EXECUTIVE SUMMARY

Present Status report describes a progress in the investigation of persistent organic pollutants (POP) long-range transport and accumulation in the environment achieved under EMEP in 2002. The work was performed in accordance with the EMEP work-plan for 2002 [ECE/EB.AIR/75, Annex IV].

The main objectives of the work-plan for 2002 are:

- Assessment of transboundary transport of benzo[a]pyrene (B[a]P): calculation of B[a]P transboundary transport and contamination of European region for 1999.
- Evaluation of PCDD/F transport and accumulation in various environmental compartments in 1999.
- Tentative simulation of PCBs and γ-HCH transport and accumulation from European sources on the hemispheric scale (including the Arctic).

Main results of these activities are shortly described below.

According to calculations essential deposition fluxes are observed in regions with intensive B[a]P emissions: Poland, the Czech Republic, Slovakia, Germany, Lithuania and Latvia. ***For a considerable part of the territory of European countries B[a]P mean annual concentrations in the surface air reach 1 ng/m^3 or higher***. In some countries the ***exceedance of mean diurnal concentration of 1 ng/m^3 can take place during more than 100 days a year.***

The analysis of ***transboundary fluxes*** demonstrates that the highest B[a]P air concentrations caused by external emission sources take place in Slovakia, the Czech Republic and Hungary. High calculated values of B[a]P export are obtained for Germany, Poland and France.

The analysis of calculated ***spatial distributions of PCDD/F concentrations and depositions*** in the environment shows that ***these pollutants are widely spread over Europe***. Relatively high soil concentrations in some parts of the Scandinavian Peninsula are obtained. They can be explained by the role of forests in the formation of soil contamination levels. ***Sea currents also contribute to PCDD/F long-range transport. The half-life of PCDD/Fs in the environment is estimated to be about 30 years.***

The investigation of PCDD/F toxicity congener composition in emissions and the environment showed that ***to improve the assessment of PCDD/F contamination in the EMEP region the evaluation of transport of main PCDD/F congeners is important***. However, with the accuracy about 50% pilot simulation of PCDD/F transport and accumulation can be made by the “indicator congener” 2,3,4,7,8-PeCDF properties.

Simulations of long-range transport of selected POPs in the EMEP region show that ***from 30 to 80%*** of their annual emissions (depending on a pollutant in question) ***are transported outside the EMEP region. For substances with high outflow from the region evaluation of transport and accumulation on the hemispheric/global scale is reasonable***. Tentative calculations of POP long-range transport from European emission sources for 1990 were made for γ-HCH, PCBs and HCB by the hemispheric version of the MSCE-POP model. These calculations showed that:

Considered pollutants can reach remote regions such as Asia, the Arctic and North America.

Among the considered pollutants HCB has maximum ability to long-range transport.

In line with the evaluation of pollution models for POP are further developed. In particular, wet deposition scheme, parameterization of atmosphere/soil and atmosphere/sea exchange modules have been modified.

The assessment of POP contamination is made in close ***collaboration with national experts and subsidiary bodies to the Convention on Long-range Transboundary Air Pollution (CLRTAP)***: the expert group on POP assessment (Working Group on Strategies and Review) and Working Group on Effects.

The preparatory work for the ***intercomparison of POP multicompartment transport models*** has been started.

A detailed description of the MSC-E activities in 2002 can be found in a number of Technical Reports and Notes listed in Annex E and in Internet at EMEP (http://www.emep.int/) and MSC-E (http://www.msceast.org/) web-pages.

CONTENTS

INTRODUCTION

In view of persistent organic pollutants (POPs) physical-chemical properties (high lipophily, volatility and persistence) and comparatively low scavenging they can be transported and accumulated in the environment on the ***hemispheric and global*** scale. For the evaluation of POP environmental pollution ***multi-compartment approach*** to the assessment of POP transport and accumulation in environmental compartments such as air, soil, seawater, sediments and vegetation is under development.

Pollution of the environment by POPs is of interest for many international bodies: AMAP, CLRTAP, HELCOM, OECD, OSPAR, UNEP, WHO, WMO and others. To investigate and prevent global environmental pollution by POPs more than 100 countries signed Stockholm Convention on Persistent Organic Pollutants in 2001. In the framework of the Convention on Long-range Transboundary Air Pollution the Protocol on Persistent Organic Pollutants was signed by 36 countries in Arhus in 1998 (Denmark).

In accordance with the Protocol " In good time before each annual session of the Executive Body, EMEP shall provide information on the long-range transport and deposition of persistent organic pollutants" (Article 9). EMEP activity in this field is regulated by annual work-plan adopted by the CLRTAP Executive Body. Under EMEP two Centres CCC and MSC-E are responsible for POP monitoring and modelling activities, respectively.

The progress in POP monitoring/modelling assessment of environmental pollution achieved in 2002 is presented in this status report. A particular attention was paid to the ***assessment of depositions and concentrations*** in main environmental compartments, investigation of ***long-term trends*** of contamination in European countries from 1970 to 1999, evaluation of ***transboundary transport***, ***hemispheric transport*** from European emission sources, ***scientific evaluation*** of modelling results and ***cooperation*** with countries and organizations.

Transboundary transport is evaluated for B[a]P in 1999 on the basis of source-receptor approach in line with the assessment of contamination levels. Country-to-country matrices are calculated both for deposition and air concentrations. The latter is important since one of the main ways to human exposure is the respiratory tract and in some European countries limit values for mean annual B[a]P concentrations are set up.

PCDD/F contamination levels and long-term trends are calculated on the regional scale (EMEP region). In these calculations high contamination levels in the atmosphere are characteristic of the central and eastern parts of Europe. ***Soil concentrations may support contamination levels in other environmental compartments for several decades***. ***Sea currents play a noticeable role in PCDD/F long-range transport.***

Modelling POP long-range transport in the EMEP region showed that a ***considerable part of their annual emissions (from 30 to 80%) is transported outside the calculated domain***. Therefore, it may be expected that the influence of external sources to the contamination of the EMEP region will be essential. This shows that ***the assessment of POP long-range transport and accumulation should be performed on the hemispheric scale,*** at least for some species. In this context pilot calculations of transport from European sources for three pollutants (PCBs, γ-HCH and HCB) were performed on the hemispheric scale.

The detailed presentation of MSC-E activities in the field of POP contamination assessment can be found in a number of MSC-E Technical Reports and Notes (Annex E) and at EMEP web-page www.emep.int.

1. ASSESSMENT OF POP CONTAMINATION

The assessment of POP contamination both in the EMEP region and on the hemispheric level is performed on the basis of measurement/modelling approach. In this section we describe the availability of measurement and emission data on selected POPs in the EMEP region, main results of the evaluation of B[a]P transboundary transport and contamination levels in Europe, the investigation of PCDD/F contamination and long-terms trends in various environmental compartments, and present tentative calculations of the hemispheric transport of PCBs, γ-HCH and HCB from European sources.

1.1 Availability of measurement data

The availability of measurement data on POP deposition and concentrations in various environmental compartments is of a great importance for the evaluation of pollution levels in Europe. Measurements of POP concentration in air and precipitation at EMEP monitoring stations are co-ordinated by the Chemical Coordinating Centre (CCC).

There are 14 measurement sites (CZ3, BE4, DE1, DE9, DK31, FI96, IE2, LT15, IS91, NO39, NO42, NO99, SE2, SE3), which have reported POP data for at least one year and at least one compound. The locations of these sites are shown in Figure 1. As evident from the figure these stations are concentrated in the north-west of Europe except for site CZ3 located in Central Europe. There are no EMEP stations in the east and south of Europe.

The information on EMEP monitoring network for various POP is presented in Table 1 below. At present POP data from EMEP monitoring network relate to concentrations in the atmosphere and precipitation. Measurements in other environmental media (soil, seawater, and vegetation) obtained in the course of national campaigns are very limited.

The work on monitoring strategy with regard to modelling activities is ongoing. Important parts of this work are establishment of superstation network in European region and POP measurements of concentrations in other media than air.

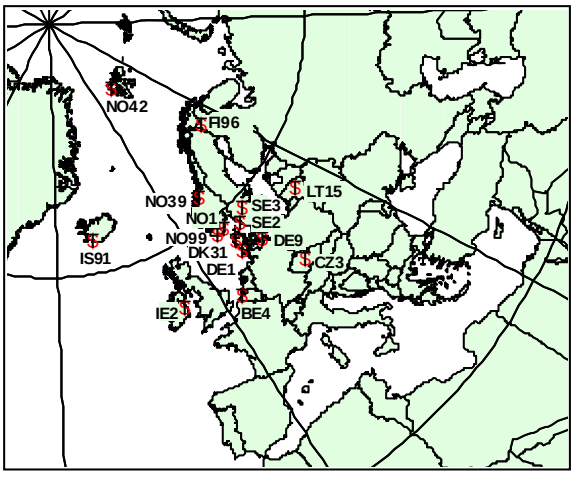


Figure 1. *EMEP measurement sites reporting data on POPs*

Table 1. *Measurement sites of EMEP monitoring network reported POP data for at least one year*

Compound	Type of measurements	Number of sites	EMEP codes of sites
PAHs (B[a]P)	air	5	CZ3***, FI96, LT15, NO42, SE2
	precipitation*	5	DE1, DE9, FI96, LT15, SE2
PCDD/Fs **	air	4	CZ3, DE9, SE2, SE3
	precipitation*	-	
PCBs	air	6	CZ3, DE9, FI96, IS91, NO42, SE2
	precipitation*	4	CZ3, DE1, DE9, IS91
HCHs (Lindane)	air	6	CZ3, FI96, IS91, NO42, NO99, SE2
	precipitation*	9	BE4, DE1, DE9, DK31, FI96, IE2, IS91, NO99, SE2
HCB	air	6	CZ3, IS91, NO1, NO39, NO42, NO99

* Some sites report deposition flux instead of concentrations in precipitation.
** Not reported by CCC.
*** Site CZ3 measures also POP concentrations in media other than atmosphere (soil, vegetation, sediments, surface waters).

The analytical laboratory intercomparison on POP measurements is continued. Preliminary results from Round 1 (analysis of standards) were promising, showing that most laboratories are able to analyse standards within ± 30%. More detailed information on monitoring activity is presented in MSC-E/CCC Technical Report 7/2002 [*Shatalov et al.*, 2002].

1.2 Emissions

The preparation of emission data for modelling is made on the basis of official emission data submitted to the UN ECE Secretariat by countries. At present there are essential gaps in official information on POP emissions and to fill these gaps emission expert estimates are used. However, the work on refinement of official emission inventories is ongoing and the situation with reporting official emission data is improving. In 2001 official information at least for one year was presented on PAH emissions by 24 countries and PCDD/F emissions – by 23 countries of EMEP region. Only a limited number of countries present information on four indicator PAH compounds listed in POP Protocol.

The simulation of PCDD/F long-range transport and accumulation for 1999 has been performed on the basis of official emission data complemented by expert estimates [*Pacyna et al.,* 1999]. Spatial distribution of emissions for 1999 used for modelling is shown in Figure 17.a. below.

Official data available for PAHs and PCDD/Fs are presented in Annex C.

At the same time, there is a lack of information needed for model evaluation of POPs transport and accumulation in the environment. In particular, data on spatial distribution, chemical composition, height distribution and seasonal variations of emissions are rather scarce. Besides, from MSC-E viewpoint, for the majority of POP official emission data are underestimated since not all source categories are included into national inventories.

Detailed description of emission data used for modelling can be found in MSC-E/CCC Technical Report 7/2002 [*Shatalov et al*., 2002].

1.3 Assessment in the EMEP region

Polycyclic Aromatic Hydrocarbons

This group of POPs contains a large number of individual compounds. Four of them: benzo[a]pyrene (B[a]P), benzo[b]fluoranthene (B[b]F), benzo[k]fluoranthene (B[k]F), and indeno[1,2,3-cd]pyrene (I[1,2,3-cd]P) are included into the POP Protocol (Annex III) as indicator compounds for the propose of emission inventories. The inclusion of these compounds to the list of priority pollutants for environment protection activities is conditioned by their high carcinogenicity, long-range transport ability and persistence in the environment.

The average concentration levels of four indicator compounds in main environmental compartments in Europe are given in Table 2.

Individual measurements can differ essentially from average figures. In particular, high levels of PAH concentrations in soil and vegetation have been obtained at the Czech site Kosetice (CZ3).

The analysis of measurement data shows that these compounds are widely spread over European territory. Details can be found in the MSC-E Technical Note 9/2002 [*Mantseva et al.,* 2002] where one can find also the characterization of PAH emission sources and the analysis of physical-chemical properties of the indicator compounds.

Based on a study of physical-chemical properties model parametrization for four indicator compounds is prepared. Below the results of model assessment for B[a]P are described; modelling the rest of indicator compounds is planned to be made in future.

Table 2. *Environmental levels of 4 indicator PAHs in various environmental media in "clean" European regions, average values*

PAH	Air ng/m^3	Precipitation ng/l	Fresh and sea waters		Soil ng/g	Vegetation ng/g
			Surface waters ng/l	Sediments ng/g		
B[a]P	0.37	4.6	13	17	15	36
B[b]F	1.0	8.6	5.1	28	26	13
B[k]F	0.4	3.8	1.3	21	8	7.8
I[1,2,3-cd]P	0.8	5.2	1.9	36	3	17

Benzo[a]pyrene

The main objectives of the assessment of B[a]P pollution at this stage are to evaluate:

- B[a]P pollution levels for European countries with the use of the refined model parametrization.
- B[a]P transboundary transport in terms of atmospheric concentrations and deposition values.

From the viewpoint of transboundary transport B[a]P atmospheric concentrations are of a particular importance since one of the main pathways of human exposure is the respiratory tract. Deposition values are important for the assessment of long-term accumulation of B[a]P in such media as soil and seawater (the analysis of B[a]P long-term trends of accumulation can be found in [*Shatalov et al.,* 2000]).

According to emission expert estimates about twofold emission reduction takes place in the period from 1970 to 1995 (Fig.2). Using the emission scenario (Fig. 3.a) based on available official data (Annex C) and expert estimates the evaluation of pollution level in European countries was performed. To illustrate the formation of these levels matrices of country-to-country concentrations and depositions were calculated. Calculations were done with spatial resolution 50x50 km^2 and meteorological data for 1999.

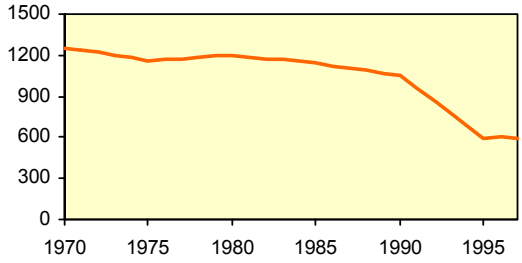


Figure 2. *European emission dynamics from 1970 to 1999, t/y*

Spatial distribution of contamination

Concentration fields in 1999. Calculations show that over vast regions of Poland, in some regions of Germany, the Czech Republic, Slovakia, Hungary, Yugoslavia and Georgia mean annual concentrations in the surface air are rather high (Fig. 3.b), more than 1 ng/m^3, exceeding the limit value set up in a number of European countries [*Ежегодник,* 1994; *Policy on* …, 1994, *Zurek et al*., 2000]. The maximum value of mean annual concentrations is not higher than 5 ng/m^3. It is of interest to consider maximum mean diurnal concentrations in the surface air in 1999.

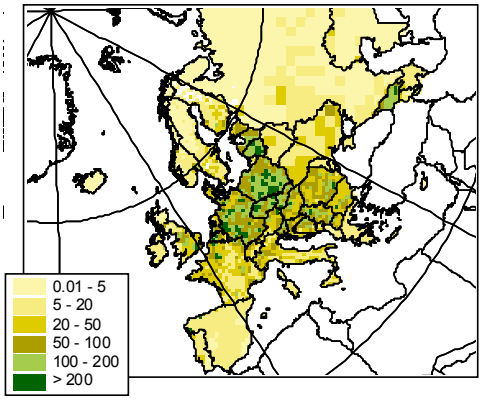


Figure 3.a. *Emission fields for B[a]P in 1999, g/km^2/y*

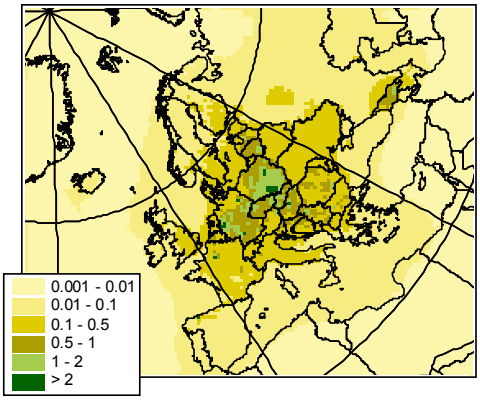


Figure 3.b. *Mean annual concentrations in the surface air for B[a]P in 1999, ng/m^3*

High mean diurnal concentrations (more than 1 ng/m^3) were obtained for the majority of countries in Central Europe (Fig. 4). In 1999 high diurnal values up to 2 - 20 ng/m^3 were obtained for Poland, Germany, the Czech Republic (Black Triangle), Lithuania and Latvia. These values are several times higher than mean annual ones.

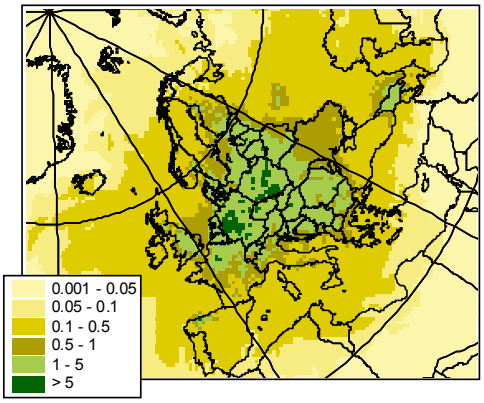


Figure 4. *B[a]P maximum mean diurnal concentrations in the surface air in* 1999, *ng/m^3*

They occur in the cold season when B[a]P concentrations are highest. It is clearly demonstrated by the plot of B[a]P seasonal concentration variations in 1999 (Fig.5). These concentration variations are caused by seasonal variations of emissions, deposition velocity and degradation rates [*Shatalov et al.*, 2001].

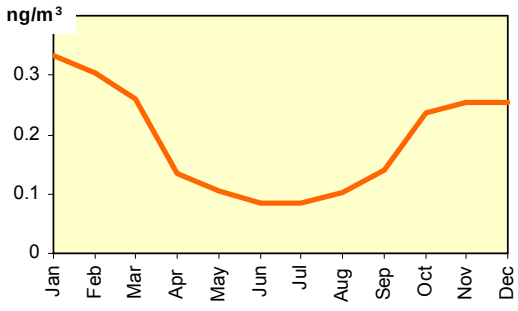


Figure 5. *B[a]P seasonal concentration variations in 1999, ng/m^3*

The exceedance of 1 ng/m^3 concentration level occurred more than 100 days a year over vast territory of Europe (Fig. 6).

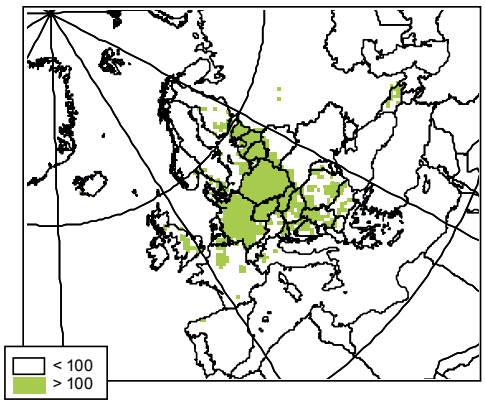


Figure 6. *Number of days with mean diurnal concentration higher than 1 ng/m^3 in 1999*

Deposition in 1999. Let us pass over to the consideration of B[a]P deposition spatial distribution over Europe.

In 1999 total deposition of B[a]P to the EMEP domain amounted to 184 tonnes. It is approximately half of annual emissions. The value of deposition fluxes over the continental part of the EMEP domain varies within 1 - 200 g/km^2/y (Fig. 7). Essential fluxes (100 - 200 g/km^2/y) are observed in regions with intensive emissions: Poland, the Czech Republic and Germany.

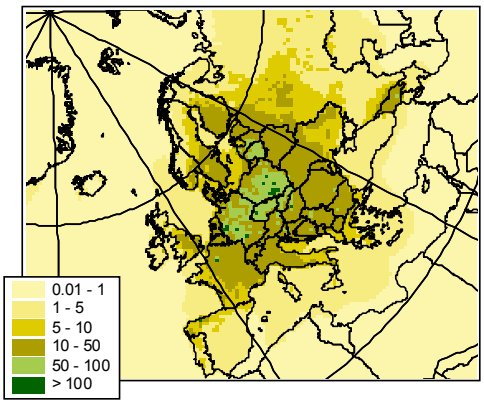


Figure 7. *B[a]P deposition field in 1999, g/km^2/y*

In view of updated emission values atmospheric concentrations and depositions differed from those obtained in the previous year [*Shatalov et al.*, 2001].

Transboundary transport

B[a]P pollution in European region is formed to a considerable extent due to B[a]P transboundary transport. Its evaluation was made on the base of country-to-country matrices. Transboundary transport contributes significantly both to air pollution (air concentrations) and deposition in the EMEP region. Details can be found in the Technical Report [*Shatalov et al.,* 2002] and in Internet http://www.emep.int/, http://www.msceast.org/.

Air concentrations. Calculations show that in 1999 noticeable contribution to air pollution due to transboundary transport takes place for Slovakia – 480 pg/m^3, the Czech Republic – 340 pg/m^3 and Hungary – 320 pg/m^3 (Fig. 8).

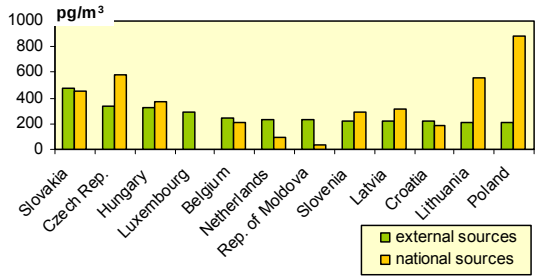


Figure 8. *The relationship of contributions from national and external sources to air concentrations in a number of European countries, pg/m^3*

Calculations for a number of countries (Belgium, Luxembourg, the Netherlands, Moldova, Slovakia and Croatia) indicate the prevalence of contributions from external emission sources over national ones.

Depositions. B[a]P depositions from the majority of European countries outside their own territories (export) are comparable with depositions to the country itself emphasizing once more the role of transboundary transport. For such countries as Germany, Poland and France (which are characterized by high emissions) export amounts to about 45% of total depositions caused by their national emissions. B[a]P highest depositions from external sources (import) are characteristic of Slovakia and the Czech Republic (63 and 48% of total deposition to these countries, respectively). It should be mentioned that for the majority of European countries import slightly exceeds depositions from internal sources except for the Czech Republic, Lithuania, Poland, Yugoslavia, Romania and Germany, i.e. countries with essential emissions.

Country-oriented information

The calculation results make it possible to analyse in detail B[a]P pollution and transboundary transport for each country. These results are exemplified below by transboundary transport evaluation for the UK.

Pollution from the UK sources. According to expert estimates, total UK emissions of B[a]P in 1999 makes up 12 tonnes per year. Spatial distribution of emissions in the UK is characterized by high emission values in the southern part of the country and low emissions in its northern part (Fig. 9).

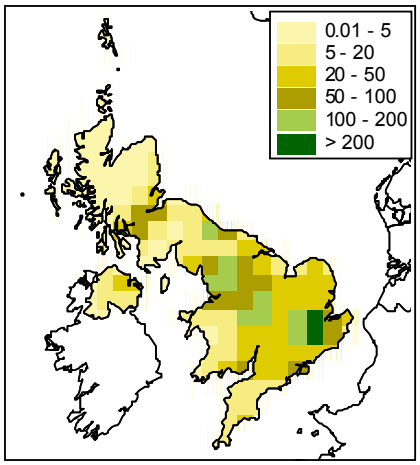


Figure 9. *B[a]P emission flux, g/km^2/y*

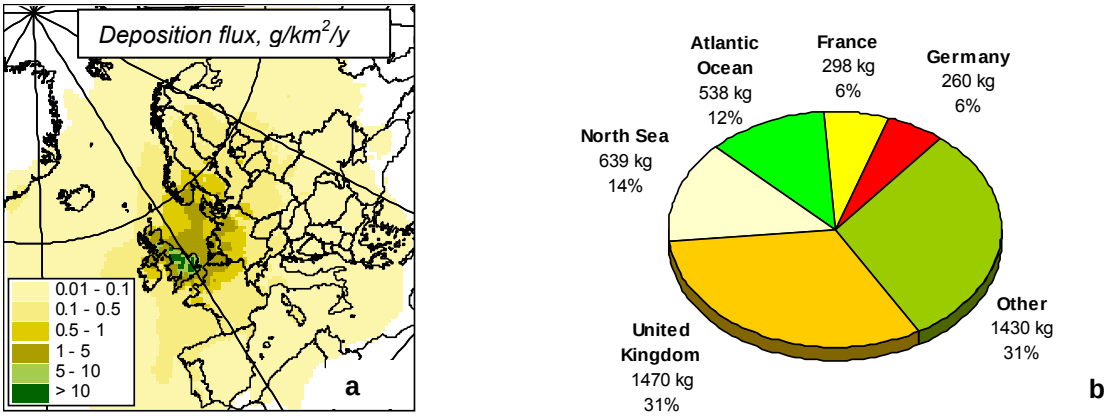


Figure 10. *B[a]P depositions from the UK emission sources to other European countries and regions in 1999*

The deposition field from the UK and the pie chart demonstrating the distribution of depositions from the UK emission sources between European countries and regions are shown in Figure 10. As seen from the map, the pollution from the UK is spread over neighbouring countries (especially France and Germany), the North Sea and the Atlantic Ocean. Total UK emissions (12 tonnes) is transported outside the EMEP region (4.7 tonnes), degrades (2.6 tonnes) and is deposited to European territory (4.7 tonnes). The distribution of this last part between main countries and regions is shown by the pie chart (Fig. 10.b).

Depositions from the UK sources may be considered in the context of their contribution to the contamination of other countries and regions. Fractions of the UK input to total depositions to different European countries and regions are shown in Figure 11.

As evident from the figure, the UK sources are responsible for a noticeable part of depositions to other European countries and regions. In particular, about 30% of total deposition to the North Sea is caused by the UK emission sources.

Similar results can be obtained for fractions of air concentrations in European countries and regions caused by the UK emission sources (Fig. 12). For example, the UK sources are responsible for about 15% of air concentrations in Ireland and about 30% of air concentrations over the North Sea.

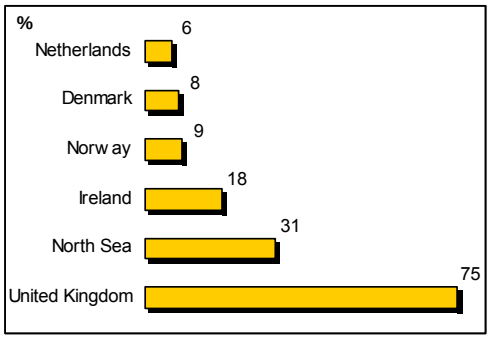


Figure 11. *Fractions of total B[a]P depositions to some European countries and regions caused by the UK sources in 1999, %*

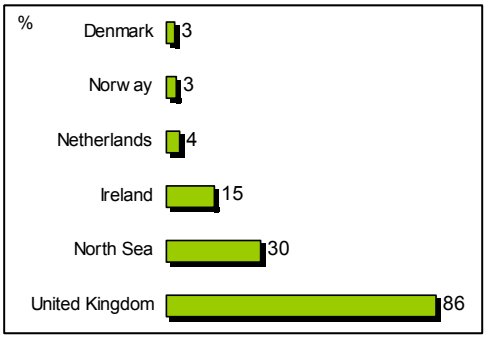


Figure 12. *Fractions of B[a]P concentrations in surface air layer for some European countries and regions caused by the UK sources in 1999, %*

Pollution of the UK. Spatial distribution of total deposition to the UK (both from external and internal sources) is shown in Figure 13.

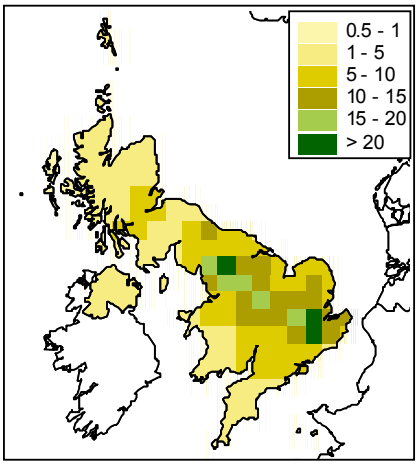


Figure 13. *B[a]P total deposition flux to the UK in 1999, g/km^2/y*

The highest depositions 29 g/km^2/y are in the southern part of the UK. In the same region essential B[a]P emission fluxes (380 g/km^2/y) take place. The lowest depositions are in the north of the UK (0.5 - 5 g/km^2/y). The mean value over the country amounts to 8.4 g/km^2/y.

The contribution of B[a]P tansboundary transport from European countries to the UK depositions is represented by a pie chart (Fig. 14).

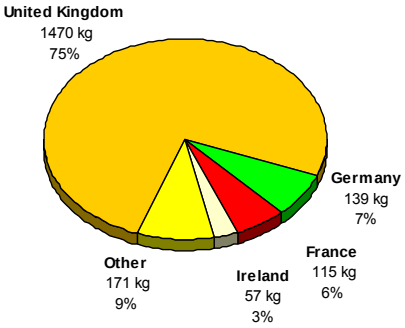


Figure 14. *Contributions of European countries to B[a]P depositions to the UK*

One can see that about 25% of total depositions to the UK are formed due to sources located outside the country.

Similar results are obtained for the formation of air pollution over the UK territory due to emission sources of different European countries. Concentration values caused by these sources are shown by a pie chart (Fig. 15).

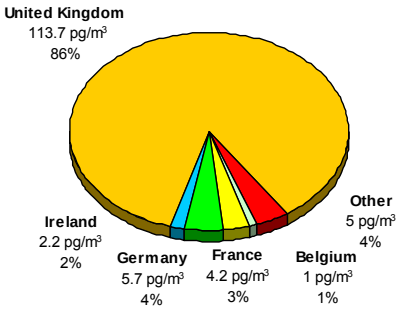


Figure 15. Contribution *of B[a]P external and internal emission sources to air concentrations in the UK, pg/m^3*

Model verification

B[a]P mean annual concentrations in air and precipitation and deposition fluxes were compared with measurement data. More than 75% of calculated concentrations in air are within a factor of 3 with respect to measurements, the rest of concentrations are within a factor of 6. On the average concentrations in precipitation and depositions are described by the model more precisely than air concentrations (within factors 4 and 5).

Model estimates of concentration levels and transboundary fluxes in European countries and a detailed description of the comparison of calculated against measured data can be found in Internet: www.msceast.org/countries/index.html.

Dioxins and furans (PCDD/Fs)

Here we present evaluation of long-term trends of PCDD/F contamination in different media, its spatial distribution in 1999 and media response to emission reduction based on simulation of PCDD/F transport for the period from 1970 to 1999. Preliminary investigation of PCDD/F transport and accumulation was made in [*Shatalov et al.,* 2001].

Investigations made on the previous stage together with available measurement data show that the main accumulating medium for PCDD/Fs is soil (according to calculations soil contains more than 75% of overall PCDD/F environmental toxicity). At the same time, soil concentrations obtained in [*Shatalov et al,* 2001] were strongly underestimated (about two orders of magnitude). Fractions of overall toxicity in seawater and vegetation are less valuable. In this context ***a particular attention has been paid to the evaluation of soil contamination***.

The model modification at this stage concerns the refinement of degradation rates in different environmental compartments and of atmosphere/soil exchange scheme. As a result of analysis of the main degradation processes carried out in [*Sinkkonen and Paasivirta*, 2002] the half-life of PCDD/Fs in soil about 60 years has been obtained. This value is at present used in the MSCE-POP transport model as well as in other modellers [*Beyer and Matthies*, 2001].

Accumulation of PCDD/F in the environmental media substantially depends on their congener composition. Main congeners of PCDD/F (8 congeners) determining about 75% of total PCDD/F toxicity in main environmental media were selected. At the present stage of investigation model parameterization for all these congeners is prepared. However, with accuracy about 40 – 60% properties of the indicator congener 2,3,4,7,8-PeCDF can be used for the assessment of PCDD/F total toxicity. Below we present calculations with the use of physical-chemical properties of the indicator congener. At the next stage it is planned to evaluate spatial distribution and contamination by all 8 selected PCDD/F congeners.

Long-term trends. Being transported from emission sources to different locations, PCDD/Fs are accumulated in such environmental compartments as soil, seawater and vegetation. Due to high accumulation capacities of soil and seawater and high persistence of PCDD/Fs in these media, accumulation process takes considerable time (decades). To take into account long-term accumulation, environmental contamination by PCDD/Fs in 1999 is assessed by simulations for sufficiently long time period (from 1970 to 1999). For this period available official emission data (Annex C) and expert estimates were used. Here we present calculated dynamics of concentrations in main environmental media (atmosphere, soil, seawater, vegetation) in comparison with emission dynamics for whole Europe from 1970 to 1999 (Fig. 16).

Soil dynamics for PCDD/Fs drastically differs from emission dynamics (Fig. 16.a). Namely, whereas PCDD/F emissions decrease about 5 times from 1980 to 1999, the decrease of soil content begins only with 10-year lag (from 1990) and is rather slow. It is conditioned by large half-life in soil (about 60 years according to model assumptions). Similar behaviour is characteristic of forest litter content, which can be in essence viewed as an upper soil layer: it decreases 1.5 times beginning with 1985 (Fig. 16.b).

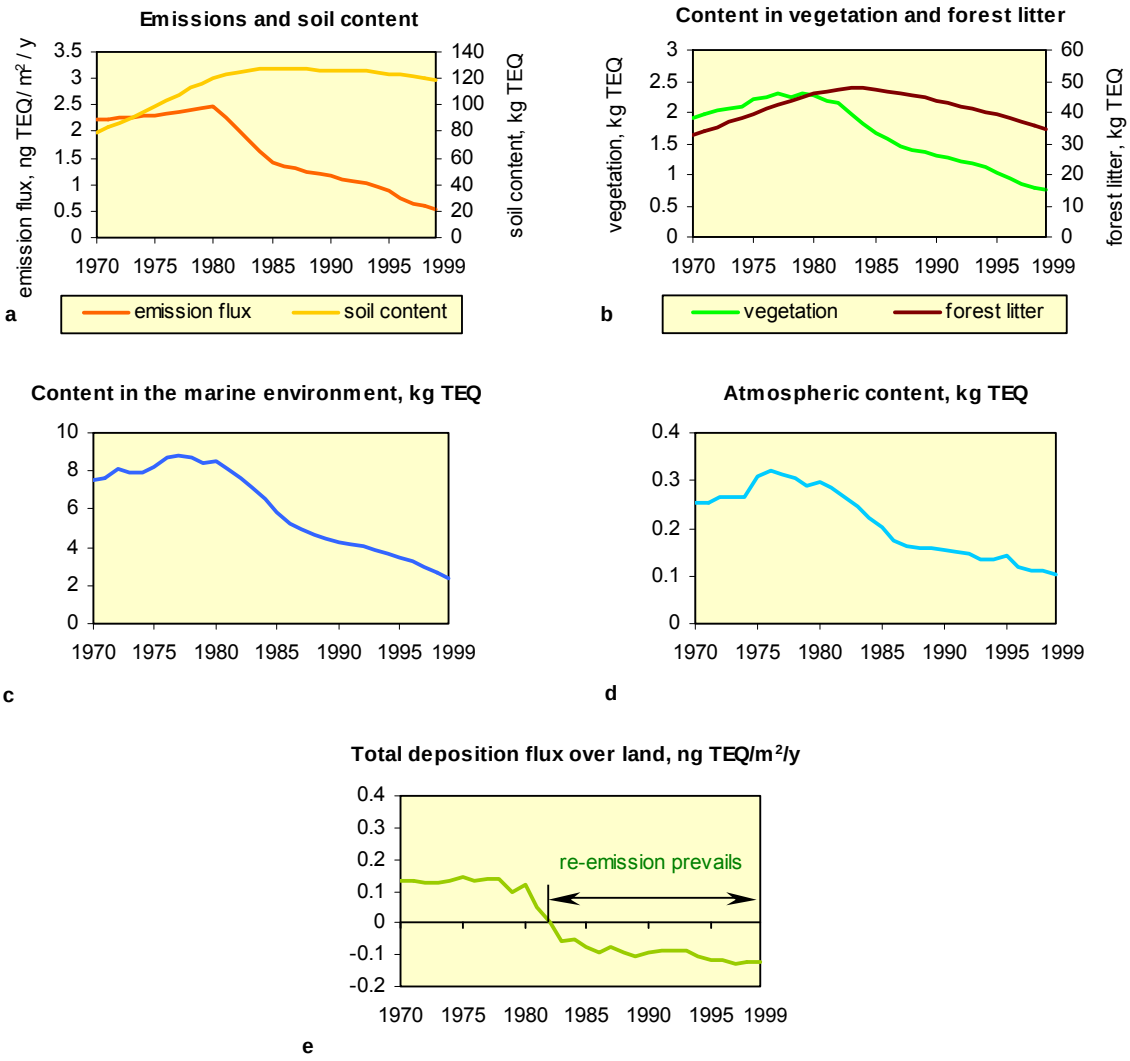


Figure 16. *PCDD/F European emission dynamics, medium contents and deposition over land for 1970 – 99*

Dynamics of content in other compartments follows emission dynamics though their reduction is less than that for emissions: 3 times in the atmosphere and vegetation and about 4 times in seawater. This can be partly explained by the influence of re-emission from soil (see Figure 16.e where negative values of deposition flux mean predominance of re-emission process). Calculations show that in the middle of the 80s due to emission reduction the re-emission flux (evaporation from soil to the atmosphere) becomes comparable with emissions. Re-emission slows down the decrease of concentrations in the atmosphere and, as a consequence, in seawater and vegetation.

Thus, ***the decrease of PCDD/F content in soil is much slower than that of emissions.*** Due to slow reduction of soil content ***the accumulations in this medium can support the overall environmental contamination for a long time (decades) even at full emission reduction (zero emission scenario)***. This will be demonstrated below where zero emission scenario is considered.

The above data describe European dynamics of contamination from 1970 to 1999. More detailed trend analysis is performed for each European country. The results can be found on the EMEP web-page www.emep.int.

Spatial distribution of contamination in 1999. On the basis of the assessment of long-term accumulation in the environment, spatial distributions of PCDD/F contamination were evaluated. Spatial distribution of air concentrations for 1999 in comparison with that of emissions is presented in Fig. 17. According to emission data used, average emission flux in Europe in 1999 is about 0.7 ng TEQ/m^2/y. Countries with high emission levels (more than 3 ng TEQ/m^2/y) are the Czech Republic, Belgium, Switzerland, Luxembourg and Slovakia. The comparison of spatial distribution of air contamination with that of emissions shows that regions with high air concentrations mainly correspond to regions with high emission levels though atmospheric contamination is spread much wider. In accordance to their physical-chemical properties PCDD/Fs are transported over rather long distances in atmosphere and about 60% of annual PCDD/F emissions are transported outside the EMEP region.

The average air concentration level in Europe is about 5 fg TEQ/m^3. Concentrations around 14 fg TEQ/m^3 and more are calculated for the Czech Republic, Switzerland, Belgium, Slovakia and Austria. In particular, relatively high concentration level in Austria is caused by transboundary transport since for this country emission density is less than the average over Europe.

Soil concentrations over Europe assessed as a result of their long-term accumulation is around 3 pg TEQ/g on the average. High soil concentrations (about 10 pg TEQ/g) are characteristic of Germany, Belgium, the Netherlands, Luxembourg and parts of the Czech Republic, France, Switzerland and the United Kingdom (Fig. 18). Contrary to atmospheric concentrations, areas with high soil concentrations do not strictly coincide with areas with high emission levels since soil concentrations are result of long-term accumulation together with long-range transport. Relatively high concentrations (from 1 to 5 pg TEQ/g) in some parts of Europe (e.g. the Scandinavian Peninsula) could be explained by the role of forests in scavenging of PCDD/F aerosol phase with subsequent removal to soil.

Compared with PCDD/F behaviour in soil, accumulation in seawater and vegetation is less investigated. At present the following preliminary estimates are obtained.

The average seawater concentration is about 13 fg TEQ/l with maximum of 100 fg TEQ/l (Fig. 19.a). Values of seawater concentrations above 10 fg TEQ/l are characteristic of regions located close to main emission sources (the Mediterranean, the North and the Black Seas).

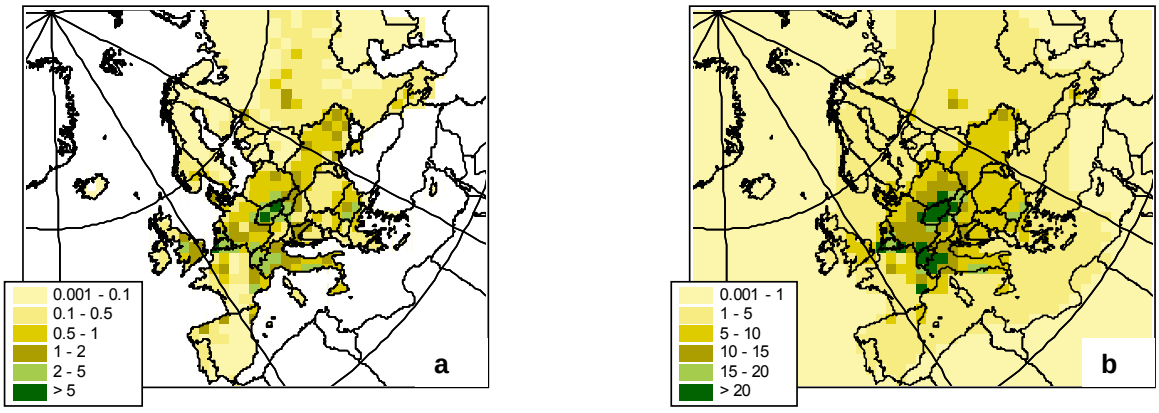


Figure 17. *Spatial distribution of emission flux, ng TEQ/m^2/y (a) and of surface air concentrations, fg TEQ/m^3 (b) for PCDD/F mixture in 1999*

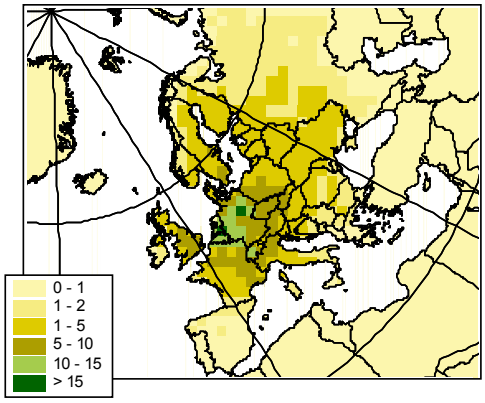


Figure 18. *PCDD/F concentrations in soil in 1999, pg TEQ/g*

Relatively high concentrations (1 to 5 fg TEQ/l) near the north boundary of the Scandinavian Peninsula can be explained by PCDD/F transport with sea currents from highly polluted regions. The calculated concentration in vegetation (Fig. 19.b) can reach up to 20 pg TEQ/g with average around 3 pg TEQ/g.

The comparison of calculations against measurements (see below) shows that PCDD/F measured and calculated levels for seawater and vegetation differ significantly from each other. However, since these media do not contribute much to total environmental toxicity, the above evaluation of air and soil concentrations looks more or less reasonable.

On the basis of the obtained spatial distribution of contamination in the main environmental compartments average pollution levels in European countries are calculated. These data can be found in Internet (the structure of Internet web-page for a country is described in Annex B) or in the EMEP/MSC-E Technical Note 7/2002 [*Shatalov et al.*, 2002]. An example of these data is presented in Table 3.

Table 3. Average contamination levels in different environmental compartments in some European countries, TEQ units

Country	Air fg/m^3	Soil pg/g	Vegetation* pg/g	Seawater* fg/l
Albania	4.65	1.16	1.15	18.4
Armenia	4.11	0.40	0.90	-
…	…	…	…	…
UK	4.66	5.24	3.45	11.6

* Concentrations in seawater and vegetation are less reliable and will be refined by future simulations, see the next section.

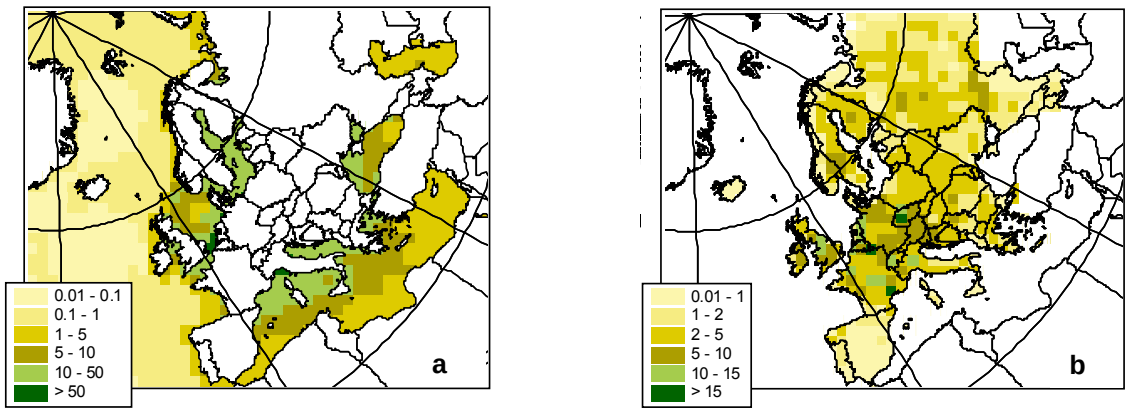


Figure 19. *Calculated PCDD/F concentrations in seawater, fg TEQ/l (a) and in vegetation, pg TEQ/g (b) in 1999*

Model verification. The comparison of the present calculations with available measurements showed that atmospheric concentrations agree with measurements within a factor of 6 and about 70% of calculated values are within a factor of three with respect to measurements. Calculated soil concentrations agree with measurements within a factor of 6 also and more than 50% of them are within a factor of 4. Thus ***modifications made for the description of PCDD/F behaviour in soil improved the agreement between measured and modelled concentrations in this medium***. Concentrations in seawater and vegetation are mainly within an order of magnitude as compared to measurements. To refine the agreement of calculated and measured concentrations in these media additional investigations are planned.

Media response to emission reduction. After investigation of long-term trends for 1970 to 1999 and contamination levels for 1999 an attempt was made to evaluate the media response to emission reduction ***under the assumption of full emission cessation*** (zero emission scenario) for the period from 2000 to 2010. The initial medium concentrations were taken from the above calculations for 1999.

Calculations show that even at zero emission scenario total PCDD/F toxicity *Q* in the whole environment decreases very slowly (Fig. 20).

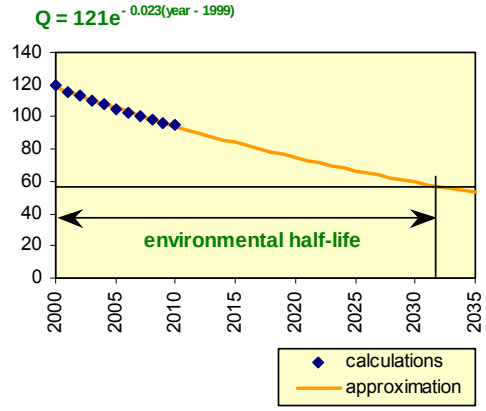


Figure 20. *Dynamics of total environmental PCDD/F toxicity Q for 2000 – 10 under the assumption of full emission cessation, kg TEQ*

Exponential approximation (shown on the same plot) gave the overall environmental half-life of PCDD/F to be about 30 years. This value of environmental half-life under zero emission scenario provides the most optimistic estimate of PCDD/F clearance time of the environment. The main result of the above investigations is that ***accumulations of dioxins/furans in soil can support the environmental contamination for decades***.

1.4 Assessment on the hemispheric scale

Calculations of long-range transport of selected POPs in the EMEP region show that from 30 to 80% of annual emissions are transported outside the EMEP region. Therefore, emission sources located outside the EMEP region may affect European contamination. Thus, the assessment of European pollution by some POPs is reasonable to be made at the hemispheric scale.

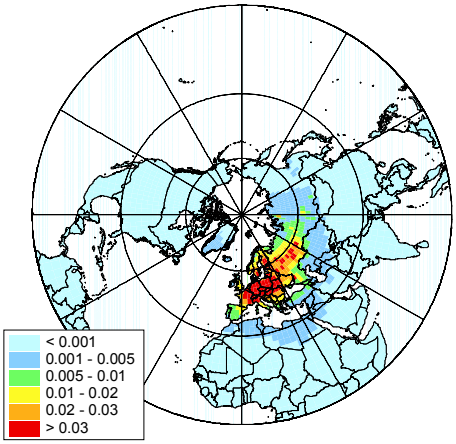
The first version of hemispheric MSCE-POP model [*Malanichev et al.*, 2002] is a multicompartment model with Eulerian type of the advection scheme and spatial resolution 2.5°x2.5° (Annex D).

Hemispherical model is being developed with the financial support of WMO and AMAP. Pilot results on the pollution assessment for 1990 on the hemispheric scale are presented for γ-HCH, PCBs and HCB below. These results should be considered as a demonstration of operability of the current model version.

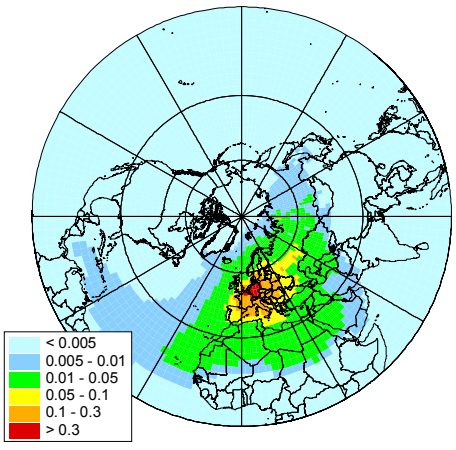
Polychlorinated biphenyls (PCBs). Modelling of PCB long-range transport for 1990 was made on the basis of a combination of two sets of PCB emission data. It includes expert estimates of European PCB emission sources for 1990 obtained from [*Pacyna et al.,* 1999] and expert estimates of PCB emission sources in Russia [*AMAP Report 2000:3*, 2000].

For modelling of the whole PCB's mixture transport physical-chemical properties of PCB-153 were used.

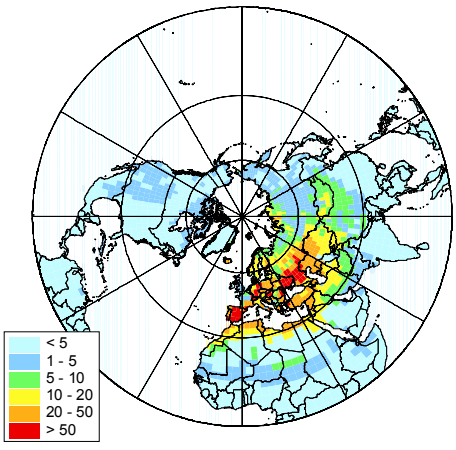
Spatial distribution of PCB concentration in the surface air obtained by the MSCE-POP model is presented in Figure 21.a. Spatial distributions of mean annual PCB concentrations in soil and vegetation are shown in Figures 21.b and 21.c, respectively.



b - concentrations in soil, ng/g



a - concentrations in surface air, ng/m^3



c - concentrations in vegetation, ng/g

Figure 21. *Spatial distribution of annual PCB contamination in main environmental compartments in 1990*

From these figures one can see that PCBs from considered sources are transported by the air over long distances. These pollutants are able to reach remote regions such as Asia, the Arctic and North America.

Contamination of vegetation corresponds to the location of main emission sources and correlates well with vegetation density. Soil concentrations are underestimated. For accurate evaluation of contamination in this compartment long-term calculations should be made [*Shatalov et al.,* 2000].

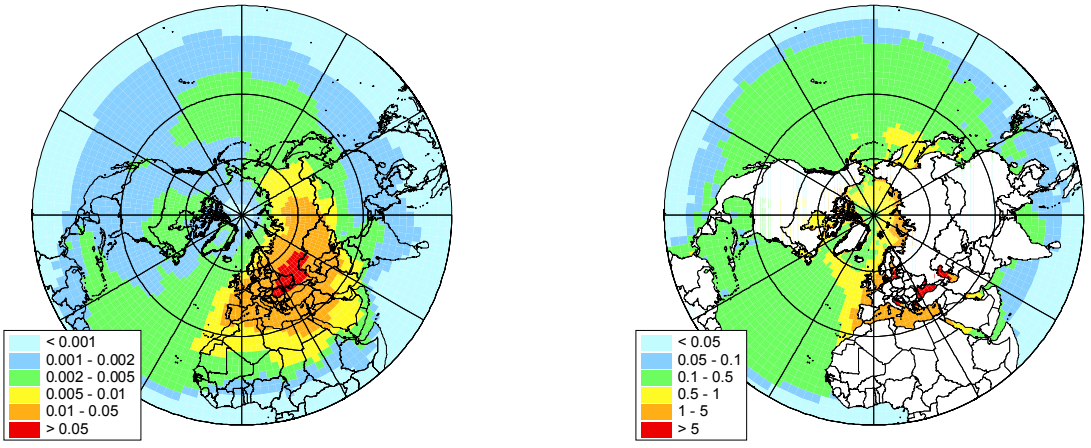
Tentative comparison of calculated and measured air contamination levels *for PCB-153* shows that calculated values satisfactory agree with measured values. Thus measured levels of air concentrations in Europe in 1990 - 98 years range within 0.008 - 0.046 ng/m^3, whereas calculated values range within 0.002-0.016 ng/m^3.

Hexachlorobenzene (HCB). As emission data expert estimates of HCB emissions from European sources in 1990 made by [*Pacyna et al.,* 1999] were used. Model parameterization used for modelling is described in the EMEP report [*Shatalov et al.,* 2001]. As it was shown in [*Shatalov et al.,* 2001] the marine environment is most likely the main accumulator of HCB. For this pollutant the sea model block describing HCB marine transport and atmosphere/sea exchange process is tested. Thus we present here maps of spatial distribution of HCB in the atmosphere and seawater (Fig. 22) obtained by simulations for 1990.

According to simulation results, HCB from European sources can reach such remote regions as Asia, Africa, the Arctic and America (Fig. 22.a). In comparison with maximum European concentrations (about 0.08 ng/m^3) concentrations in Asia and Northern Africa induced by European sources are 10 times lower. The comparison of these results with those for PCBs and γ-HCH (see below) shows that HCB has much higher potential for long-range transport than these pollutants.

The analysis of HCB spatial distribution in seawater (Fig. 22.b) shows high enough concentration levels in remote areas in the Atlantic and the Pacific Oceans. Relatively high HCB water concentrations near the northern boundaries of the Scandinavian Peninsula pointed out the role of marine transport of this pollutant.

It should be taken into account that simulations for longer periods can enlarge calculated marine concentrations due to HCB accumulation in seawater.



a - concentrations in air, ng/m^3

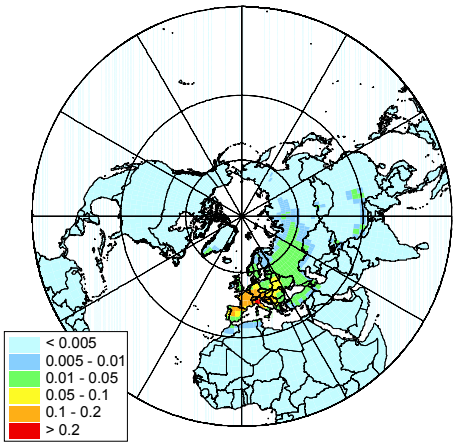
b – concentrations in seawater, pg/l

Figure 22. *HCB concentrations in the surface atmospheric layer and seawater for 1990*

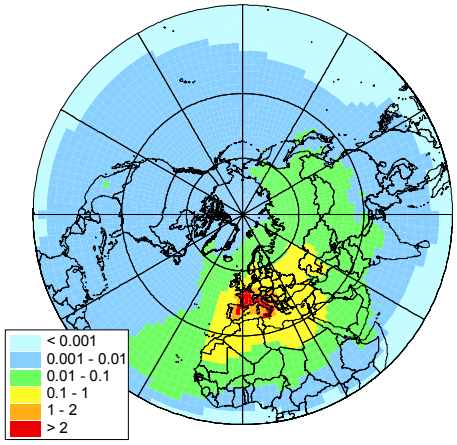
Tentative comparison of calculated and measured air contamination levels for HCB shows that calculated values are in a reasonable agreement with measured values. Thus measured levels of air concentrations in Europe in 1980 - 98 range within 0.002 - 0.21 ng/m^3, whereas calculated values range within 0.005 - 0.08 ng/m^3.

Hexachlorocyclohexane (γ–HCH). Emission sources from Europe according to [*Pacyna et al.*, 1999] were taken into account in calculations. γ-HCH calculated spatial distributions in the main environmental media (the atmosphere, soil and vegetation) are shown in Figure 23.

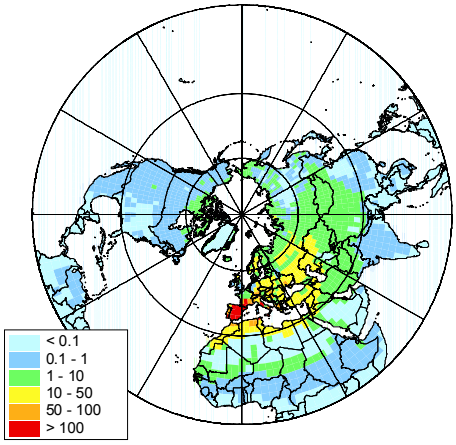
It is seen that during one-year period γ-HCH can be transported from Europe to rather vast region of the Northern Hemisphere including the Arctic, Asia region, and some parts of North America. It should be noted, that concentrations obtained as a result of calculations for long enough period will be different from that obtained for one year. Tentative comparison of calculated and measured air contamination levels shows that calculated values are more than two times higher than measured levels for most of EMEP measurement stations.



b - soil concentrations, ng/g



a - air concentrations, ng/m^3



c - concentrations in vegetation, ng/g

Figure 23. *Spatial distribution of γ-HCH contamination in main environmental compartments in 1990*

Conclusive remarks

Pilot calculations demonstrate that the MSCE-POP hemispherical model produces reasonable results of atmospheric long-range transport of selected POPs in comparison with available measurements. At the next stage more efforts will be made to improve the description of:

- POP accumulation in soil and vegetation;
- Sea current transport, redistribution of pollutants between different phases and sedimentation in the marine environment.
- Snow scavenging and the influence of sea ice cover.

More detailed information on POP hemispheric modelling can be found in the MSC-E Technical Report 8/2002 [*Malanichev et al.*, 2002].

2. SCIENTIFIC EVALUATION

In the recent years the MSC-E results on model evaluation of POP environmental pollution were presented for examination and evaluation on a number of international meetings:

- 6th SECOTOX World Congress and 6th European Conference on Ecotoxicology and Environmental Safety, Kraków, Poland, August 2001
- MEPOP/NMR/AMAP Workshop on Mercury and POPs, Roskilde, Denmark, September 2001
- SETAC Europe, Copenhagen, Denmark, September 2001
- OECD/UNEP Workshop on Multimedia Models, Ottawa, Canada, October 2001

Model assessment of the environmental pollution, exchange processes between environmental compartments, and the comparison of modelling results against measurements were discussed at these meetings.

The results of model development and model evaluation of POP contamination on regional and hemispheric scales were published in a number of papers, reports, and technical notes (see Annex E).

Recently the results of the assessment of POP long-range transport and accumulation in the environment were reported at the 3d Meeting of the EMEP Task Force on Measurements and Modelling (TFMM), Geneva, March 2002. TFMM discussed in depth the results of the work done in the field of POP measurements and modelling and approved them. Among the priority direction of future EMEP activities TFMM noted:

- Further development of hemispheric approach to the assessment of POP long-range transport and accumulation in media.
- Elaboration of measurement/modelling approach to the assessment of POP behaviour in the environment.
- POP model intercomparison study.
- Contributions to the work on evaluation of new substances and risk assessment.

3. CO-OPERATION

Evaluation of POP contamination is made in close co-operation with national experts and international programmes and, in particular, it includes:

- Co-operation with subsidiary bodies of the Convention:
  - Expert group on POP assessment (WG on Strategies). In the framework of this co-operation proposals on model evaluation of new substances and substances under re-assessment were prepared and submitted to the expert group by MSC-E.
  - Task Force on Health Aspects (WG on Effects). MSC-E has made a contribution to the TF report on health risks from persistent organic pollutants due to long-range transboundary air pollution.
  - Task Force on Emission Inventories and Projections on improvement of POP emission inventories (Joint MSC-E/TFEIP Workshop on emissions).
- Co-operation with countries:
  - Intercomparison study of POP multicompartment models. The work on model intercomparison is performed in collaboration with national experts involved in modelling activities. MSC-E proposals for the intercomparison program has been sent to the EMEP countries and considered at 3^{d} TFMM meeting (March 2002). Representatives of the following countries: Canada, the Czech Republic, Germany, Lithuania, Switzerland, the UK, the USA and expressed their willingness to take part in the POP model intercomparison study.
  - Joint interpretation and reporting of modelling and measurement results together with national experts from the Czech Republic, Lithuania, Germany and the United Kingdom.
- Participation in international activities:
  - AMAP assessment report;
  - UNEP/GEF Project “Regionally Based Assessment of Persistent Toxic Substances”, Regions III (Europe), IV (Mediterranean), VII (Central and North-East Asia);
  - RAIPON/AMAP/GEF Project "Persistent Toxic Substances (PTS), Food security and Indigenous Peoples of the Russian North";
  - assessment of POP contamination of regional seas in the framework of HELCOM.

In the framework of these activities MSC-E provides countries and international bodies with the information on model assessment of POP contamination spatial distribution both on regional and hemispheric levels, long-term trends of POP contamination of environmental compartments, evaluation of media responses to emission reductions, etc. Such co-operation and information exchange is mutually beneficial and leads to better understanding of POP transport on European and hemispheric levels.

4. FURTHER ACTIVITIES

In accordance with the EMEP Task Force on Measurements and Modelling recommendations and Strategy for EMEP 2000 – 2009 hemispheric modelling, contributions to risk assessment and POP model intercomparison are recommended for future activities. Below we present more detailed list of proposed activities in the field of POP assessment.

Assessment of POP contamination:

- Hemispheric modelling of contamination of environmental media and transcontinental transport of HCB, PCBs and γ-HCH.
- Assessment of transboundary transport, contamination of environmental media and evaluation of long-term trends for selected PAHs (B[a]P, B[b]F, B[k]F, I[1,2,3-cd]P).
- Assessment of long-range transport, contamination of environmental media and evaluation of long-term trends for PCDD/Fs (8 congeners).

Model development:

- Further development of hemispheric/global version of the multicompartment MSCE-POP model (2.5°x2.5° and 1°x1° resolution) taking into account transport by sea currents and redistribution between environmental compartments (the atmosphere, soil, seawater, and vegetation).
- Developing of source-receptor approach for pollutants with essential fraction of the gaseous phase on the example of PCBs, taking into account pollutant quantities earlier accumulated in environmental compartments (soil, seawater).
- Modification of the air/soil exchange block (refinement of redistribution of POPs between air, soil solute and organic matter in soil and transport over the soil profile with dissolved organics).
- Modification of air/sea exchange block taking into account transport by sea currents, redistribution between different phases, sedimentation process and influence of ice cover.
- Refinement of air/vegetation exchange parameters (including degradation rates).
- Improvement of parameterizations for selected POPs.
- Widening of the list of modelled POPs (PAHs: B[k]F, B[b]F, I[1,2,3-cd]P).

Intercomparison study of POP models:

Preliminary Stage. Review of process description and parameterization of models.

Stage I. Process description and parameterization.

Stage II. Calculated mass redistribution between environmental compartments.

Stage III. Calculated and measured concentrations in various environmental compartments.

Stage IV. Model applicability to the evaluation of overall environmental persistence and long-range transport potential for new substances.

Co-operation with subsidiary bodies:

- Support of the expert group on POP assessment in its work on new substances and substances under re-assessment. Collection and analysis of physical-chemical data, evaluation of long-range transport potential and environmental persistence for some substances in accordance with the request of expert group on POPs.

- Contributions to the work on elaborating effect-based approach to POPs (risk assessment): the identification of hot spots of environmental pollution and evaluation of media response to emission reduction (clearance rates);

- Co-operation with TFEIP on the improvement of POP emission data quality.

Co-operation with national experts and international organizations/projects:

- Co-operation with national experts from the Czech Republic, Germany, Lithuania, the UK, etc. in the field of POP contamination assessment.

- Co-operation with AMAP, HELCOM, OECD, UNEP, WMO, WHO and other organizations/programs in the field of assessment of POP environmental contamination and health effects.

CONCLUSIONS

The following results are obtained on the basis of long-term modelling of B[a]P and PCDD/F transport and accumulation and of hemispheric transport modelling of PCBs, γ-HCH and HCB from European emission sources:

- From 30 to 80% of annual emission is transported outside the EMEP region depending on a pollutant in question. Tentative calculations made for γ-HCH, PCBs and HCB for 1990 for the Northern Hemisphere with European emissions showed the ability of these POPs to reach such remote regions as Asia, the Arctic, and North America. Among the considered pollutants HCB possesses the largest ability to the long-range transport.

- The values of annual mean air concentrations of B[a]P in Europe are mostly within the range of 0.1 – 1 ng/m$^{3.}$ They reach higher values (1 – 5 ng/m^3) in some areas in Central and Eastern Europe. The exceedance of maximum diurnal concentrations over the value of 1 ng/m^3 takes place for more than 100 days per year for a considerable part of Europe. High B[a]P deposition fluxes (100 - 200 g/km^2/y) are characteristic of the central and eastern Europe. The analysis of B[a]P transboundary fluxes on the basis of available official emission data and expert estimates showed that main exporters for B[a]P are Germany, Poland and France. Maximum deposition fluxes due to transboundary transport are characteristic of Slovakia, the Czech Republic and Luxembourg.

- About 80% of overall PCDD/F toxicity in the environment is accumulated in soil. High contamination levels for PCDD/Fs (over 5 fg TEQ/m^3) are characteristic of the central an eastern parts of Europe. Relatively high soil concentrations (up to 5 pg TEQ/g) are calculated for some parts of the Scandinavian Peninsula. Assessment of long-term trends of PCDD/F contamination showed that the accumulation in soil could support the environmental contamination by these pollutants for decades.

- To improve the quality of assessment of environmental pollution by dioxins/furans modelling of the main 8 PCDD/F congeners is reasonable.

- Intercomparison study of different model types is very important for better understanding of POP behaviour in different environmental compartments and validation of multicompartment POP models.

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Annex A

FULFILMENT OF THE EMEP WORK-PLAN FOR 2002

EMEP work-plan elements in 2002

Persistent organic pollutants (POPs)

Description/objectives: Improve the monitoring and modelling data on concentrations, depositions and transboundary fluxes of selected POPs. Study further physico-chemical properties of POPs in different environmental compartments, taking into account their transport within the EMEP region and on the hemispheric/global scale. Further develop POPs emission data. Support preparatory work for the review of the Protocol on POPs.

Main activities and time schedule:

(a) MSC-E will report to the EMEP Steering Body in 2002 on: an assessment of transboundary transport of benzo[a]pyrene (BaP) (deposition and concentration fields and country-to-country matrix) for 2000; an evaluation of transport and accumulation of PCDD/Fs and HCB in various compartments; first results of the calculation of PCB regional and hemispheric transport (including to the Arctic) and estimation of its accumulation in different environmental compartments; an assessment of long-range transport of selected POPs to regional seas. It will support the ad hoc expert group on POPs and its national experts in their work on new substances and contribute to work to develop an effects based approach under the Working Group on Effects;

(b) MSC-E will further develop its models by: modifying the modelled behaviour in soil; modifying modelled air/sea exchange; refining degradation rates in vegetation and litter in view of vegetation types and climatic conditions; improving the gas/particulate partitioning description and the parameterization of aerosol deposition; refining the physico-chemical properties of PAHs, γ-HCH, PCDD/Fs and HCB; modifying the hemispheric version of the POP multicompartment model for PCB and γ-HCH transport. It will initiate preparations for model intercomparisons;

(d) CCC, MSC-E and the Task Force on Emission Inventories and Projections, in consultation with the parties will improve the POPs emission data quality. They will adjust European emission inventories for POPs to the modelling requirements. CCC will develop profiles of chemical species of selected the POPs and collate information on the height of major point sources;

(e) The Task Force on Measurements and modelling will review the monitoring and modelling work of EMEP on POPs. CCC and MSC-E will provide a summary report to the Task Force on their work related to POPs.

Fulfilment of the EMEP work-plan for 2002 is presented in Tables A1, A.2 below.

Progress in model assessment of POP contamination in 2002

Table A.1. EMEP region

Pollutant	Model development	Simulations	Assessment of the environmental pollution	Comparison with measurement data
PAHs	1. Examination of physical-chemical properties and available measurement data for B[a]P, B[b]F, B[k]F, I[1,2,3-cd]P. 2. Refinement of wet deposition parameterization. 3. Assessment of inflow to the EMEP region.	1. Calculation of "country-to-country" matrices for B[a]P for 1999. 2. Additional B[a]P simulation for 1996-1999 (50x50km^2) for comparison with measurements.	1. Source-receptor analysis for B[a]P. 2. Assessment of spatial distribution of B[a]P contamination in environmental compartments	Comparison of B[a]P concentration in air and precipitation and deposition fluxes for 1996-1999
PCDD/Fs	1. Examination of physical-chemical properties of 8 priority congeners. 2. Refinement of process description for atmosphere/soil exchange	1. Simulation for 8 congeners and their mixture for the period 1970 – 1998 using emission expert estimates. 2. Simulation for PCDD/F mixture for 1970 – 1999 using available official emission data and expert estimates	1. Tentative assessment of PCDD/F toxicity spatial distribution for 1999. 2. Examination of long-term trends of PCDD/F contamination in different media. 3. Evaluation of media response to emission reductions for 2000 – 2010. 4. Evaluation of congener composition of PCDD/F toxicity in environmental media.	1. Comparison of calculated and measured congener composition of PCDD/F toxicity in atmosphere, soil and vegetation. 2. Comparison of calculated and measured PCDD/F concentrations in atmosphere, soil, seawater and vegetation, and deposition fluxes.

Table A.2. Northern Hemisphere

Pollutant	Model development	Simulations	Assessment of the environmental pollution	Comparison with measurement data
PCBs	Development of hemispheric version of MSCE-POP multicompartment model, including transport of pollutants with sea currents.	Simulation of hemispheric PCB transport for 1990 with European and Russian emission sources (expert estimates).	Preliminary evaluation of contamination in the Northern Hemisphere from European and Russian emission sources.	Tentative comparison of measured and calculated pollution levels in Europe.
γ-HCH **HCB**	Development of hemispheric version of MSCE-POP multicompartment model, including transport of pollutants with sea currents.	Simulation of hemispheric γ-HCH transport for 1990 with European emission sources (expert estimates).	Preliminary evaluation of contamination in the Northern Hemisphere from European emission sources.	Tentative comparison of measured and calculated pollution levels in Europe.

Refinement of the air/vegetation exchange scheme (redistribution of pollutant amount deposited to a forest between vegetation and soil) were performed for all the pollutants under consideration. Investigations of degradation rates in vegetation and forest litter is planned for the next year.

Annex B

THE STRUCTURE OF COUNTRY-ORIENTED INFORMATION ON POPs IN Internet (http://www.emep.int/, http://www.msceast.org/)

Emissions in 1998 (1999)

The calculations for 1970-1999 have been carried out on the basis of official emission data and expert estimates adapted from POPCYCLING-Baltic project [*Pacyna et al.,* 1999]. Total emissions of the country as well as links to the maps of spatial distributions of emissions for 1998 (HCB, PCBs) and 1999 (PCDD/Fs, B[a]P) used for modelling are presented.

POPs	Emission total	Map
PCDD/Fs	value	link to map
B[a]P	value	link to map
HCB	value	link to map
PCBs	value	link to map

Mean annual concentrations in main environmental compartments

Calculated concentrations in various media including the atmosphere (means over the country, minimum and maximum values in the country) as well as links to the corresponding maps of spatial distributions are presented in the table.

POP	Mean	Min	Max	Map
Concentrations in air, ng/m^3 (for PCDDs – fg/m^3 TEQ)				
PCDD/Fs	value	value	value	link to map
HCB	value	value	value	link to map
PCBs	value	value	value	link to map
B[a]P	value	value	value	link to map
Concentrations in soil, ng/g d.w. (for PCDDs – fg/g d.w. TEQ)				
PCDD/Fs	value	value	value	link to map
HCB	value	value	value	link to map
PCBs	value	value	value	link to map
Concentrations in vegetation, ng/g d.w. (for PCDDs – fg/g d.w. TEQ)				
PCDD/Fs	value	value	value	link to map
HCB	value	value	value	-
PCBs	value	value	value	link to map

Since according to the modelling results the content of HCB is less then 1%, the corresponding map is not presented.

Trends in emissions and mean annual concentrations in main environmental compartments for 1970 - 99

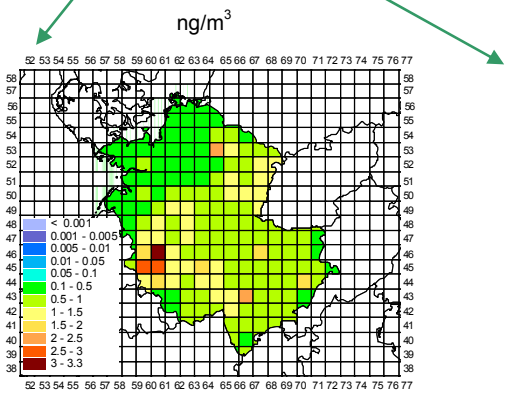
Trends in air, soil and vegetation concentrations of selected POPs, as well as trends in emission fluxes over the country are introduced.

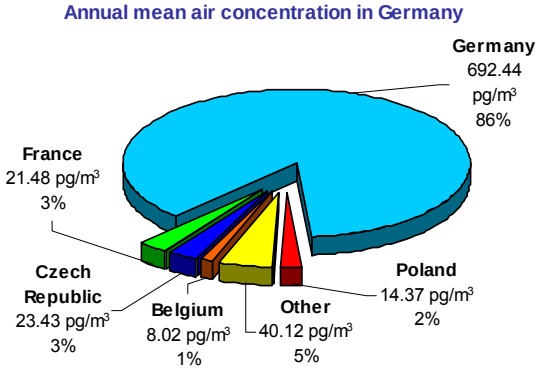
POPs	Air	Soil	Vegetation	Emission flux
PCCD/Fs	link to chart	link to chart	link to chart	link to chart
HCB	link to chart	link to chart	link to chart	link to chart
PCBs	link to chart	link to chart	link to chart	link to chart

Transboundary depositions fluxes and air concentrations of B[a]P in 1999

Contributions of European countries to annual mean air concentrations, as well as for deposition fluxes of B[a]P averaged over the country are summarized in the table presented below.

Annual mean concentrations	Deposition fluxes to the country	Deposition fluxes from the country
link to map link to pie chart	link to map link to pie chart	link to map link to pie chart





Comparison of modelling results with measurements

The comparison of modelling results with measurements obtained from EMEP monitoring network, in the course of national measurement programs and campaigns and from personal contacts with national experts (if available).

Location	Year	Measured		Calculated		Meas/ Calc	Source of measurement data
		Range	Average	Range	Average		
Country, (station)	1989-99	value	value	value	value	value	reference

Annex C

OFFICIAL EMISSION DATA USED FOR MODELLING

Table C.1. Official PAHs emission data, t/y

Country	UN ECE reported official emission data									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Austria	547	505	483	496	477	521	515	481	468	460
Belgium	354 [a]			294 [a]	235	274	184	187	187	190
Bulgaria	677					443	410	364	384	286
Croatia	11						9.3	9.2	8.6	7.9
Czech Republic	752	747	1131	1115	951	1357	971	657	657	557
Denmark [b]					10	10	11	11	10	11
Estonia	0.308	0.290	0.172	0.182	0.183	0.188	0.191	0.197	0.213	
Finland	16	13	13	13	17	17	17	16	16	17
France	2054	2467	2308	2282	1943	1971	2109	1886	1927	1896
Germany [c]	420				396					
Hungary [c]	132	122	87	81	72	68	63	60	54	55
Lithuania [b]								71	53	44
Luxembourg					1.1	0.6	0.7	0.4	0.3	0
Netherlands [c]	172		142		139	128	109	107	73	73
Norway [b]	15	15	14	15	15	15	15	15	15	14
Poland [b]	163	178	176	170	236	242	230	201	181	181
Republic of Moldova	6.2	4.9	4	3.3	3.1	4.3	3.6	5.1	4.8	4.4
Russian Federation [d]	18	17	16	15	15	15	15	15	15	15
Slovakia	42					19		19	16	17
Slovenia	24				18	17	17	19	18	18
Spain	301	307	284	288	281	233	252			
Sweden	182		153			153				
Ukraine								2.9	0.77	
United Kingdom	243	230	209	159	149	122	67	55	49	44

[a] - Referring to Flanders only.
[b] - Sum of 4 indicator PAHs.
[c] - 6 Borneff PAHs.
[d] - Benzo[a]pyrene only.

Table C.2. Official emission data on 4 indicator PAHs, t/y

Country	UN ECE reported official emission data									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Denmark [a]					9.974	10.445	11.461	11.150	10.487	11.181
benzo[a]pyrene					2.687	2.819	3.119	3.040	2.854	3.047
benzo[b]fluoranthene					3.640	3.768	4.175	4.067	3.830	4.100
benzo[k]flouranthene					1.368	1.386	1.533	1.492	1.419	1.503
Indeno [1,2,3-cd]pyrene					2.279	2.472	2.634	2.551	2.384	2.531
Lithuania [a]								71.2	53.1	44.5
benzo[a]pyrene									14.155	
benzo[b]fluoranthene									10.772	
benzo[k]flouranthene									10.350	
indeno[1,2,3-cd]pyrene									17.859	
Poland [a]	163	178	176	170	236	242	230	201	181	181
benzo[a]pyrene									54.4	53.5
benzo[b]fluoranthene									55.4	55.1
benzo[k]flouranthene									15.8	14.9
indeno[1,2,3-cd]pyrene									55.5	57

[a] - total of 4 compounds

Table C.3. Official data on dioxins/furans emissions, g TEQ/y

Country	UN ECE reported official emission data									
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Austria	92.06	85.35	70.86	64.28	58.38	61.00	60.21	56.67	53.83	50.62
Belarus								16.4	15.68	15.19
Belgium	448 [a]				147.6[b]	437.5	108.1	122.6	116.3	135.9
Bulgaria	554.2					456.0	340.9	309.6	288.4	245.3
Croatia	178.6						97.35	95.04	110.8	97.96
Cyprus	0.772									
Czech Republic	1252	1220	1220	1140	1135	1135	921.5	830.2	766.7	643.2
Denmark										95
Finland [c]	35.4	34.8	33.1	34.7	41.5	40.7	39.8	39.1	39.5	41.1
France	2206	2268	2312	2392	2363	2107	1865	1253	836	558
Germany	1196					309				
Hungary	157	151	126	122	104	116	108	103	93.6	37.6
Lithuania								5.62	5.97	5.03
Luxembourg	40				23	24	16	16	8	
Netherlands	618		505		143	74.2	60.7	55.3	43.8	34.8
Norway						125	105	105		
Poland	368.3	349.2	338.1	396.6	360.9	387.7	366.2	347.7	290.4	287.4
Russian Federation	991	947	901	878	82 5	769	637	614	606	625
Slovakia	224.5					372.7		194.2	187.6	161
Slovenia	8.6				5.67	4.94	4.91	3.82	3.53	3.51
Spain	181	190	200	196	185	157	155			
Sweden	58-127			19-46						
United Kingdom	1142	1123	1098	1049	953.2	819.5	588.6	384.2	361.0	345.7

[a] - Referring to Flanders only

[b] - Referring to Brussels and Wallonia only

[c] - Emissions prior to 1994 are underestimated and will be updated

Annex D

STRUCTURE OF MSCE-POP MODEL

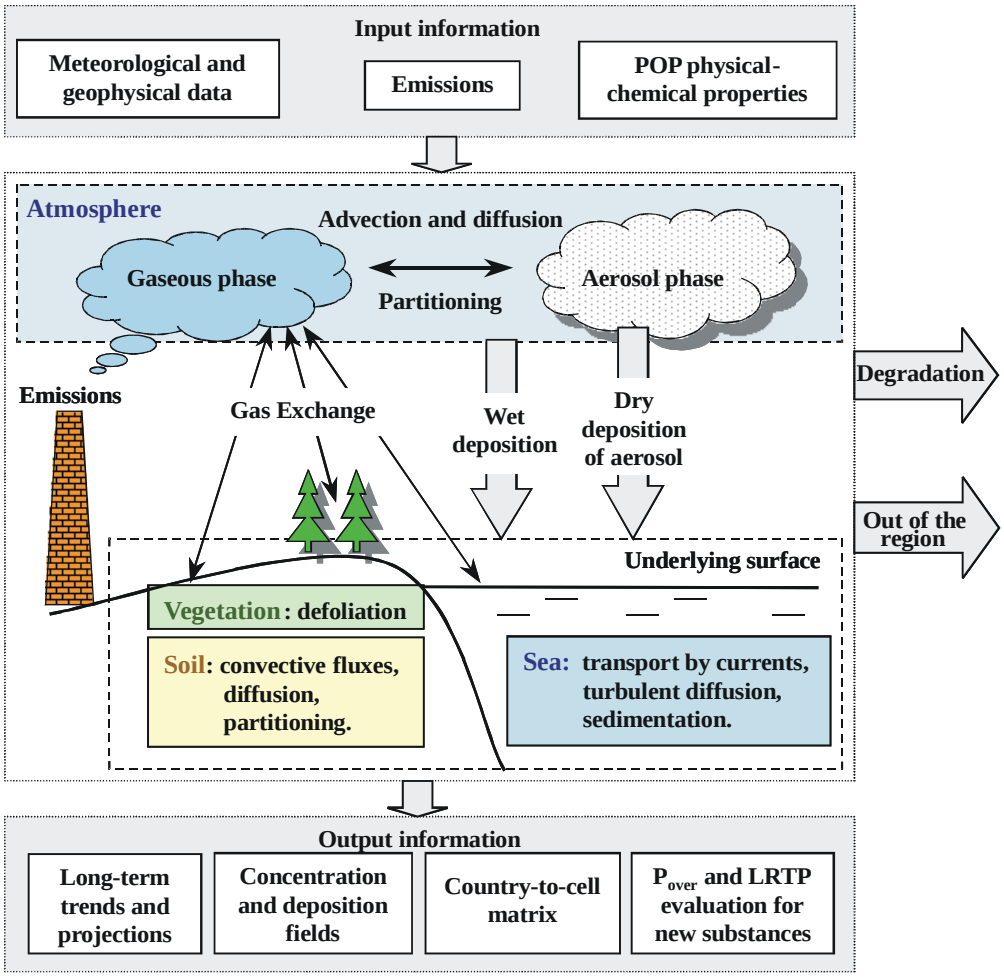


Figure D. Structure of the MSCE-POP multicompartment transport model

As seen from Figure D, the model includes such environmental media as the atmosphere, soil, seawater, and vegetation. In particular, apart from atmospheric transport the model takes into account the transport of pollutants by sea currents. This is essential for the pollutants, which tend to be accumulated in the marine environment (e.g. HCB and γ-HCH; see below). Vegetation is considered for some pollutants (to describe their transport from vegetation to soil, forest litter as an intermediate media between vegetation and soil was introduced). The figure displays also sets of input and output model data.

At present two versions of the model are being elaborated. First is the regional MSCE-POP model designed for simulations of POP long-range transport and accumulation in the environment in the EMEP domain. This model can be run with resolution 150×150 or 50×50 km. Second is the pilot MSCE-POP model for simulations on the hemispheric scale with resolution $2.5^{o}\times2.5^{o}$. Model parameterizations for PAHs (B[a]P), PCBs (7 congeners), PCDD/Fs (8 congeners), γ-HCH and HCB are at present under development.

Annex E

PUBLICATIONS

The list of recent publications on POP contamination assessment follows:

Dutchak S., A. Malanichev, V.Shatalov, O.Travnikov and J.Munthe [2000] Long-Range Transport of Persistent Organic Pollutants and Heavy Metals: Progress and Scientific Needs, EUROTRAC Newsletter, No. 22, pp. 21 - 26.

Erdman L., A.Gusev and N.Pavlova [2001] Atmospheric Input of Persistent Organic Pollutants to the Mediterranean Sea. WMO, Map Technical Reports Series No.130

Holoubek I., A. Ansorgová, V. Shatalov, S. Dutchak, J. Kohoutek [2001] Regional background monitoring of PBT compounds. The comparison of the results from measurements and monitoring. Environ. Sci. Pollut. Res. 8, 201-211.

Holoubek I., V. Shatalov, S. Dutchak, A. Ansorgová, J. Kohoutek, I. Holoubková [2001] Regional background monitoring of PBTs in Central Europe and comparison with model results. Workshop “Slowly degradable organics in the atmospheric environment and air-sea exchange”. Max Planck Institute for Meteorology. Report No. 335, Hamburk, Germany, 45-50.

EMEP/MSC-E Technical Notes describing 2002 activities together with short annotations are listed in Table E.

Table E. 2002 MSC-E Technical Reports and Notes devoted to the assessment of POP contamination on regional and global/hemispheric scales

Title	Short content
Behavior of persistent organic pollutants in soil	Examination of POP distribution between different phases in soil and transport with dissolved organics. Recommendations for modelling.
Assessment of POP transport and accumulation in the environment	Evaluation of PCDD/F long-range transport, long-term trends and accumulation in the environment for 1999. Comparison of environmental behaviour of selected congeners. Evaluation of environmental pollution levels and transboundary transport of B[a]P.
Modelling POP hemispheric transport	Development of hemispheric POP transport model. Preliminary model runs for the influence of γ-HCH, PCBs and HCB in 1990. Tentative evaluation of European sources on the contamination of remote regions.
Polycyclic aromatic hydrocarbons in the environment	Description of emission source types. Analytical review of measurement data and physical-chemical properties. Tentative model parameterization for preliminary calculations, of 4 indicator PAH transport.
Expert estimates of PCDD/F and PCB emissions for some European countries	Expert estimates for PCB and PCDD/F emissions in the European part of former Soviet Union and for Russian Federation in 1990, 1995 and 1997 for different source categories. Spatial distributions of emissions.