Emission estimates for diffuse sources
Netherlands Emission Inventory

Leaching of heavy metals from farmland and uncultivated land

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NETHERLANDS NATIONAL WATER BOARD - WATER UNIT

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1 Description of emission source

Past and present pollution of land with heavy metals as a result of atmospheric deposition and the application of fertiliser have led to an increase in the levels of heavy metals in the soil of farmland and uncultivated land. These heavy metals of human origin, together with amounts that are naturally occurring in the soil, cause emissions into groundwater and surface water. This fact sheet describes how emissions of the heavy metals cadmium, copper, nickel, lead and zinc into surface water are quantified. The emissions are attributed to the governmental target sector "Agriculture".

2 Explanation of calculation method

Emissions are calculated using a model comprising three parts: a geostatic model that estimates current metal content in the soil, the STONE model that schematises soil properties and calculates hydrology, and a chemical equilibrium model that estimates concentrations in the moisture in the soil. This calculation method of emissions is different from that applied to other diffuse sources, where emissions are generally determined as the product of an activity rate and an emission factor.

3 Leaching model

Figure 1 [1] represents the model used to calculate the leaching.

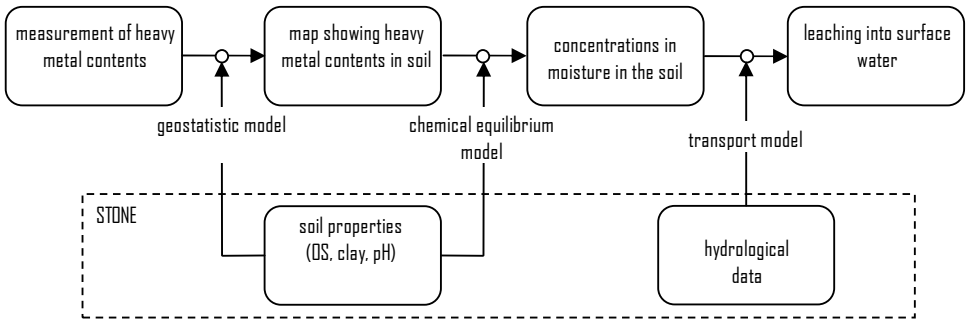


Figure 1. Schematic representation of the heavy metal leaching model

The current soil heavy metal content values are used as the basis for calculating heavy metal leaching. The Netherlands is divided into 198,923 units (so called plots) for the purposes of calculating heavy metal leaching. Heavy metal concentrations are allocated to these units by means of a geostatistical model based on relationships between soil properties and heavy metal concentrations, taking account of the regional variation. Background soil and groundwater concentrations are used for the deeper subsoil (on average below 0.7 metres below ground level).

The chemical equilibrium model used to calculate concentrations in the moisture in the soil is a non-linear sorption isotherm in which the sorption constant depends on the soil properties.

The soil properties are schematised in accordance with the STONE model [2] that is used to calculate emission of Nitrogen and Phosphorus into surface water. Long-term average water drainage amounts from the STONE model are also used to arrive at the final leaching calculations. In order to calculate the emission for each unit, the water drainage values for each soil layer are multiplied by the concentrations in the moisture in the soil.

4 Effects of policy measures

The effects of emission-reducing measures on heavy metal leaching are taken into account only indirectly. The model calculations are based on current soil heavy metal concentrations. Measures leading to a change in soil heavy metal load, and thereby to a change in soil concentrations, are implicitly taken into consideration.

5 Emissions calculated

The calculated emission values for national emission inventory 2008 and preceding inventory years are given in table 1.

Table 1: Leaching in tonnes/year on the basis of a long-term (1971-2000) weighted hydrology

	Cadmium	Copper	Nickel	Lead	Zinc
ER-C 2003[1)]	0.7	28	14	12	250
ER-C 2005[2)]	1.63	23.7	110.4	39.1	1187
ER-C 2006[3)]	0.23	20.5	21.3	42.9	146
ER-C 2008	0.095	12.0	23.3	1.26	127

1) only national calculations
2) first calculations are regional
3) better spatial schematisation of heavy metal content in the soil

Differences between emission amounts of various years of calculation are explained in chapter 9. As the emissions were calculated using a stationary model and a long-term average hydrology, it is impossible to detect any trends in emissions. There is also little point in representing trends because leaching has a minimal impact on the total stock of heavy metals in the soil, and therefore emission is likely to vary only slightly from one year to the next (apart from variations due to changes in hydrology).

6 Release into environmental compartments

The calculated emissions are emissions into surface water.

7 Description of emission pathways to water

The model quantifies the pathway 'leaching into surface water'.

8 Spatial allocation

The model used does produce a spatial distribution of emissions. However, many of the drainage areas (a sub-unit of a water catchment area) in the National Emission Inventory Database are smaller than the minimum area for which the model used is able to give reliable outcomes. For that reason, individual drainage areas are clustered to form larger units [3] and then distributed among the drainage areas.

The fact that the model does not calculate leaching for surface water and urban areas is also taken into account. The outcomes from the leaching model do not therefore cover the entire country. This means that no leaching values are calculated for drainage areas that consist entirely of surface water.

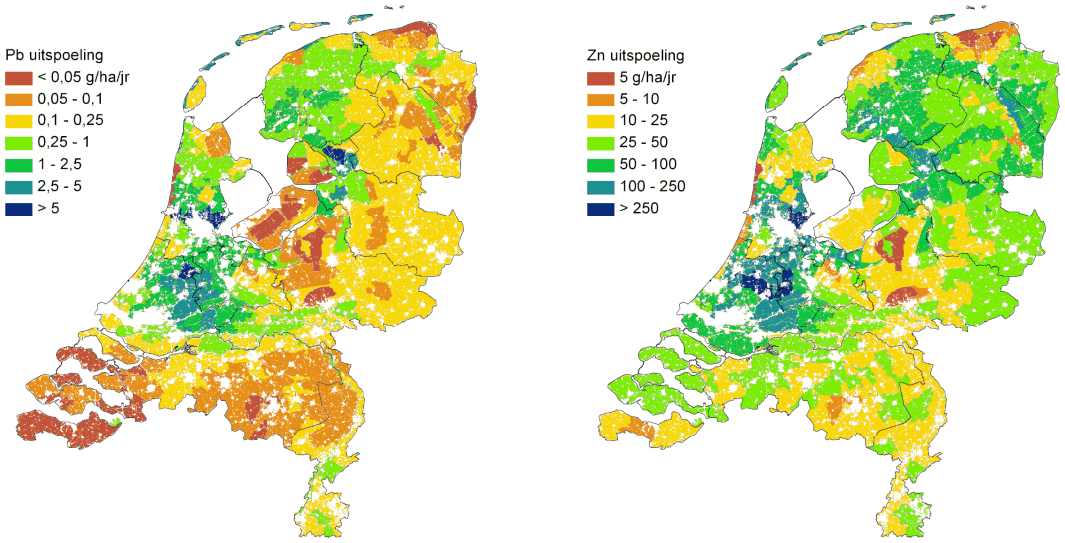
The following assumptions have been used when clustering the National Emission Inventory drainage areas [3]:

1. Exclusion. No leaching calculation needs to be performed for drainage areas than consist entirely of water (polder) and/or urban areas;

2. Size. All drainage areas less than 50 km^2 in area are clustered to form units covering at least 50 km^2;
3. Hydrological coherence. The clustered drainage areas must, taken together, form a coherent new hydrological unit;
4. Spatial diversity. The drainage area clusters must be composed so as to retain the greatest possible spatial diversity.

Leaching calculations are then performed for each drainage area within a cluster of this type, with the result expressed as g/ha.

The lead and zinc emissions for each cluster are shown in the figures below as an example.



Pb uitspoeling = Pb leaching
Zn uitspoeling = Zn leaching
g/ha/jr = g/ha/yr

9 Comments and changes in regard to previous years

Various improvements to the leaching model have been made since the previous calculations of heavy metal leaching for the National Emission Inventory (ERC 2006) [4]. They relate to:

a) improvements in hydrology (including distribution of wet and dry sandy soils, as dry sandy soils have become less dry) [5];
b) new estimates of background levels in subsoil close to the surface and background concentrations in deeper groundwater [6];
c) a better chemical equilibrium model, with improved calculation of subsoil concentrations (concentrations of lead and copper in particular may have been overestimated in previous calculations) [7];
d) better spatial schematisation of heavy metal content in the soil (because the allocation to STONE units applied in the past did not always match the spatial spread of heavy metal contents in the soil) [7].

The influence of the various improvements on emission estimates is shown in table 2.

Table 2: Influence of model improvements on leaching estimates in tonnes/year

Metal	ERC 2006	+ a)	+ a) and b)	+ a), b) and c)	+ a), b), c) and d) (=ERC 2008)
Cadmium	0.23	0.30	0.33	0.11	0.095
Copper	20.5	25.1	24.6	11.7	12.0
Nickel	21.3	22.5	37.2	22.6	23.3
Lead	42.9	51.2	35.3	1.56	1.26
Zinc	146	187	164	126	127

The improved chemical equilibrium model in particular has led to a considerable decline in emission estimates for cadmium, copper and lead. This is because the improved model calculates lower concentrations in the groundwater in the subsoil. These reductions are plausible for copper and lead, as the earlier calculated concentrations were higher than the measured concentrations (in the case of lead, about 100 times higher). However, the current calculated concentrations of lead are now lower than the measured concentrations (about two to ten times lower), and so the calculated emissions may be slightly too low.

10 Accuracy and indicated subjects for improvement

The method used in Emission Inventory publications has been followed as far as possible in classifying the quality of information [8]. It is based on the CORINAIR (CORe emission INventories AIR) methodology, which applies the following quality classifications:

A: a value based on a large number of measurements from representative sources;
B: a value based on a number of measurements from some of the sources that are representative of the sector;
C: a value based on a limited number of measurements, together with estimates based on technical knowledge of the process;
D: a value based on a small number of measurements, together with estimates based on assumptions;
E: a value based on a technical calculation on the basis of a number of assumptions.

The emission calculation results have undergone limited measurement testing [9]. On a broad scale, the outcomes appear to be in line with the measurements. Emission calculation is classified as D. The outcomes are less reliable on a regional scale, but a further step has been introduced into the spatial allocation process to distribute emissions. Spatial allocation is also classified as C. All the emissions directly enter water. For that reason distribution over compartments and emission pathways into water are classified as A.

Element of emission calculation	Reliability classification
Emissions	D
Distribution among compartments	A
Emission pathways to water	A
Spatial allocation	C

11 Request for reactions

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12 References

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