Emission estimates for diffuse sources
Netherlands Emission Inventory

Unintended fertilization of ditches

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

Unintended fertilization of ditches

1 Description

When fertilisers and manure are spread on farmland, part of it will cause unintended load of ditches. Thus the neighbouring surface water will be polluted with substances contained in fertilisers, such as nitrogen (N) and phosphorus (P). This fact sheet describes a method of calculating emissions of nitrogen and phosphorus into water as a result of discharge into ditches during application of manure and artificial fertiliser. This emission source is attributed to the governmental target sector "Agriculture". Since 1995 a distinction has been made between fertiliser application to arable land and to pasture, but in the preceding years no such distinction was made.

2 Explanation of calculation method

Emissions are calculated by multiplying an activity rate (AR), in this case the surface area of ditches adjacent to farmland, by an emission factor (EF), expressed as nutrient load per km^2 of ditch. This method of calculation is explained in detail in the 'Handreiking Regionale aanpak diffuse bronnen' [1].

Emission = AR x EF

Where:
AR = Ditch surface area adjacent to farmland (km^2)
EF = N and P load per area of ditch (tonnes/km^2/year)

3 Activity rates

The activity rate is the surface area of ditches directly adjacent to farmland. It is assumed that a ditch with farmland on both sides will receive twice as much fertiliser. For that reason the ditch area is doubled in this case.

The surface area of ditches directly adjacent to farmland is calculated by multiplying the farmland surface area (pasture or arable land) by the ditch density (10 km/km^2), [2]), the number of ditch sides (2), the average width of the ditch (0.002 km) and the proportion of ditch sides that run alongside farmland (0.83 [3]). Farmland surface area statistics are published once a year by RIVM, the Netherlands National Institute for Public Health and the Environment. The activity rates are shown in table 1.

Table 1: Activity rate: Surface area of ditches directly adjacent to farmland (km^2)

Type of farmland	1985	1990	1995	2000	2005	2006
Pasture			348.6	335.3	334.7	330.7
Arable land			302.1	308.8	309.0	286.1
Total	670.3	665.9	642.5	644.1	643.7	616.8

4 Emission factors

The emission factor is the amount of N and P per km^2 of ditch surface area that ends up in the ditch. The computer program "Kantstrooi Advies Systeem" (see appendix 1) and the annual fertiliser application volume are used to calculate fertiliser load in ditches (tables 2 and 3).

Table 2: Emission factors: Amount of nitrogen per ditch surface area (kg N/km² of ditch)

Fertiliser	1985	1990	1995	2000	2005	2006
Manure	672	527				
• Pasture			0	0	0	0
• Arable land			199	147	128	134
Artificial fertiliser	10,260	7,920				
• Pasture			7,613	6,374	4,669	3,992
• Arable land			4,130	3,534	3,093	3,310

Table 3: Emission factors: Amount of phosphorus per ditch surface area (kg P/km² of ditch)

Fertiliser	1985	1990	1995	2000	2005	2006
Manure	128	102				
• Pasture			0	0	0	0
• Arable land			37.7	34.6	28.7	31.0
Artificial fertiliser	891	592				
• Pasture			333	440	255	143
• Arable land			553	408	364	405

5 Effects of policy measures

Fertiliser distribution techologies have changed in recent years. The Agriculture Discharge Decree came into force in 2000. This requires fertiliser distributors to have features to control application at the edge. This is taken into account at the percentages for various application techniques described in appendix 1.

6 Emissions calculated

Emissions of nitrogen and phosphorus are calculated by multiplying the ditch surface area by the emission factor (kg per ditch surface area). The emissions are shown in tables 4 and 5.

Table 4: Emission of nitrogen in ditches (tonnes N/year)

Fertiliser	1985	1990	1995	2000	2005	2006
Manure	450	350				
• Pasture			0	0	0	0
• Arable land			60	45	40	38
Artificial fertiliser	6,870	5,280				
• Pasture			2,650	2,137	1,562	1,320
• Arable land			1,250	1,091	956	947
Total N	**7,320**	**5,630**	**3,960**	**3,270**	**2,560**	**2,306**

Table 5: Emission of phosphorus in ditches (tonnes P/year)

Fertiliser	1985	1990	1995	2000	2005	2006
Manure	85	68				
• Pasture			0	0	0	0
• Arable land			11	17	9	9
Artificial fertiliser	597	394				
• Pasture			120	148	85	47
• Arable land			170	126	113	116
Total P	**682**	**462**	**301**	**290**	**210**	**172**

7 Release into environmental compartments

All of the emissions produced by unintended fertilization of ditches directly enter the surface water.

8 Description of emission pathways to water

All of the emissions into water take place by means of direct discharge into surface water.

9 Spatial allocation

The spatial allocation of emissions is assigned on the basis of a set of digital maps held by the Netherlands Environmental Assessment Agency (PBL). These maps present the spatial distribution of all kinds of parameters throughout the Netherlands, such as population density, traffic intensity, area of agicultural 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 [4] 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 6: Summary of spatial allocation method

Element	Locators
Unintended fertilization of ditches	Arable crop area

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

Arable crop area
The arable crop 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 data in the yearly agricultural census (Statistics Netherlands). 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

There have been no changes to the methods compared to previous version.

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 [5]. 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 based on RIVM data and then calculated using a number of assumptions (which are themselves largely based on other studies). The activity rate is therefore based on a number of measurements, plus assumptions, and is therefore classified as C. The emission factor is based on

fertiliser use data and then the edge-spreading advisory system is applied to work out how much ends up in ditches. The emission factor is based on a small number of measurements and is classified as D.
There is only one compartment and one emission pathway into water. No other compartments or pathways would be possible under the definition of this fact sheet, and this element is therefore classified as A.
Spatial allocation is carried out on the basis of data for arable farming, horticulture, etc. This data is quite accurate and relevant for spatial allocation: class C.

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

The most significant areas for improvement are:
- The Emission Inventory currently records the total emission of Nitrogen and Phosphorous. Values for emissions from arable land and from pasture are not available. The total emission values are also used in spatial allocation. Spatial allocation could be improved when emission values for pasture and for arable land would be assessed separately. In such case emissions for pasture and for arable land would be shown separately in spatial allocation.
- The computer program "Kantstrooi Advies System" was launched in 1989, and fertiliser application techniques may have improved since then. Revision of the computer programme could make the calculations more up-to-date, reflecting the state of the art.

12 Request for reactions

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13 References

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[2] Gaast, J.W.J. en van Bakel, P.J.T., 1997. Differentiatie van waterlopen ten behoeve van het bestrijdingsmiddelenbeleid in Nederland, rapport 526, DLO-Staring Centrum, Wageningen.

[3] Twisk, W., van Strien, A.J. en ter Keurs, W.J., 1991. Emissies naar het oppervlaktewater door meemesten van sloten. H_2O 24 (1), 2-5.

[4] Molder, R. te, 2007. Notitie ruimtelijke verdeling binnen de emissieregistratie. Een overzicht.

[5] 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.

[6] Melman, Th.C.P. en Huele, R., 1989. Het kantstrooi advies systeem. Centrum voor Milieukunde Leiden, CML mededeling 53, Rijksuniversiteit Leiden.

Appendix 1
Calculation of emission factors

Emission factors are calculated in a two-stage process:
Stage 1: calculating fertiliser load in ditches using the "Kantstrooi Advies Systeem".
Stage 2: correcting the value for fertiliser load obtained in stage 1 for the application methods used.

Stage 1
calculating fertiliser load in ditches using the "Kantstrooi Advies Systeem"

The computer program "Kantstrooi Advies Systeem" (KAS) works out the consequences of the size of the strip of land to which no fertiliser is applied for the farm and the environment [6]. If the distance from the ditch is too small, a large quantity of fertiliser will be wasted as it is sprinkled into the ditch. If the distance is too great, the edges of the land will not receive enough fertiliser. This will be detrimental to yields. The KAS system works out fertiliser load in ditches for a variety of fertiliser application methods at a given distance from the ditch and a given fertiliser application rate per hectare of arable land. The system can be used to calculate fertiliser load as shown in table B1.3. Data on the fertiliser application method and the application rate are needed to execute this calculation.

<u>Fertiliser application</u>
A number of assumptions are made with regard to fertiliser application (spreader, working width and distance from the ditch):

- 1985 and 1990:
  - All manure is applied to the land using a "Schuitemaker" spreader.
  - 55% of artificial fertiliser is applied using a pendulum spreader ("Vicon") and 45% using a disc spreader ("Amazone").
- From 1995 onwards:
  - All manure is applied to the land using a "Schuitemaker" spreader.
  - Artificial fertiliser is applied to pasture land using a pendulum spreader ("Vicon") and to arable land using a disc spreader ("Amazone").

More information about these spreaders is given in table B1.1. These values are used in the edge-spreading advisory system to work out fertiliser load.

Table B1.1: Spreaders in the KAS system, used to calculate fertiliser load, with the working width and distance from the ditch used in the calculation.

Spreader	Working width (m)	Distance from the ditch (m)
Schuitemaker SR 10000 L with spreader plate	12	6
Vicon Superflow 603 full-field	12	6
Amazone ZAU 1001, full-field	14	7

<u>Fertiliser application rate</u>
The fertiliser application rate per hectare is worked out by dividing the total amount of fertiliser applied (determined by RIVM) by the total area of farmland (determined by Statistics Netherlands). This gives the load levels shown in table B1.2.

Table B1.2: Fertiliser application (kg/ha of farmland)

Substance	Fertiliser	1985	1990	1995	2000	2005	2006
Nitrogen (kg N/ha)	Manure	305	239				
	• Pasture			362	146	142	1)
	• Arable land			170	154	132	121
	Artificial fertiliser	260	201				
	• Pasture			278	234	198	171
	• Arable land			120	102	100	107
Phosphorus (kg P/ha)	Manure	58	47				
	• Pasture			55	27	25	1)
	• Arable land			35	36	29	28
	Artificial fertiliser	23	15				
	• Pasture			12	16	11	6
	• Arable land			16	12	12	13

1) No more detailed information on the amount of manure applied to pasture. As slurry spreaders are not used to apply manure to pasture, practically no ditch load occurs. The absence of a value is not significant to subsequent calculations.

Stage 2
correcting the value for fertiliser load obtained in stage 1 for the application methods used

Fertiliser load was calculated in stage 1 using the edge-spreading advisory system. The results of this calculation are shown in table B1.3.

Table B1.3: Fertiliser load (nitrogen and phosphorus) in ditches (kg/m^2 of ditch), as calculated using the edge-spreading advisory system.

Substance	Fertiliser	1985	1990	1995	2000	2005	2006
Nitrogen (kg N/km^2 ditch)	Manure	790	620				
	• Pasture			0	0	0	0
	• Arable land			440	397	338	312
	Artificial fertiliser	10,260	7,920				
	• Pasture			8,700	7,284	6,225	5,323
	• Arable land			5,900	5,048	4,949	5,296
Phosphorus (kg P/km^2 ditch)	Manure	150	120				
	• Pasture			0	0	0	0
	• Arable land			88	93	76	72
	Artificial fertiliser	891	592				
	• Pasture			380	503	340	190
	• Arable land			790	583	583	648

The calculation in stage 1 assumes that all fertiliser is applied using the three types of equipment referred to above. However, this is not the case and therefore a further correction is applied. This is done on the basis of the following assumptions:

- Manure:
  - Unintended fertilization of ditches occurs only when a slurry tank is used.
  - Unintended fertilization arises only from liquid manure and not from solid manure.
- Artificial fertiliser:
  - Use of edge-spreading equipment results in a 50% reduction in emissions.
  - Other application techniques do not result in emission reduction.

Table B1.4 indicates how fertiliser is applied to pasture and arable land. It also indicates what proportion of manure is in liquid form.

Table B1.4: Application of fertiliser using a slurry tank and edge-spreading equipment.

Fertiliser	1985	1990	1995	2000	2005	2006
Manure						
• Slurry tank	100%	100%				
○ Pasture			0%	0%	0%	0%
○ Arable land			58%	37%	38%	43%
• Other methods	0%	0%				
○ Pasture			100%	100%	100%	100%
○ Arable land			42%	63%	62%	57%
• Liquid manure in the slurry tank	85%	85%	74-78% [1)]	100%	100%	100%
Artificial fertiliser						
• Edge-spreading equipment	0%	0%				
○ Pasture			25%	25%	50%	50%
○ Arable land			60%	60%	75%	75%
• Other methods	100%	100%				
○ Pasture			75%	75%	50%	50%
○ Arable land			40%	40%	25%	25%

[1)] In 1995: 74% of the P and 78% of the N was in liquid form

The emission factors were calculated by multiplying the fertiliser load in the ditches (table B3) by the application methods fraction (table B4) using the formulae set out below:

$$EF_{manure} = Load_{manure} \times f_{slurry\ tank} \times f_{liquid}$$
$$EF_{artificial\ fertiliser} = Load_{artificial\ fertiliser} \times (1 - 0.5 \times f_{edge\text{-}spreading\ equipment})$$

Where:

EF_{manure}	= Emission factor for manure (kg/km^2 ditch)
$EF_{artificial\ fertiliser}$	= Emission factor for artificial fertiliser (kg/km^2 ditch)
$Load_{manure}$	= Manure load according to the edge-spreading advisory system (kg/km^2 ditch)
$Load_{artificial\ fertiliser}$	= Artificial fertiliser load according to the edge-spreading advisory system (kg/km^2 ditch)
$f_{slurry\ tank}$	= Fraction of manure applied using a slurry tank
f_{liquid}	= Fraction of manure that is in liquid form
$f_{edge\text{-}spreading\ equipment}$	= Fraction of artificial fertiliser applied using edge-spreading equipment

This calculation is executed separately for each substance (Nitrogen and Phosphorous) and each type of land use (pasture and arable land). These calculations are then assembled to produce the emission factors in tables 2 and 3.