.58	0.001	**BA**
BE	0.001	0.11	0.001	2.28	1.09	0.002	0.01	0.01	0.01	0.03	0.001	0.07	0.00	**BE**
BG	0.001	0.11	0.003	0.10	0.15	0.08	2.26	0.34	0.53	0.01	0.001	1.25	0.002	**BG**
BY	0.06	0.12	0.06	0.16	0.44	0.05	0.09	0.15	0.38	0.02	0.002	0.41	0.002	**BY**
CH	0.00	0.22	0.001	1.12	0.30	0.003	0.04	0.14	0.05	0.02	0.00	3.95	0.00	**CH**
CY	0.00	0.00	0.00	0.004	0.004	0.01	0.11	0.01	0.004	0.00	0.00	0.07	0.00	**CY**
CZ	0.002	0.13	0.01	0.35	0.49	0.01	0.05	0.28	0.89	0.02	0.001	0.59	0.00	**CZ**
DE	0.01	0.75	0.02	5.93	4.74	0.02	0.10	0.23	0.40	0.18	0.01	1.80	0.001	**DE**
DK	0.003	0.06	0.01	0.16	0.92	0.003	0.01	0.01	0.03	0.04	0.002	0.06	0.00	**DK**
EE	**1.95**	0.03	0.17	0.05	0.20	0.01	0.01	0.01	0.02	0.01	0.001	0.06	0.00	**EE**
ES	0.002	**94.57**	0.004	2.93	1.27	0.02	0.31	0.42	0.19	0.10	0.01	3.27	0.001	**ES**
FI	0.29	0.16	**6.96**	0.22	0.93	0.03	0.05	0.07	0.11	0.05	0.01	0.27	0.001	**FI**
FR	0.01	9.56	0.01	**70.46**	6.47	0.04	0.33	0.80	0.36	0.33	0.01	8.92	0.001	**FR**
GB	0.004	0.73	0.01	1.38	**102.3**	0.02	0.05	0.05	0.08	1.62	0.02	0.30	0.001	**GB**
GE	0.001	0.03	0.002	0.03	0.05	**46.28**	0.14	0.03	0.05	0.003	0.00	0.18	0.002	**GE**
GR	0.001	0.19	0.002	0.15	0.14	0.08	**40.44**	0.32	0.26	0.01	0.001	3.04	0.001	**GR**
HR	0.001	0.16	0.002	0.16	0.14	0.01	0.23	**33.74**	3.00	0.01	0.00	3.77	0.001	**HR**
HU	0.002	0.12	0.004	0.16	0.22	0.02	0.12	4.34	**46.48**	0.01	0.001	1.48	0.001	**HU**
IE	0.001	0.18	0.002	0.23	2.02	0.004	0.02	0.01	0.01	**7.27**	0.01	0.08	0.00	**IE**
IS	0.001	0.09	0.005	0.08	0.27	0.01	0.01	0.01	0.01	0.03	**0.45**	0.07	0.001	**IS**
IT	0.003	1.29	0.01	1.78	0.67	0.04	1.50	4.56	1.16	0.04	0.002	**152.6**	0.002	**IT**
KY	0.00	0.02	0.001	0.01	0.01	0.07	0.03	0.01	0.01	0.001	0.00	0.07	**33.77**	**KY**
KZ	0.02	0.27	0.06	0.25	0.56	1.34	0.41	0.20	0.25	0.04	0.004	0.91	9.07	**KZ**
LT	0.03	0.04	0.03	0.08	0.26	0.01	0.02	0.03	0.06	0.01	0.001	0.10	0.00	**LT**
LV	0.25	0.04	0.06	0.08	0.28	0.01	0.02	0.02	0.05	0.01	0.001	0.09	0.00	**LV**
LU	0.00	0.01	0.00	0.62	0.04	0.00	0.001	0.001	0.002	0.002	0.00	0.01	0.00	**LU**
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	**MC**
ME	0.00	0.005	0.00	0.01	0.01	0.002	0.02	0.04	0.07	0.00	0.00	0.07	0.00	**ME**
MD	0.001	0.01	0.002	0.02	0.04	0.04	0.05	0.03	0.08	0.002	0.00	0.09	0.001	**MD**
MK	0.00	0.04	0.00	0.03	0.04	0.01	1.50	0.11	0.11	0.002	0.00	0.70	0.00	**MK**
MT	0.00	0.001	0.00	0.00	0.00	0.00	0.001	0.001	0.00	0.00	0.00	0.01	0.00	**MT**
NL	0.00	0.09	0.002	0.78	1.41	0.002	0.01	0.01	0.02	0.04	0.001	0.06	0.00	**NL**
NO	0.02	0.32	0.09	0.42	3.08	0.03	0.06	0.07	0.10	0.16	0.02	0.33	0.002	**NO**
PL	0.02	0.29	0.04	0.62	1.52	0.03	0.12	0.56	1.76	0.07	0.005	1.14	0.001	**PL**
PT	0.00	2.74	0.00	0.16	0.14	0.002	0.02	0.03	0.02	0.01	0.00	0.20	0.00	**PT**
RO	0.005	0.20	0.01	0.23	0.38	0.14	0.58	1.01	4.09	0.02	0.002	1.94	0.004	**RO**
RS	0.001	0.15	0.002	0.14	0.19	0.02	0.73	2.35	2.30	0.01	0.001	2.72	0.001	**RS**
RU	1.11	1.13	1.45	1.23	3.54	8.54	1.34	0.92	1.42	0.20	0.02	3.46	0.24	**RU**
RUA	0.07	0.61	0.18	0.58	1.73	1.22	0.69	0.41	0.50	0.11	0.01	1.83	1.34	**RUA**
SE	0.09	0.28	0.50	0.50	2.51	0.03	0.07	0.09	0.14	0.12	0.01	0.38	0.002	**SE**
SI	0.00	0.06	0.001	0.08	0.05	0.01	0.04	3.81	0.58	0.003	0.00	3.06	0.00	**SI**
SK	0.002	0.06	0.003	0.11	0.18	0.01	0.05	0.56	5.74	0.01	0.00	0.61	0.00	**SK**
TJ	0.00	0.01	0.00	0.01	0.01	0.04	0.02	0.01	0.00	0.00	0.00	0.03	1.76	**TJ**
TM	0.002	0.04	0.003	0.03	0.05	0.44	0.08	0.03	0.03	0.003	0.00	0.16	0.21	**TM**
TR	0.01	0.36	0.01	0.30	0.42	4.13	4.74	0.47	0.57	0.03	0.002	2.98	0.01	**TR**
UA	0.03	0.27	0.05	0.33	0.78	0.77	0.62	0.72	2.75	0.04	0.003	1.65	0.02	**UA**
UZ	0.002	0.03	0.003	0.03	0.05	0.24	0.06	0.02	0.03	0.003	0.00	0.12	5.22	**UZ**
	EE	**ES**	**FI**	**FR**	**GB**	**GE**	**GR**	**HR**	**HU**	**IE**	**IS**	**IT**	**KY**	

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

Receptors ↓ Emitters ⟶

	KZ	LT	LV	LU	MC	ME	MD	MK	MT	NL	NO	PL	
AL	0.002	0.001	0.001	0.00	0.004	0.46	0.003	8.45	0.02	0.01	0.003	0.14	AL
AM	0.02	0.00	0.00	0.00	0.00	0.001	0.001	0.02	0.001	0.001	0.001	0.03	AM
AT	0.005	0.01	0.01	0.012	0.01	0.02	0.003	0.14	0.01	0.11	0.02	2.05	AT
AZ	0.22	0.002	0.002	0.00	0.001	0.003	0.003	0.05	0.002	0.002	0.002	0.08	AZ
BA	0.005	0.004	0.004	0.002	0.01	0.93	0.005	0.93	0.01	0.02	0.01	0.69	BA
BE	0.001	0.002	0.002	0.13	0.001	0.001	0.00	0.01	0.00	1.14	0.01	0.10	BE
BG	0.02	0.01	0.01	0.002	0.01	0.13	0.07	9.49	0.02	0.02	0.01	0.83	BG
BY	0.03	1.06	0.50	0.004	0.004	0.01	0.05	0.16	0.004	0.08	0.09	12.42	BY
CH	0.001	0.002	0.002	0.01	0.02	0.01	0.001	0.05	0.004	0.04	0.01	0.14	CH
CY	0.00	0.00	0.00	0.00	0.00	0.002	0.00	0.03	0.001	0.00	0.00	0.01	CY
CZ	0.003	0.015	0.01	0.01	0.005	0.01	0.004	0.10	0.004	0.12	0.03	10.29	CZ
DE	0.01	0.06	0.06	0.33	0.02	0.02	0.01	0.17	0.01	5.10	0.17	8.97	DE
DK	0.001	0.01	0.02	0.002	0.001	0.001	0.001	0.01	0.00	0.13	0.12	0.83	DK
EE	0.003	0.09	0.58	0.001	0.00	0.002	0.002	0.02	0.001	0.03	0.04	0.79	EE
ES	0.01	0.01	0.01	0.01	0.043	0.04	0.004	0.33	0.04	0.08	0.03	0.38	ES
FI	0.02	0.10	0.26	0.003	0.002	0.01	0.01	0.08	0.003	0.12	0.35	2.04	FI
FR	0.01	0.02	0.02	0.49	1.10	0.05	0.01	0.45	0.03	0.89	0.09	1.26	FR
GB	0.01	0.01	0.02	0.012	0.003	0.005	0.003	0.06	0.003	0.49	0.21	0.85	GB
GE	0.04	0.002	0.002	0.00	0.001	0.005	0.01	0.11	0.004	0.004	0.003	0.17	GE
GR	0.01	0.005	0.005	0.001	0.01	0.13	0.03	15.86	0.06	0.02	0.01	0.50	GR
HR	0.004	0.004	0.004	0.002	0.01	0.14	0.004	0.52	0.01	0.02	0.01	0.97	HR
HU	0.01	0.01	0.01	0.003	0.01	0.06	0.01	0.39	0.01	0.04	0.02	3.54	HU
IE	0.002	0.002	0.003	0.002	0.001	0.001	0.001	0.02	0.001	0.05	0.03	0.13	IE
IS	0.01	0.002	0.003	0.001	0.001	0.001	0.00	0.01	0.001	0.02	0.05	0.09	IS
IT	0.01	0.01	0.01	0.01	0.47	0.30	0.01	1.92	0.18	0.08	0.03	1.36	IT
KY	6.46	0.001	0.001	0.00	0.001	0.003	0.001	0.04	0.002	0.002	0.002	0.05	KY
KZ	**195.3**	0.05	0.07	0.003	0.01	0.03	0.04	0.54	0.02	0.07	0.10	1.70	KZ
LT	0.005	**5.64**	0.80	0.002	0.001	0.004	0.005	0.04	0.001	0.05	0.05	4.96	LT
LV	0.005	0.98	**6.33**	0.002	0.001	0.003	0.004	0.03	0.001	0.05	0.06	2.24	LV
LU	0.00	0.00	0.00	**0.31**	0.00	0.00	0.00	0.001	0.00	0.02	0.001	0.01	LU
MC	0.00	0.00	0.00	0.00	**0.005**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	MC
ME	0.001	0.00	0.00	0.00	0.00	**0.02**	0.002	0.25	0.001	0.002	0.001	0.06	ME
MD	0.01	0.01	0.005	0.00	0.001	0.01	**2.25**	0.11	0.001	0.01	0.01	0.70	MD
MK	0.002	0.001	0.001	0.00	0.003	0.09	0.004	**72.16**	0.01	0.01	0.003	0.18	MK
MT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001	**0.05**	0.00	0.00	0.00	MT
NL	0.001	0.003	0.005	0.01	0.001	0.001	0.001	0.01	0.00	**10.24**	0.03	0.22	NL
NO	0.03	0.04	0.08	0.01	0.004	0.01	0.005	0.08	0.004	0.26	**12.39**	1.42	NO
PL	0.02	0.38	0.19	0.02	0.01	0.04	0.03	0.35	0.01	0.42	0.22	**281.2**	PL
PT	0.001	0.001	0.001	0.001	0.003	0.003	0.00	0.03	0.002	0.01	0.004	0.05	PT
RO	0.04	0.02	0.02	0.005	0.02	0.23	0.64	2.32	0.02	0.07	0.05	4.48	RO
RS	0.01	0.01	0.01	0.002	0.01	5.42	0.02	13.33	0.02	0.03	0.02	1.21	RS
RU	10.37	1.003	1.60	0.02	0.03	0.13	0.25	2.14	0.05	0.51	0.87	18.14	RU
RUA	34.36	0.11	0.18	0.01	0.01	0.06	0.05	0.87	0.03	0.19	0.33	3.64	RUA
SE	0.03	0.13	0.29	0.01	0.004	0.01	0.01	0.12	0.004	0.34	2.28	3.28	SE
SI	0.002	0.002	0.002	0.001	0.01	0.01	0.001	0.08	0.003	0.01	0.003	0.41	SI
SK	0.004	0.01	0.01	0.003	0.005	0.02	0.01	0.16	0.004	0.03	0.02	10.06	SK
TJ	0.67	0.00	0.001	0.00	0.00	0.001	0.001	0.02	0.001	0.001	0.001	0.02	TJ
TM	2.07	0.004	0.005	0.00	0.001	0.01	0.004	0.09	0.004	0.01	0.01	0.16	TM
TR	0.14	0.03	0.02	0.004	0.02	0.13	0.14	3.17	0.11	0.06	0.04	1.92	TR
UA	0.31	0.21	0.16	0.01	0.02	0.09	1.26	1.19	0.02	0.15	0.15	21.98	UA
UZ	8.11	0.004	0.005	0.00	0.001	0.005	0.004	0.08	0.003	0.01	0.01	0.16	UZ
	KZ	LT	LV	LU	MC	ME	MD	MK	MT	NL	NO	PL	

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

Receptors ↓ Emitters ⟶

	PT	RO	RS	RU	RUA	SE	SI	SK	TJ	TM	TR	UA	UZ	Total	
AL	0.001	0.30	2.98	0.05	0.00	0.003	0.01	0.06	0.00	0.001	0.77	0.39	0.001	**36.77**	**AL**
AM	0.00	0.04	0.01	0.11	0.001	0.001	0.001	0.005	0.00	0.03	2.33	0.21	0.01	**28.17**	**AM**
AT	0.003	0.28	0.36	0.08	0.001	0.02	0.61	1.21	0.00	0.002	0.30	0.54	0.002	**41.67**	**AT**
AZ	0.00	0.10	0.04	1.09	0.07	0.004	0.001	0.01	0.004	0.25	2.02	0.64	0.11	**58.78**	**AZ**
BA	0.002	0.82	4.56	0.07	0.001	0.01	0.08	0.33	0.00	0.002	0.56	0.69	0.003	**49.35**	**BA**
BE	0.002	0.02	0.01	0.02	0.00	0.01	0.002	0.01	0.00	0.00	0.02	0.05	0.00	**31.13**	**BE**
BG	0.002	10.20	5.53	0.55	0.004	0.02	0.03	0.33	0.001	0.01	5.54	5.40	0.01	**79.06**	**BG**
BY	0.004	0.91	0.25	3.27	0.04	0.29	0.02	0.60	0.001	0.01	0.70	17.49	0.01	**60.22**	**BY**
CH	0.003	0.05	0.06	0.02	0.00	0.01	0.02	0.03	0.00	0.00	0.09	0.08	0.00	**14.15**	**CH**
CY	0.00	0.02	0.02	0.01	0.00	0.00	0.001	0.003	0.00	0.00	1.80	0.07	0.00	**2.87**	**CY**
CZ	0.002	0.27	0.26	0.10	0.001	0.04	0.05	2.05	0.00	0.001	0.18	0.71	0.002	**74.47**	**CZ**
DE	0.01	0.34	0.26	0.32	0.01	0.25	0.04	0.43	0.00	0.004	0.38	1.24	0.005	**102.95**	**DE**
DK	0.002	0.03	0.02	0.06	0.001	0.33	0.002	0.03	0.00	0.00	0.04	0.15	0.00	**11.52**	**DK**
EE	0.001	0.05	0.02	0.98	0.003	0.27	0.002	0.03	0.00	0.001	0.06	0.42	0.001	**6.37**	**EE**
ES	0.67	0.27	0.29	0.09	0.002	0.02	0.04	0.11	0.001	0.003	0.64	0.49	0.004	**108.27**	**ES**
FI	0.01	0.20	0.10	3.11	0.02	2.09	0.01	0.13	0.001	0.004	0.32	1.42	0.01	**21.07**	**FI**
FR	0.07	0.38	0.42	0.19	0.004	0.08	0.11	0.22	0.001	0.004	0.76	0.80	0.01	**119.61**	**FR**
GB	0.02	0.12	0.07	0.13	0.004	0.09	0.01	0.08	0.00	0.003	0.22	0.45	0.004	**112.09**	**GB**
GE	0.001	0.26	0.08	1.55	0.004	0.01	0.003	0.03	0.001	0.04	5.36	1.53	0.02	**64.23**	**GE**
GR	0.003	1.64	2.03	0.41	0.002	0.01	0.02	0.18	0.001	0.005	11.51	2.86	0.01	**86.20**	**GR**
HR	0.002	0.60	2.77	0.06	0.001	0.01	0.82	0.56	0.00	0.002	0.40	0.68	0.003	**56.95**	**HR**
HU	0.002	3.39	3.85	0.12	0.001	0.03	0.32	12.89	0.00	0.002	0.35	3.49	0.003	**88.10**	**HU**
IE	0.004	0.03	0.02	0.03	0.001	0.01	0.002	0.01	0.00	0.001	0.07	0.09	0.001	**10.70**	**IE**
IS	0.004	0.02	0.01	0.07	0.01	0.02	0.002	0.01	0.001	0.002	0.07	0.07	0.003	**1.70**	**IS**
IT	0.02	0.97	1.82	0.17	0.002	0.03	0.68	0.51	0.001	0.004	2.19	1.29	0.01	**184.57**	**IT**
KY	0.001	0.04	0.03	0.16	0.02	0.003	0.001	0.01	4.60	0.203	0.56	0.24	15.92	**62.64**	**KY**
KZ	0.01	1.24	0.44	26.97	10.22	0.18	0.02	0.24	2.18	1.88	7.09	13.00	14.79	**295.23**	**KZ**
LT	0.002	0.13	0.06	1.14	0.01	0.25	0.005	0.10	0.00	0.001	0.12	1.13	0.001	**16.56**	**LT**
LU	0.000	0.002	0.001	0.002	0.00	0.001	0.000	0.001	0.00	0.00	0.00	0.01	0.00	**1.45**	**LU**
LV	0.002	0.10	0.04	0.84	0.01	0.35	0.004	0.07	0.00	0.001	0.11	0.91	0.001	**14.04**	**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	**0.01**	**MC**
ME	0.00	0.81	2.74	0.01	0.00	0.001	0.003	0.03	0.00	0.00	0.06	0.16	0.00	**4.59**	**ME**
MD	0.00	4.65	0.13	0.25	0.001	0.02	0.004	0.11	0.00	0.003	0.60	9.49	0.005	**19.12**	**MD**
MK	0.001	0.42	4.16	0.06	0.001	0.004	0.01	0.08	0.00	0.001	0.78	0.44	0.00	**83.70**	**MK**
MT	0.00	0.00	0.001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.002	0.00	0.00	**0.07**	**MT**
NL	0.002	0.02	0.01	0.03	0.001	0.02	0.002	0.02	0.00	0.00	0.03	0.10	0.00	**20.64**	**NL**
NO	0.01	0.19	0.10	0.60	0.03	0.82	0.01	0.10	0.001	0.005	0.35	0.85	0.01	**24.01**	**NO**
PL	0.01	1.36	0.72	1.46	0.14	0.62	0.10	4.85	0.001	0.01	0.60	11.68	0.01	**352.70**	**PL**
PT	**4.06**	0.03	0.02	0.01	0.00	0.003	0.003	0.01	0.00	0.00	0.06	0.05	0.00	**7.80**	**PT**
RO	0.01	**129.9**	9.54	0.97	0.01	0.08	0.102	2.14	0.002	0.02	3.90	21.54	0.02	**190.96**	**RO**
RS	0.003	3.82	**82.4**	0.16	0.001	0.02	0.06	0.72	0.00	0.003	1.21	1.76	0.004	**127.70**	**RS**
RU	0.05	6.59	2.04	**640.9**	4.40	2.33	0.11	1.69	0.12	0.88	23.39	124.08	1.19	**890.85**	**RU**
RUA	0.02	1.89	0.75	37.00	**177.3**	0.53	0.05	0.46	0.63	0.72	8.69	14.20	2.55	**300.44**	**RUA**
SE	0.01	0.31	0.16	0.93	0.03	**20.44**	0.01	0.17	0.001	0.005	0.42	1.47	0.01	**40.63**	**SE**
SI	0.001	0.12	0.21	0.03	0.00	0.005	**3.52**	0.22	0.00	0.001	0.11	0.21	0.00	**14.99**	**SI**
SK	0.002	0.78	0.54	0.10	0.001	0.03	0.09	**25.87**	0.00	0.002	0.20	2.51	0.00	**63.97**	**SK**
TJ	0.00	0.02	0.01	0.07	0.01	0.001	0.001	0.004	**20.27**	0.23	0.28	0.10	7.25	**31.00**	**TJ**
TM	0.001	0.15	0.07	1.01	0.08	0.01	0.003	0.03	0.82	**13.99**	1.74	0.99	10.21	**34.44**	**TM**
TR	0.01	4.86	1.72	4.09	0.02	0.07	0.05	0.43	0.003	0.09	**661.5**	20.27	0.06	**726.32**	**TR**
UA	0.01	12.73	1.85	14.80	0.04	0.34	0.11	3.93	0.01	0.09	9.02	**657.1**	0.13	**742.28**	**UA**
UZ	0.001	0.13	0.06	1.02	0.12	0.01	0.003	0.03	8.91	2.63	1.25	0.99	**53.52**	**83.79**	**UZ**
	PT	**RO**	**RS**	**RU**	**RUA**	**SE**	**SI**	**SK**	**TJ**	**TM**	**TR**	**UA**	**UZ**	**Total**	