Chapter 2

MODEL ASSESSMENT FOR THE NETHERLANDS

Model assessment of pollution levels of lead in the Netherlands in 2007 is presented in this chapter. Information on pollution levels regularly produced under EMEP with resolution 50x50 km\(^2\) markedly extended by means of modelling with fine (5x5 km\(^2\)) resolution. The chapter describes concentration and deposition fields, source-receptor relationships and contribution of emission source categories to the pollution levels in the Netherlands.

2.1. Air concentrations and deposition of lead in the Netherlands with fine spatial resolution

Information on heavy metal pollution levels annually reported by EMEP includes various aspects of pollution levels assessment and is disseminated among all EMEP countries. However, this information can be significantly diversified due to availability of more detailed country-specific information and application of modelling with fine (5x5 km\(^2\)) spatial resolution. In particular, fine resolution allows reproducing more spatial details in the maps of pollution levels, compared to maps with coarse resolution. Furthermore, it becomes reasonable to present the information not only for a country as a whole, but also for its individual provinces (Fig. 2.1).

Spatial distribution of lead pollution levels depends on a number of factors such as anthropogenic emissions, atmospheric transport, precipitation patterns, and properties of the underlying surface. Annual mean near-surface concentrations of lead in air in the Netherlands in 2007 range from 4 to 15 ng/m\(^3\) over most part of the country (Fig. 2.2a), and total (wet and dry) deposition fluxes vary from 1 to 4 kg/km\(^2\)/y (Fig. 2.2b). These ranges are similar to those obtained for 50x50 km. However, maximum levels of pollution differ markedly: maximum air concentrations in the Netherlands simulated with fine resolution are 137 ng/m\(^3\), and deposition – 11.6 kg/km\(^2\)/y, whereas the corresponding values for 50-km resolution are 10.5 ng/m\(^3\) and 1.5 kg/km\(^2\)/y (Fig. B1, B4 in Annex B).

The highest air concentrations (more than 30 ng/m\(^3\)) and deposition (more than 4 kg/km\(^2\)/y) levels are noted for the province Noord-Holland. These high levels are caused by emissions from large metallurgical enterprise located in this province.

The southern part of the country is characterized by higher pollution levels compared to the northern part. It is explained by relatively high emissions and wind re-suspension in this part of the country, and by transboundary transport from emission sources in neighbouring countries (mostly Belgium and Germany). In the southern part (provinces Zuid-Holland,
Limburg, Noord-Brabant, Utrecht) the concentrations typically range from 5 to 7 ng/m³. Deposition in the southern provinces varies from 1.2 to 2.5 kg/km²/y. In the northern part of the country (provinces Groningen, Friesland, Drente, Flevoland, Overijssel) the range of air concentrations is 4-5 ng/m³, and that of deposition - 1-2 kg/km²/y.

**Fig. 2.2.** Calculated concentrations of Pb in air (a) and total deposition (b) in the Netherlands in 2007 with resolution 5x5 km².

Total deposition consists of two parts: wet deposition (removal of pollutant from the air by atmospheric precipitation) and dry deposition (uptake of pollutant by elements of the underlying surface). In the Netherlands wet deposition is higher than dry deposition and their contribution to total deposition varies from 64% to 83% (Fig. 2.3). The largest fraction of wet deposition is noted for the Groningen province, and the lowest – for the Gelderland and Utrecht provinces.

Spatial distribution of wet deposition is similar to that of total deposition (Fig. 2.4a): the levels in the southern part of the Netherlands are higher than those in the northern part, and the highest levels occur in the Noord-Holland province. Wet deposition field follows mainly pattern of emission sources rather than annual precipitation amounts. It is explained by the fact that spatial variability of annual precipitation sums in the Netherlands (800 – 1300 mm, Fig. 2.4b) is much lower than the variability of anthropogenic emissions or re-suspension (about two orders of magnitude).
Spatial distribution of dry deposition is mostly governed by two factors, namely distribution of emission sources and land-cover categories. According to modelling approaches, dry deposition velocity to surfaces covered with forests is significantly higher than that to surfaces covered with low vegetation such as grasslands or arable lands. For example, relatively large dry deposition fluxes in the Noord-Holland and Utrecht provinces are explained mostly by influence of emission sources (Fig. 2.5a). However, similar levels of deposition in the Gelderland province are caused to high extent by significant fraction of area covered by forests (Fig. 2.5b). On the other hand, there are large forested areas in the south of Friesland province. However, dry deposition to this area is not high compared to the other parts of the country because of relatively low emissions in the northern part of the Netherlands.
2.2. Source-receptor relationships for individual provinces

Deposition to the territory of the Netherlands comes from three groups of sources including anthropogenic emissions (national and foreign), emissions from sources located outside the EMEP region (so-called non-EMEP sources) and from secondary sources, in particular, re-suspension of previously deposited heavy metals from anthropogenic sources. According to the model calculations, total deposition of lead to the Netherlands in 2007 made up almost 48 tonnes. About 18% are caused by national sources, 27% - by anthropogenic sources from foreign EMEP countries, 52% - by contribution of wind re-suspension. The contribution of non-EMEP sources is minor (around 3%). Contributions of re-suspension (55%) and foreign sources (29%) simulated with coarse resolution (50x50 km²) are similar to those modelled with fine resolution (5x5 km²). However, the contribution of national sources is considerably lower (12%). It is likely that the main reason for this is change of spatial resolution. It is assumed in the modelling that emission is distributed homogeneously over gridcells. Therefore, if a grid cell is shared by two or more countries, emissions of one country ‘creep’ over foreign territory. It is obvious that the larger gridcell, the stronger is this effect. The same effect has already been indicated in the similar country-specific assessment for Croatia [Ilyin et al., 2011].

![Fig. 2.6. Total annual deposition of lead to the Netherlands (the map) and contributions of national, foreign emission sources and re-suspension to deposition in provinces of the Netherlands (the pie charts)
Country-specific assessment produced annually under EMEP includes information on pollution levels for the entire country. The use of fine resolution makes reasonable to extent it by providing similar information for individual administrative regions. Information on contributions of different emission sources to deposition in the Dutch provinces is available in Annex C. The ratio between emission sources varies in different provinces. In most of provinces the major contribution (51-57%) is done by wind re-suspension (Fig. 2.6). The exception is the Noord-Holland province where the contribution is 38%. This province is characterized by the highest (47%) contribution of national sources. In addition to Noord-Holland, there are two other provinces – Flevoland and Utrecht – where the contribution of national sources exceeds or equals to the contribution of foreign sources. In the other provinces deposition from foreign sources exceeds deposition from national sources. The major contribution of foreign sources is noted for the provinces located in the southern part of the country - Limburg (38%), Zeeland and Noord-Brabant (34% each). The contribution on non-EMEP sources is relatively small in all provinces ranging from 2 to 4%.

Spatially averaged deposition fluxes from different emission sources in the Dutch provinces exhibit significant variability over the country. The maximum total deposition (more than 2 kg/km²/y) is noted for the Noord-Holland province, while the lowest (0.9 kg/km²/y) – in the Groningen province (Fig. 2.7). The Noord-Holland province is characterized by the highest deposition flux from national sources, which equals to 0.95 kg/km²/y. The reason for this is large emission source locating in this province and accounting for about 60% of total national emission of lead in the Netherlands. Concentration of so large fraction of emission in one province predetermines spatial distribution of deposition from national sources over the country. In the provinces located close to Noord-Holland, such as Utrecht, Flevoland, Zuid-Holland, Gelderland, the deposition fluxes from national sources vary from 0.21 to 0.36 kg/km²/y. In the more remote provinces (Friesland, Overijssel, Drente, Noord-Brabant) the deposition ranges from 0.14 to 0.16 kg/km²/y, and in the most distant provinces (Zeeland, Limburg, Groningen) the deposition varies within 0.11 – 0.13 kg/km²/y limits.

The relatively high deposition fluxes caused by foreign anthropogenic sources are noted for provinces in the southern part of the Netherlands – Zeeland, Noord-Brabant and Limburg (0.5 – 0.6 kg/km²/y). It is caused by transboundary atmospheric transport from neighbouring Belgium and Germany. Lower deposition levels (0.24 – 0.28 kg/km²/y) from foreign sources occur in the central and northern parts of the country (Noord-Holland, Flevoland, Friesland, Groningen).

Spatially averaged deposition fluxes caused by wind re-suspension are distributed more uniformly compared to those from anthropogenic sources. They range from 0.53 kg/km²/y (Groningen) to 0.81 kg/km²/y (Limburg).
Although wind re-suspension used in the model assessment of pollution levels in the Netherlands is uncertain parameter, it is highly important to include it into the modelling of heavy metal pollution. The reason is the magnitude of anthropogenic emission is insufficient to explain observed levels of lead in air and in precipitation both in the Netherlands and in the EMEP region as a whole. Taking into account significant uncertainty of wind re-suspension, and inability to control this process, further analysis of transboundary transport is given for anthropogenic component.

Contribution of foreign emission sources to deposition from the anthropogenic sources in the Netherlands ranges from 25% to 80% over the most part of the country (Fig. 2.8). Spatial distribution of the contribution is explained by existence of powerful emission sources in the central part of the country. Nearby the sources the contribution is the lowest and it increases with distance from the source reaching the highest values along the state borders. In the provinces bordering Belgium (Zeeland, Noord-Brabant, Limburg) it exceeds 80%. In the northern part of the country along the Dutch-German border the contribution is 70-80%. There are also ‘local’ minimums of the contribution bound to emission sources with relatively high emissions, e.g., in the provinces Drente or Limburg.

Contributions of emission sources of individual foreign countries to anthropogenic deposition in the Netherlands in 2007 were determined. Besides, modelling with fine resolution makes possible to establish source-receptor relationships for individual provinces. Three main countries-contributors as well as three main provinces-contributors of lead deposition were determined for each province of the Netherlands (Fig. 2.9). The same numerical information is summarized in Annex C.

Among foreign sources the main contributors are Germany, Belgium, the United Kingdom, and France. In the southern part of the country (Zeeland, Noord-Brabant) and in some central provinces (Utrecht, Zuid-Holland, Noord-Holland) the Belgium emission sources are the main foreign contributors to deposition. In Zeeland their contribution is 48%, and in Noord-Brabant – 41%. In the central provinces Utrecht and Zuid-Holland their contributions are around 20%. In Flevoland and the southernmost province Limburg the contributions of the German and Belgian sources are almost the same. Germany is the main foreign contributor to lead deposition in the northern and western parts of the country (Drente, Groningen, Gelderland, Friesland, Overijssel), where its contribution ranges from 19 to 28%.

The Noord-Holland province is the major national contributor to lead anthropogenic deposition in almost all provinces. The contribution of sources of this province to its own territory is 75%, and in the other provinces it ranges from 5 to 32%. In many provinces (Drente, Flevoland, Friesland, Gelderland, Groningen, Overijssel, Utrecht and Zuid-Holland) the contribution of Noord-Holland sources is even higher than the sum of contributions made by sources of other provinces. Only in the Limburg province the major contribution from national sources is made by sources located in this province.
2.3. Contribution of the Dutch provinces to transboundary transport within the country and to the EMEP region

Lead emitted by sources of the Dutch provinces can deposit to a territory of a province, or can be transported to the other provinces or even behind the country’s borders. Fractions of emitted mass of lead deposited in different parts of the country or transported outside the country’s borders were established for each of the provinces. Besides, emissions from sea surface caused by shipping were also treated as individual ‘province’ in order to take into account all mass of lead emitted in the Netherlands.

From 5% to 12% of lead are deposited to territory of a province where it is emitted, and from 4 to 19% - to other provinces (Fig. 2.10). The most of lead (72-90%) emitted in the Dutch provinces is transported through state borders to foreign countries. Fraction of emitted substance transported across the state borders is explained mainly by location of a province. For example, the largest fraction entering transboundary transport is noted for the Limburg province, which looks as a narrow stripe between Belgium and Germany. The fraction is the lowest for Utrecht and Flevoland – the provinces located in the central part of the country.
For the country as a whole 19% of emitted lead are deposited to the country’s territory. When modelling with coarse resolution (50x50 km²), this fraction is around 13% (Fig. B3b in Annex B). Therefore, the use of fine resolution for assessment of pollution levels in the Netherlands changes estimates of source-receptor relationships for the Netherlands: Compared to modelling with coarse resolution, more lead is deposited within the country’s territory and less is transported beyond the state borders.

Total deposition of lead, emitted by sources of each province and deposited to the other Dutch provinces was estimated. It allowed determining of main provinces - receptors of lead emitted by sources of each province (Fig. 2.11). As seen from the Figure, the main receptor is own territory of a province. Magnitude of the deposition strongly depends of the emissions in a province. Since the highest emission is noted for the Noord-Holland province, deposition from its emission sources is also the highest among the other provinces-emitters: more than 2500 kg of lead are deposited to its own territory and around 500 kg to neighbouring countries.

**Fig. 2.10.** Fractions of lead emitted in the Dutch provinces and deposited to territory of a province, to other provinces of the country and transport abroad

**Fig. 2.11.** Total deposition of lead emitted by sources of the Dutch provinces to territories of the provinces. Deposition scales vary for different provinces. ‘Other’ include deposition to the remaining Dutch provinces.
Maps of spatial distribution of deposition fluxes, caused by emission sources of individual provinces demonstrate more details about atmospheric transboundary transport between provinces. The deposition caused by emission sources of provinces Noord-Holland and Limburg is exemplified in Fig. 2.12. Noord-Holland is characterized by the highest emissions in the country. Therefore, deposition fluxes caused by its sources are comparable with total deposition fluxes (Fig. 2.2b). The highest fluxes (more than 1 kg/km²) are noted for the Noord-Holland province and they decline with distance from the province. Near the state borders the fluxes are within the range of 0.03 – 0.1 kg/km²/y.

Significant emission sources of the Limburg province are situated near the borders with Belgium and Germany. That is why deposition values of lead from these sources to Limburg and to neighbouring regions of these countries are similar.

Fig. 2.12. Total deposition of lead from emission sources of Noord-Holland (a) and Limburg (b) provinces. Please, note that the ranges of deposition shown in two maps are different.

2.4. Contribution of key source categories to lead pollution in the Netherlands

The highest contribution to deposition of lead in the Netherlands is made by iron and steel production group, followed by transport and industrial processes. The contribution of these groups to deposition of lead in the Netherlands from national sources is similar to their contributions to emissions (Fig. 2.13, Table 1.1).

Contribution of emission source categories to deposition from national sources in each province was established and summarized in Annex D. In most of provinces the major contribution comes from ‘Iron and steel production’ (Fig. 2.14). This contribution is the highest (91%) in the Noord-Holland province, because in this province most of emission from this sector is concentrated. In the neighbouring provinces (Zuid-Holland, Utrecht, Flevoland) and provinces located to the north-east of Noord-Holland (Freisland, Groningen, Drente, Overijssel) this source category also contributes at least half even more to deposition from national sources (50-71%).

Fig. 2.13. Contribution of different emission source categories of the Netherlands to lead deposition in the country from national sources as a whole in 2007
‘Transport’ (except aviation) is the second by importance source of lead pollution in the Netherlands. Its contribution ranges from 5% in Noord-Holland to 30% in Noord-Brabant. The highest emissions from transport are noted for the provinces Utrecht, Noord-Holland and Zuid-Holland. That is why the contribution of transport sector is significant in Utrecht and Zuid-Holland. However, it is the lowest in the Noord-Holland province because of predominance of the category ‘Iron and steel production’.

The largest emissions from group of sources ‘Aviation’ occur in the provinces Flevoland and in Drente, close to border with Groningen. Therefore, the highest (12-16%) contribution of aviation is noted for these provinces. In the other provinces the contribution of this group varies from 1 to 8%.

Emissions from group ‘Industrial processes’ are concentrated mostly in the southern part of the country, in particular, in the provinces Limburg, Zeeland and Noord-Brabant. Consequently, main contribution of this group to national deposition is obtained for these provinces: 34%, 31% and 15%, respectively. In the other provinces the range of its contribution constitutes 1 – 10%.

Emissions from group of source categories ‘Small combustion installations’ are distributed more or less uniformly over the country. Contribution of this group to national deposition varies within 4-10% range in most of the provinces. The exception is the Noord-Holland province where contribution of iron and steel production is overwhelming.

Fig. 2.14. Lead deposition from national sources (map) and contributions of national emission source categories to anthropogenic deposition from national emissions in provinces of the Netherlands in 2007
Maps of spatial distribution of deposition caused by various emission source categories and their contribution to deposition from anthropogenic sources (national and foreign) are demonstrated in Fig. 2.15. The highest deposition flux caused by group ‘Iron and steel production’ takes place in the Noord-Holland province (Fig. 2.15a). Its magnitude exceeds 0.5 kg/km²/y which is more than 50% of anthropogenic deposition. Over the other parts of the Netherlands the contribution ranges from 10% to 50%. Even over territories of foreign countries the contribution exceeds 10% near the state borders.

Compared to ‘Iron and steel production’ the contribution of the other groups of source categories is smaller both in absolute and relative terms. Deposition fluxes from sources of ‘Transport’ group are relatively high (0.08 – 0.2 kg/km²/y) in the Noord-Holland, Utrecht, Zuid-Holland and Gelderland provinces (Fig. 2.15b), which is explained by significant population density and, hence, higher emissions from transport sector. Relative contribution to deposition from ‘Transport’ sources is also the biggest in these provinces and it varies from 10 to 20%. Over the other parts of the Netherlands the deposition from this source category ranges from 0.01 to 0.08 kg/km²/y, or from 5% to 10% in relative terms.

The highest deposition fluxes from ‘Aviation’ group of source categories are concentrated in several gridcells where airports are situated. In the provinces Drente, Limburg, Noord-Holland and Flevoland maximum deposition is 0.2 – 0.3 kg/km²/y (Fig. 2.15c). Relative contribution of this group of sources is 10 – 50% in the vicinity of airports, and over the other part of the country it varies from 1 to 10%.

Main emission sources belonging to group ‘Industrial processes’ are located in the southern part of the country. Therefore, the highest (0.2-0.4 kg/km²/y) deposition from this group of sources takes place near the sources in the provinces Zeeland, Limburg and Gelderland (Fig. 2.15d). Over most of the southern and central parts of the country the deposition flux ranges from 0.01 to 0.08 kg/km²/y, and over the north of the country – from 0.003 to 0.01 kg/km²/y. Relative contribution to anthropogenic deposition from this group of sources has similar spatial pattern and it varies from 1-5% in the north and from 5 to 20% in the south of the country.

Compared to the other source categories, spatial distribution of deposition from group ‘Small combustion installations’ is more uniform and it ranges from 0.01 to 0.03 kg/km²/y over major part of the country (Fig. 2.15e). Relative contribution to anthropogenic deposition lies within 1-5% limits.
**Iron and steel production**

**Transport**

**Aviation**

*Fig. 2.15. Deposition of lead (left) and relative contributions to deposition from anthropogenic (national and foreign) sources (right) caused by iron and steel production (a), transport (b), aviation (c), industrial processes (d) and emissions from small combustion installations (e)*
Fig. 2.15(continued). Deposition of lead (left) and relative contributions to deposition from anthropogenic (national and foreign) sources (right) caused by iron and steel production (a), transport (b), aviation (c), industrial processes (d) and emissions from small combustion installations (e)