Emission estimates for diffuse sources
Netherlands Emission Inventory

Nutrient discharges by greenhouse cultivation

Version dated June 2008

NETHERLANDS NATIONAL WATER BOARD - WATER UNIT
in cooperation with DELTARES and TNO

Nutrient discharges by greenhouse cultivation

1 Description of emission source

Nutrient discharges of greenhouse cultivation are caused by two processes:

- Drainage water is released during cultivation in the soil (soil-grown crops) when surplus water is removed via drainage. Surplus water is not re-used (recirculation), but is lost directly in surrounding ditches of greenhouses.
- Spray water is released during cultivation of crops on substrate (substrate-grown crops). The crops are grown in a rooting medium (such as rock wool) that is separated from the soil. Since 1996 producers have been required to recirculate surplus water, causing leaching to be lower than in systems without recirculation.

Leaching of water from greenhouse cultivation causes emissions mainly of nitrogen and phosphorus into surface water, soil and sewers. This emission source is allocated to the governmental target sector "Agriculture" within the National Emission Inventory.

2 Explanation of calculation method

Emissions are calculated by multiplying an activity rate (AR), in this case the greenhouse area, by an emission factor (EF), expressed as the amount of emissions of nitrogen and phosphorus per hectare. Emission factors are calculated for each substance (N or P) and for each cultivation system (soil-grown crops or substrate-grown crops). This method of calculation is explained in detail in the "Handreiking Regionale aanpak diffuse bronnen" [1].

Emission = AR x EF

Where:
AR = area of soil-grown and substrate-grown crop (ha)
EF = nitrogen and phosphorus emission per ha (kg/ha/year)

3 Activity rates

The activity rate is the area of substrate-grown and soil-grown crop. It is assumed that surplus water is recirculated in substrate-grown crops but not in soil-based crops. Surveys of substrate-grown crops were collected in 1985 and 1990. In those years producers did not yet recirculate surplus water, and so no distribution over the type of cultivation was applied. Statistics Netherlands has no data available for substrate-grown crops for 2006. In 2005, 65% of vegetables and 18% of ornamental plants were grown on substrate. These percentages have been used to work out values for substrate-grown crops in 2006.

Table 1: Greenhouse cultivation area (ha) [8]

Type of cultivation	1985	1990	1995	2000	2005	2006
Substrate-grown crop			3,951	4,368	3,967	3,996
Soil-grown crop			6,202	6,123	6,527	6,498
Total	8,973	9,769	10,154	10,491	10,494	10,494

4 Emission factors

Emission factors are defined as the amount of emission of nitrogen or phosphorus per hectare. This is worked out by multiplying the concentration of nitrogen or phosphorus in the water by the amount of water leached per hectare. A fixed concentration and a fixed quantity of water leached per hectare are used for this purpose. These were determined on the basis of a study into waste

water problems in greenhouse cultivation [2]. The concentration and the flow rate are given in table 2, while table 3 shows the emission factors.

No distinction is made between soil-grown crops and substrate-grown crops in the year 1985 and the year 1990. A considerable amount of water was leached in those years because producers raising substrate-grown crops did not recirculate surplus water at that time. Only emission factors derived for soil-grown crops are used for those years.

Table 2: Concentrations of nitrogen and phosphorus in drainage water and spray water, and the flow rate of the quantity of water leached [2].

Type of cultivation	Nitrogen (mg N/l)	Phosphorus (mg P/l)	Flow rate (m^3/ha/day)
Substrate-grown crop	210	25	0.75
Soil-grown crop	155	7	6

Table 3: Emission factors: Nitrogen and phosphorus emissions per hectare from greenhouse cultivation

Type of cultivation	Nitrogen (kg N/ha/year)	Phosphorus (kg P/ha/year)
Substrate-grown crop	57.5	6.84
Soil-grown crop	339	15.3

5 Effects of policy measures

One measure affecting the calculation method is the increasing number of greenhouses that are connected to the sewers. This has an impact on the release into environmental compartments (chapter 7).

6 Emissions calculated

Emissions of Nitrogen and Phosphorus are calculated by multiplying the area from the type of cultivation by an emission factor for emission per hectare. Calculated emissions are shown in tables 4 and 5.

Table 4: Nitrogen emissions from cultivation with and without recirculation (tonnes/year)

Type of cultivation	1985	1990	1995	2000	2005	2006
Substrate-grown crop			227	251	228	230
Soil-grown crop			2,105	2,078	2,216	2,167
Total	3,050	3,320	2,330	2,330	2,440	2,400

Table 5: Phosphorus emissions from cultivation with and without recirculation (tonnes/year)

Type of cultivation	1985	1990	1995	2000	2005	2006
Substrate-grown crop			27	30	27	27
Soil-grown crop			95	94	100	100
Total	138	150	122	124	127	127

7 Release into environmental compartments

Emissions caused by discharge from greenhouse cultivation end up in surface water, soil and the sewers. The emission distribution is analogous to the distribution of zinc emissions from greenhouses used in horticulture (see [4]). The fractions are shown in table 6.

Table 6: Emission distribution

Type of cultivation	1985	1990	1995	2000	2005	2006
Surface water	25%	25%	25%	25%	25%	25%
Soil	75%	75%	75%	50%	25%	25%
Sewers				25%	50%	50%

Tables 7 and 8 show the emissions as presented in the emissions inventory. However, the calculation has been adjusted. The emissions reported in 1990 are actually those which occurred in 1985, those reported in 1995 occurred in 1990, etc. This will be taken into account in the next set of calculations to be performed in 2009.

Table 7: Nitrogen emissions to surface water, soil and sewers (tonnes/year)

Type of cultivation	1990	1995	2000	2005	2006
Surface water	761	829	583	602	611
Soil	2280	2490	1750	602	611
Sewers	0	0	0	1200	1220

Table 8: Phosphorus emissions to surface water, soil and sewers (tonnes/year)

Type of cultivation	1990	1995	2000	2005	2006
Surface water	34	37	31	31	32
Soil	103	112	92	31	32
Sewers	0	0	0	63	64

8 Description of emission pathways to water

Emissions into water arise from direct emissions into surface water and indirectly as a result of emissions from the sewer system, combined sewer overflows, and effluents from waste water treatment plants. The fact sheet "Effluents from waste water treatment plants and sewer systems" [5] describes this in further detail.

9 Spatial allocation

The spatial allocation of emissions is worked out on the basis of a set of digital maps held by the Netherlands Environmental Assessment Agency (MNP). These maps present the spatial distribution of all kinds of parameters throughout the Netherlands, such as population density, traffic intensity, area of agricultural crops, etc. For the purposes of emission registration these maps are used as 'locators' to determine the spatial distribution of emissions. The range of possible locators is limited (see [6] for a list of available locators), as not every conceivable parameter can be used as a locator. That is why the locator judged to be the best proxy of the activity rate of the emission in question is used.
It is assumed that the distribution of emissions throughout the country is proportional to the national distribution of the locator.

The table below shows the locator used for the spatial allocation of the various emission sources.

Table 9: Summary of spatial allocation method

Element of	Locators
Nutrients from greenhouses	Greenhouse surface area

The method used to determine the locators is described in [4]:

Greenhouse surface area
The greenhouse area was calculated using the map of grid cell distribution based on land use produced by the Netherlands national land use register (LGN) and the CBS agriculture survey. This map shows twelve land use categories down to an area of 500 x 500 metres. Total agricultural acreage is based on values in the CBS agriculture survey. The distribution of the various classes throughout the Netherlands is taken directly from LGN5, the national land use database for 2003-2004. Therefore, the total area from the CBS survey is distributed among locations as shown in LGN5.

10 Comments and changes in regard to previous version

The methodology was revised in the 2008 inventory. In subsequent inventories it will be assumed that all emissions are direct to water. However, some emissions do end up in the sewers. That is why the distribution of zinc emissions from greenhouses used in horticulture (see [4]) is now to be used as a model for the distribution over the compartments.

11 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 [7]. 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 activity rate is the greenhouse area. These values are determined by Statistics Netherlands on the basis of surveys. The estimate is therefore based on a large number of measurements at representative sites, and the AR is classed as A. The emission factor is based on measurements and calculations in 1988, at which time sufficient measurements were carried out but the values may already have changed significantly as a result of changes in operational practices. However, a recent survey [3] shows that the emission factors used are of the same order of magnitude as the emission factors measured, and the emission factor is therefore placed in reliability class C.
With regard to the distribution of nutrients among compartments, it is assumed that this is identical to the distribution of zinc emissions from greenhouses used in horticulture. Since that is an assumption, this factor is classified as D. Emission pathways to water are classified as B, as some emissions pass directly to water and some go via the sewers. Spatial allocation is based on data for fruit, vegetable and flower-growing in the Netherlands. This is a reliable indicator for emissions due to greenhouse cultivation (class B).

Element of emission calculation	**Reliability classification**
Activity rates	A
Emission factor	C
Distribution among compartments	D
Emission pathways to water	B
Spatial allocation	B

Areas for improvement:

- In addition to emission factors split-up for substrate-grown and soil-grown crops it might be possible to take into account a separate emission factors relating to food plant production and ornamental plant growing. A study into emissions of nitrogen and phosphorus from greenhouse cultivation [3] clearly shows that emissions from these two forms of cultivation can vary considerably (see also appendix 1).
- In order to improve spatial allocation, it might be possible to apply a spatial distribution to emissions on the basis of substrate-grown and soil-grown crops. This would allow emissions caused by substrate-grown crops and those caused by soil-grown crops to be assessed separately.
- At the moment there is a time lag in the recording of emissions in the emission inventory. Emissions that occurred in 1985 are reported as 1990 emissions, and so on. The next inventory should include the correct emissions.

12 Request for reactions

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13 References

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[4] Rijkswaterstaat waterdienst, 2008. Corrosie gegalvaniseerd staal en bladzink, factsheets diffuse bronnen. RWS-WD, Lelystad, juni 2008

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[7] Most, P.F.J. van der, van Loon, M.M.J., Aulbers, J.A.W. en van Daelen, H.J.A.M., juli 1998. Methoden voor de bepaling van emissies naar lucht en water. Publicatiereeks Emissieregistratie, nr. 44.

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Appendix 1
Validation of the emission factors

RIZA carried out a survey into emissions of nitrogen and phosphorus from greenhouse cultivation in 2004 [3]. Water boards were asked to collect data on emissions from businesses in the sector. Producers are required to keep monthly records of spray water, drain water and drainage water volumes. They are also obligated to measure nitrogen and phosphorus concentrations in the water at least once a month.

This data can be used to calculate nitrogen and phosphorus emissions per hectare. In the case of food plant production, this results in average emission levels not exceeding 10 kg N/ha/year and 5 kg P/ha/year. Emissions from ornamental plant production are much higher: for roses, average emissions are over 250 kg N/ha/year and around 57 kg P/ha/year.

We can compare these values with emissions per hectare as calculated in this fact sheet. Table B1.1 shows average emission factors for 2000, 2004 and 2005.

Table B1.1: Average emission factors for nitrogen and phosphorus, as calculated in this fact sheet.

Element	Nitrogen (kg N/ha/year)	Phosphorus (kg P/ha/year)
Average emission factor (2000)	222	11.8
Average emission factor (2004)	231	12.1
Average emission factor (2005)	233	12.1

The average calculated emission factors for 2000, 2004 and 2005 lie between the emission factors for food plant production and ornamental plant production. In the light of this it was decided not to change the calculation method.