

8. Atmospheric Supply of Lindane to the Baltic Sea in 2003

This chapter presents a short description of model evaluation of lindane atmospheric input to the Baltic Sea, its sub-basins and catchment area in 2003. Modelling of lindane atmospheric transport and depositions was carried out using MSCE-POP model (Gusev et al., 2005). Latest available official information on lindane emission from HELCOM countries and other European countries was used in computations. Based on these data levels of annual and monthly lindane depositions to the Baltic Sea region have been obtained and their monthly variations are estimated. Model results were compared with observed levels of lindane concentrations in air and precipitation measured at monitoring sites around the Baltic Sea.

8.1 Lindane emissions

To evaluate long-range transport and depositions of lindane to the Baltic Sea area computations were carried out for the period 1990-2003. Long period model run was carried out in order to take into account long-term accumulation of lindane in soil and sea water. Available emission data officially submitted by EMEP countries to the UN ECE Secretariat were used along with expert estimates of POPCYCLING-Baltic project (Pacyna et al., 1999). For countries, which have reported emissions only for some years, emissions for missing years were interpolated between available official data or expert estimate or have been taken equal to the last available emission value. Expert estimates of POPCYCLING-Baltic project are ended with 1996. Therefore for countries, which have not submit their emission data for 1997-2003, lindane emission was taken equal to the value of expert estimate for 1996.

Usage of lindane in most of European countries in recent decade was banned or restricted (Breivik et al., 1999). However official information on lindane emission including absence of its application for most of the countries is lacking. Following the officially reported data lindane emission to air from Denmark, Estonia, Finland, Germany, and Sweden was equal to zero in 2003. Due to the lack of official data for Latvia, Lithuania, and Poland the expert estimates (Pacyna et al., 1999) were used in computations. As in computations for the previous report no lindane emissions is assumed in Russian Federation from 1997. Total values of lindane emission of HELCOM countries and total emission within the EMEP region for 2003 are presented in the Table 8.1.

Table 8.1. Annual emissions of lindane in the HELCOM countries and in the entire EMEP area, used in computations for 2003. Units: tonnes per year

Country	2003
Denmark	0
Estonia	0
Finland	0
Germany	0
Latvia	0.003
Lithuania	0.002
Poland	0.28
Russian Federation	0
Sweden	0
TOTAL – HELCOM countries	0.285
TOTAL - EMEP	59

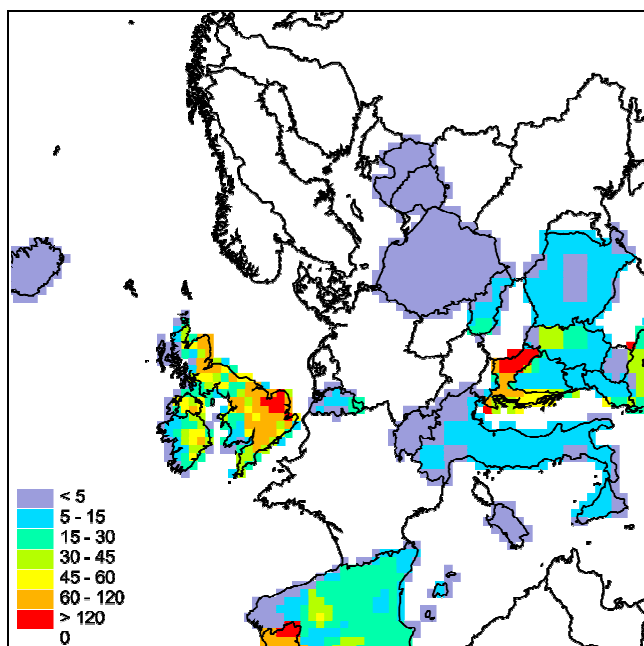


Figure 8.1. Spatial distribution of lindane emission in the EMEP domain in 2003 with resolution 50x50 km². Units: g/km²/year

Following officially submitted information the most significant emissions of lindane outside the HELCOM region belong to the following countries: the United Kingdom (15.5

tonnes/year), Portugal (13.2 tonnes/year), Spain (9.9 tonnes/year), Greece (5.9 tonnes/year), and Croatia (3.2 tonnes/year).

For modeling of lindane it was assumed that its application varies over the year and is concentrated in the growing season. Seasonal variation of lindane emission to the atmosphere is assumed to have maximum in spring and earlier summer. Following this the annual lindane emission is distributed in following way: 10% of annual emission – in February, 15% - in March, 25% - in April-June each.

8.2 Annual deposition of lindane

Annual and monthly depositions of lindane over the Baltic Sea region for 2003 were computed for six sub-basins and their catchments. The removal of lindane from the atmosphere occurs due to wet deposition and gaseous exchange with underlying surface. The latter flux can be directed from air to the underlying surface (dry deposition) and backward (re-emission). Lindane accumulated in soil, seawater, vegetation can under favorable conditions re-volatilize back to the atmosphere. The sum of wet and dry deposition represents total atmospheric input of lindane to the Baltic Sea and its catchment area. Spatial distribution of total deposition and re-emission fluxes of lindane for 2003 is given in Figure 8.2.

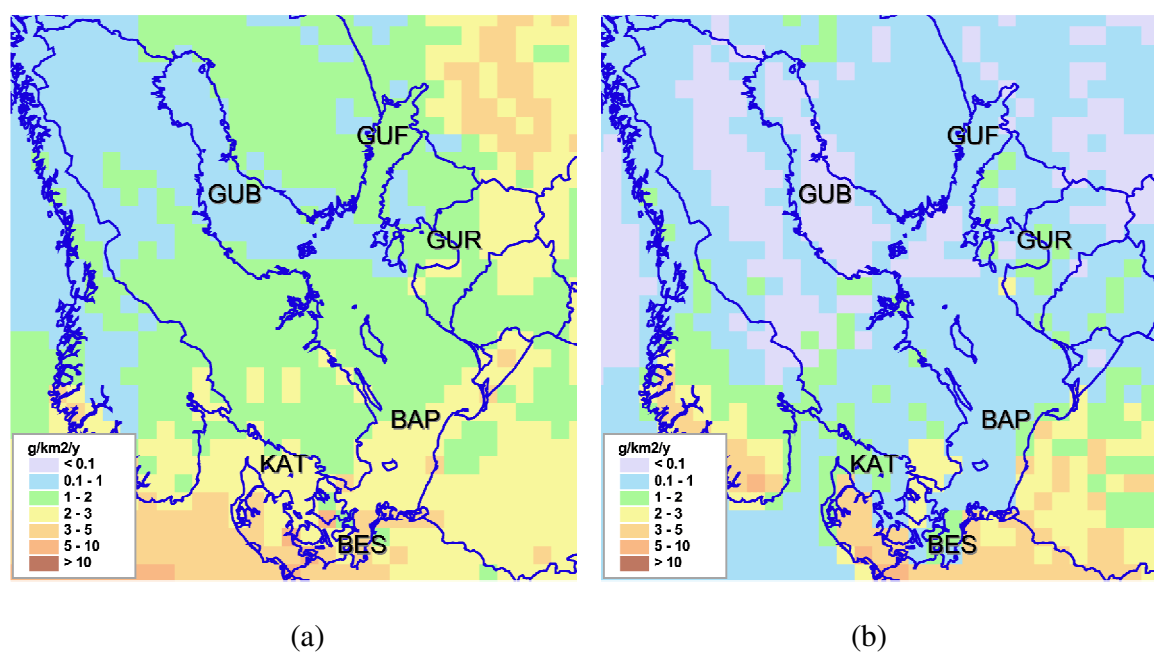


Figure 8.2. Spatial distribution of computed total depositions (a) and re-emission (b) of lindane for the Baltic Sea region in 2003 with resolution $50 \times 50 \text{ km}^2$. Units: $\text{g}/\text{km}^2/\text{year}$

Tables 8.2 and 8.3 present the distribution of wet, dry and total lindane depositions to the Baltic Sea sub-basins and catchment area for 2003. In comparison to the removal with precipitation dry deposition of lindane is considerably higher.

Most significant total deposition fluxes are obtained for the Belt Sea sub-basin (3.3 g/km²/y). Lowest deposition rate can be noted for the Gulf of Bothnia sub-basin (0.6 g/km²/y). Over the catchment area the highest level of deposition fluxes (2.6 g/km²/y) is a characteristic of the catchment area of the Baltic Proper sub-basin.

Table 8.2. Annual wet, dry, and total depositions (kg/year) and total deposition fluxes (g/km²/year) of lindane to the Baltic Sea sub-basins in 2003

	GUB	GUF	GUR	BAP	BES	KAT	Baltic Sea
<i>Dry</i>	42	25	15	174	54	49	359
<i>Wet</i>	28	9	6	84	13	18	159
<i>Total</i>	71	33	21	258	67	67	517
<i>Flux</i>	0.6	1.1	1.1	1.2	3.3	2.9	1.2

Table 8.3. Annual wet, dry, and total depositions (kg/year) and total deposition fluxes (g/km²/year) of lindane to the catchment areas of the Baltic Sea sub-basins in 2003

	GUB	GUF	GUR	BAP	BES	KAT	Catchment area
<i>Dry</i>	432	658	271	1193	32	103	2689
<i>Wet</i>	90	117	51	241	19	57	574
<i>Total</i>	522	775	322	1434	51	160	3264
<i>Flux</i>	1.1	1.8	2.3	2.6	1.9	1.9	1.9

8.3 Monthly depositions of lindane

Monthly variations of lindane total deposition over the Baltic Sea and its catchment area obtained in computations for 2003 are shown in Figure 8.3. It can be seen that total depositions both over the Baltic Sea and its catchment undergo pronounced seasonal variation. Elevated total depositions of lindane are obtained for the warm period of the year. This can be explained by the seasonal character of lindane application and by the effect of temperature variations on the gaseous exchange of lindane between the atmosphere and the underlying surface.

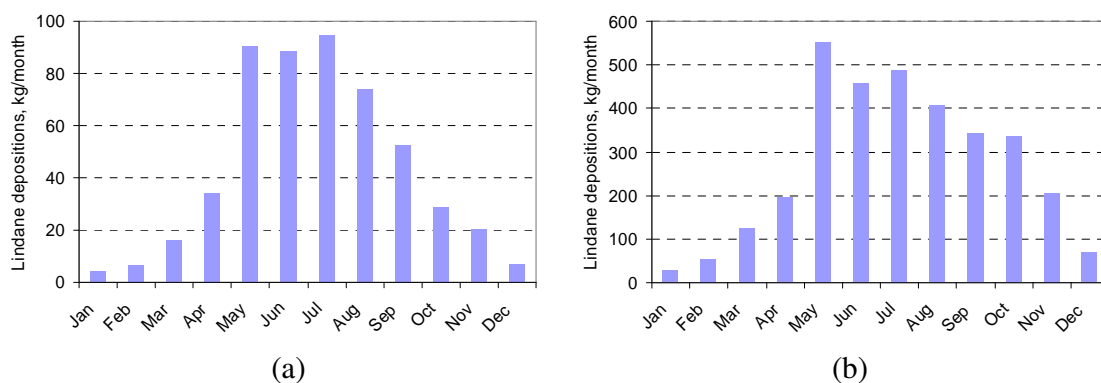


Figure 8.3. Monthly variations of lindane total depositions over the Baltic Sea (a) and its catchment area (b) for 2003, kg/month.

8.4 Comparison of model results with measurements

Model results obtained in computations were compared with available measurements of lindane concentrations for 2003 obtained at EMEP monitoring stations. Measurements of lindane for 2003 were reported by Westerland (DE01), Zingst (DE09), Lista (NO99), De Zilk (NL91), Knokke (BE04), Pallas (FI96), SE14 (Råö), and NO01 (Birkenes). Comparison of measured and computed lindane concentrations and their ratios are presented in Table 8.6. To compare the model results with measurements made at German sites the datasets obtained without rinsing were selected to be consistent with data of other sites.

Table 8.4. Comparison of observed mean annual lindane concentrations in air and precipitation with the computed concentrations for 2003

Station code	Station name	Observed	Calculated	Ratio (Obs/Calc)
<i>Lindane concentrations in air (pg/m³)</i>				
NO99	Lista	8.8	11.6	0.8
SE14	Råö	8.0	8.5	0.9
FI96	Pallas	4.1	2.1	1.9
<i>Lindane concentrations in precipitation (ng/l)</i>				
BE04	Knokke	7.02	2.24	3.1
DE01	Westerland	1.74	1.28	1.4
DE09	Zingst	1.39	0.77	1.8
NL91	De Zilk	7.58	1.92	3.9

In comparison with observed annual mean air concentrations of lindane at selected stations computed concentrations are slightly higher for SE14 (Råö) and NO99 (Lista). At FI96 (Pallas) the model underestimates measured concentrations in air about a factor of 2.

Concentrations of lindane in precipitation measured at BE04 (Knokke) and NL91 (De Zilk) are a factor of 3-4 higher than computed values. The reason for this difference can be connected with the influence of local sources not taken into account in the emission data. At the same time measured and computed annual mean concentrations in precipitation for DE01 (Westerland) and DE09 (Zingst) are in a reasonable agreement.

Comparison of measured and computed monthly mean concentrations of lindane in air and in precipitation is presented in Figures 8.4 – 8.11. In spite of some peaks not captured by the model variations of computed concentrations of lindane are consistent with observed ones.

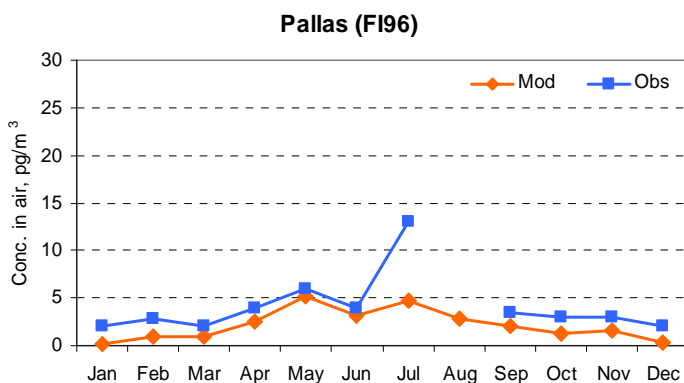


Figure 8.4. Comparison of calculated mean monthly lindane concentrations in air with measured at station Pallas (FI96). Units: pg / m^3 .

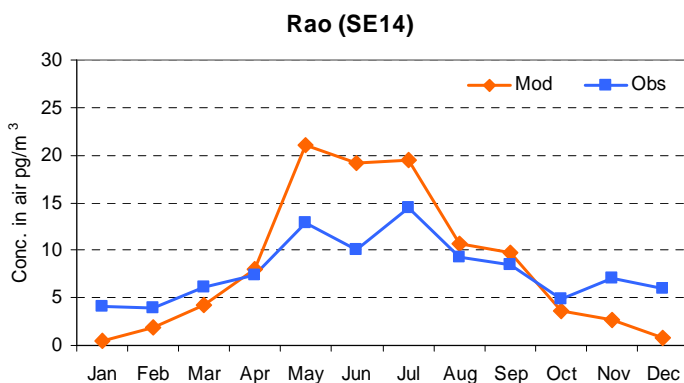


Figure 8.5. Comparison of calculated mean monthly lindane concentrations in air with measured at station Rao (SE14). Units: pg / m^3 .

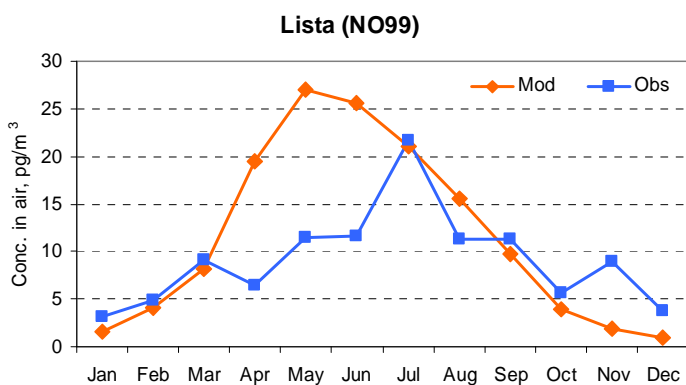


Figure 8.6. Comparison of calculated mean monthly lindane concentrations in air with measured at station Lista (NO99). Units: pg / m³.

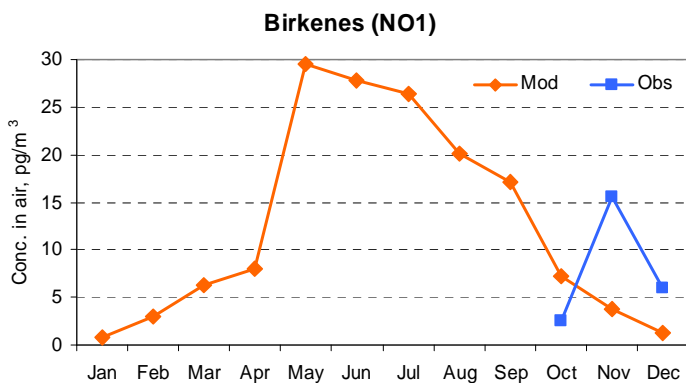


Figure 8.7. Comparison of calculated mean monthly lindane concentrations in air with measured at station Birkenes (NO1). Units: pg / m³.

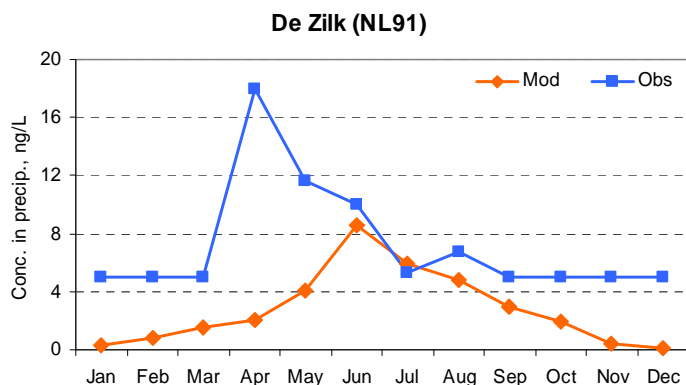


Figure 8.8. Comparison of calculated mean monthly lindane concentrations in precipitation with measured at station De Zilk (NL91). Units: ng / L.

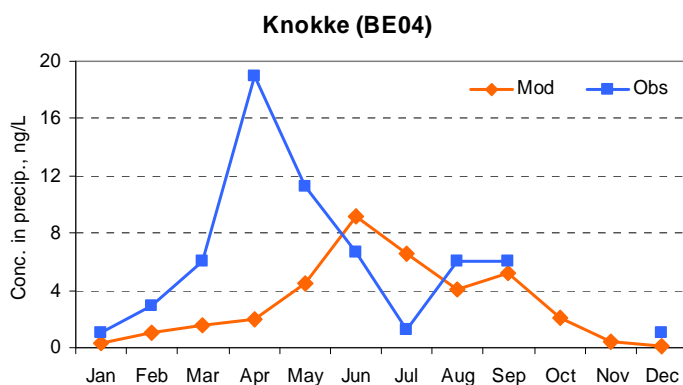


Figure 8.9. Comparison of calculated mean monthly lindane concentrations in precipitation with measured at station Knokke (BE04). Units: ng / L.

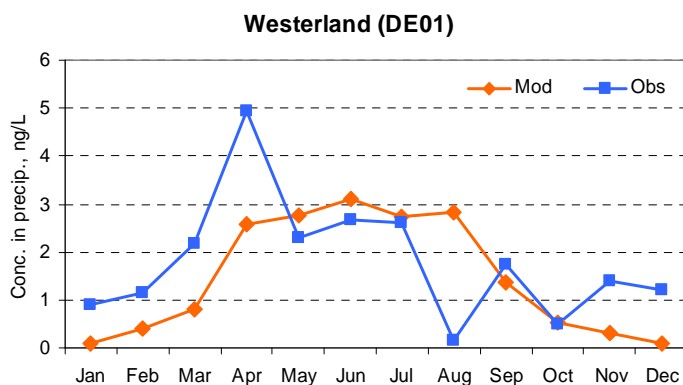


Figure 8.10. Comparison of calculated mean monthly lindane concentrations in precipitation with measured at station Westerland (DE01). Units: ng / L.

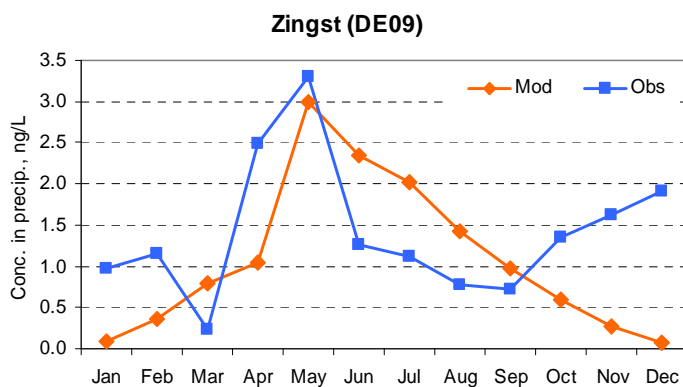


Figure 8.11. Comparison of calculated mean monthly lindane concentrations in precipitation with measured at station Zingst (DE09). Units: ng / L.