Emission estimates for diffuse sources
Netherlands Emission Inventory

Unintended fertilization of ditches

Version dated June 2008

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].

\[
\text{Emission} = \text{AR} \times \text{EF}
\]

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.

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</thead>
<tbody>
<tr>
<td>Pasture</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>670.3</td>
<td>665.9</td>
<td>642.5</td>
<td>644.1</td>
<td>643.7</td>
<td>616.8</td>
</tr>
</tbody>
</table>

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)

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</thead>
<tbody>
<tr>
<td>Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Pasture</td>
<td>672</td>
<td>527</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Arable land</td>
<td>199</td>
<td>147</td>
<td>128</td>
<td>134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>10,260</td>
<td>7,920</td>
<td>7,613</td>
<td>6,374</td>
<td>4,669</td>
<td>3,992</td>
</tr>
<tr>
<td>• Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
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</tr>
</tbody>
</table>

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

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</thead>
<tbody>
<tr>
<td>Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Pasture</td>
<td>128</td>
<td>102</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Arable land</td>
<td>37.7</td>
<td>34.6</td>
<td>28.7</td>
<td>31.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>891</td>
<td>592</td>
<td>333</td>
<td>440</td>
<td>255</td>
<td>143</td>
</tr>
<tr>
<td>• Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

5 Effects of policy measures

Fertiliser distribution technologies 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)

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>450</td>
<td>350</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Pasture</td>
<td>60</td>
<td>45</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>6,870</td>
<td>5,280</td>
<td>2,650</td>
<td>2,137</td>
<td>1,562</td>
<td>1,320</td>
</tr>
<tr>
<td>• Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total N</td>
<td>7,320</td>
<td>5,630</td>
<td>3,960</td>
<td>3,270</td>
<td>2,560</td>
<td>2,306</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>85</td>
<td>68</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>• Pasture</td>
<td>11</td>
<td>17</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>597</td>
<td>394</td>
<td>120</td>
<td>148</td>
<td>85</td>
<td>47</td>
</tr>
<tr>
<td>• Pasture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total P</td>
<td>682</td>
<td>462</td>
<td>301</td>
<td>290</td>
<td>210</td>
<td>172</td>
</tr>
</tbody>
</table>

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 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 [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>
<thead>
<tr>
<th>Element</th>
<th>Locators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unintended fertilization of ditches</td>
<td>Arable crop area</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Element of emission calculation</th>
<th>Reliability classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity rates</td>
<td>C</td>
</tr>
<tr>
<td>Emission factor</td>
<td>D</td>
</tr>
<tr>
<td>Distribution among compartments</td>
<td>A</td>
</tr>
<tr>
<td>Emission pathways to water</td>
<td>A</td>
</tr>
<tr>
<td>Spatial allocation</td>
<td>C</td>
</tr>
</tbody>
</table>

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

Any questions or comments regarding this working paper should be addressed to Richard van Hoorn, Centre for Water Management, +31 (0)320 298491, email richard.van.hoorn@rws.nl or Joost van den Roovaart, Deltares, +31 (0)6 57315874, email joostvandenroovaart@deltares.nl.

13 References


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.

Fertiliser application  
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>
<thead>
<tr>
<th>Spreader</th>
<th>Working width (m)</th>
<th>Distance from the ditch (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schuitemaker SR 10000 L with spreader plate</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Vicon Superflow 603 full-field</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Amazone ZAU 1001, full-field</td>
<td>14</td>
<td>7</td>
</tr>
</tbody>
</table>

Fertiliser application rate  
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)

<table>
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</thead>
<tbody>
<tr>
<td>Nitrogen (kg N/ha)</td>
<td>Manure</td>
<td>305</td>
<td>239</td>
<td>362</td>
<td>146</td>
<td>142</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>• Pasture</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>Pasture</td>
<td>260</td>
<td>201</td>
<td>278</td>
<td>234</td>
<td>198</td>
<td>171</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorus (kg P/ha)</td>
<td>Manure</td>
<td>58</td>
<td>47</td>
<td>55</td>
<td>27</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>• Pasture</td>
<td></td>
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<tr>
<td></td>
<td>• Arable land</td>
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<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>Pasture</td>
<td>23</td>
<td>15</td>
<td>12</td>
<td>16</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
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</tbody>
</table>

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/m² of ditch), as calculated using the edge-spreading advisory system.

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (kg N/m² ditch)</td>
<td>Manure</td>
<td>790</td>
<td>620</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>• Pasture</td>
<td></td>
<td></td>
<td>440</td>
<td>397</td>
<td>338</td>
<td>312</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>Pasture</td>
<td>10,260</td>
<td>7,920</td>
<td>8,700</td>
<td>7,284</td>
<td>6,225</td>
<td>5,323</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
<td>5,900</td>
<td>5,048</td>
<td>4,949</td>
<td>5,296</td>
</tr>
<tr>
<td>Phosphorus (kg P/m² ditch)</td>
<td>Manure</td>
<td>150</td>
<td>120</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>• Pasture</td>
<td></td>
<td></td>
<td>88</td>
<td>93</td>
<td>76</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artificial fertiliser</td>
<td>Pasture</td>
<td>891</td>
<td>592</td>
<td>380</td>
<td>503</td>
<td>340</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>• Arable land</td>
<td></td>
<td></td>
<td>790</td>
<td>583</td>
<td>583</td>
<td>648</td>
</tr>
</tbody>
</table>

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.

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<thead>
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</thead>
<tbody>
<tr>
<td>Manure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Slurry tank</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>o Pasture</td>
<td>58%</td>
<td>37%</td>
<td>38%</td>
<td>43%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Other methods</td>
<td>0%</td>
<td>0%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>o Pasture</td>
<td></td>
<td></td>
<td>42%</td>
<td>63%</td>
<td>62%</td>
<td>57%</td>
</tr>
<tr>
<td>o Arable land</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Liquid manure in the slurry tank</td>
<td>85%</td>
<td>85%</td>
<td>74-78%</td>
<td>100%</td>
<td>100%</td>
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<td>Artificial fertiliser</td>
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<tr>
<td>• Edge-spreading equipment</td>
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<td>o Pasture</td>
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<td>o Arable land</td>
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</table>

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:

\[
EF_{\text{manure}} = \text{Load}_{\text{manure}} \times f_{\text{slurry tank}} \times f_{\text{liquid}} \\
EF_{\text{artificial fertiliser}} = \text{Load}_{\text{artificial fertiliser}} \times (1 - 0.5 \times f_{\text{edge-spreading equipment}})
\]

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