Evaluation of the acidification targets:
the emission variants

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General
The National Institute of Public Health and the Environment (RIVM) contributed to the evaluation of the acidification targets announced in the Third National Environmental Policy Plan (NEPP3) in two phases. The first phase centred on the report Evaluation of the acidification targets: the basis (Evaluatie van de verzuringsdoelstellingen: de onderbouwing) (Albers et al., 2001). This report brought together the existing knowledge in the area of acidification and indicated to what extent this has changed since the current acidification targets were set (in 1989). In the second phase, new information was incorporated into the range of models available and the effects of a number of emission variants were studied. This report presents an account of that process. The purpose of these calculations is to gain insight into the interrelationship between emissions, environmental quality and health risks for the new environmental quality and emission targets to be determined in NEPP4. The following environmental quality parameters were considered: the effects of potential acid and nitrogen deposition, the direct effects of ozone on vegetation and the effects of ozone, nitrogen dioxide and particulate matter on public health.

The emission variants
The effects of seven emission levels were calculated for acidifying substances (SO$_2$, NO$_x$, NH$_3$ and VOCs) (see Table A). This was done on the basis of international agreements and emission targets set out in NEPP3. It has been assumed that foreign emissions are being reduced in accordance with the Gothenburg Protocol and the National Emission Ceiling (NEC) Directive proposed by the EU. The European Commission's 1999 NEC proposals have been used here. These set out far greater reductions than the Gothenburg agreements. In the meantime, however, the European Environment Council has adopted a common position on emission ceilings, at approximately the same level as in the Gothenburg Protocol. For the Netherlands the new NEC for NO$_x$ and VOCs is 6 kt below the Gothenburg Protocol, while the SO$_2$ and NH$_3$ figures are identical. The European Parliament is sticking to the Commission's original figures, except in the case of NH$_3$. Once the conciliation procedure has been completed, the NEC Directive is expected to come into force in mid-2001. In order to maintain sufficient 'bandwidth', the 1999 NEC proposals are used in this study.

Due to the significant influence of ammonia emissions on nearby habitats, one variant is aimed at local measures. Here, the ammonia emissions from agriculture have been geographically distributed by province in such a way that the impact of nitrogen deposition on the environment and on habitats is minimised. In addition to this, as part of a collaborative venture between several ministries, a variant describing the use of additional measures in the Netherlands has been formulated. The ambitious NEPP3 emission targets for 2010 have also been combined with similar assumptions for emissions abroad, with the help of the Maximum Feasible Reductions (MFR) scenario (Amann et al., 1999). This MFR scenario describes the results of maximising policy efforts over the next 10 years. The last variant works back from a specific desired level of environmental quality to emissions. The desired level of quality is based on the high percentage of habitats protected against the deposition of potential acids and nitrogen defined by the Directorate-General for Environmental Protection.

The aim of this study is to show the relationship between emissions and effects at various emission levels. The way in which emission levels are reached has therefore been disregarded; this means that the variants have not been assessed in terms of policy effectiveness and efficiency. For the sake of simplicity the seven emission variants have been labelled with a name and a tentative year (Table A).
### Table A. Summary of calculated emission variants

<table>
<thead>
<tr>
<th>Variant</th>
<th>Description</th>
<th>Emissions in the Netherlands (kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The Netherlands</td>
<td>EU countries</td>
</tr>
<tr>
<td>2010-basic</td>
<td>NEC</td>
<td>Goth</td>
</tr>
<tr>
<td>2010-NH\textsubscript{3} optimum</td>
<td>NEC, NH\textsubscript{3} optimum</td>
<td>Goth</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>NEC</td>
<td>NEC</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>additional measures</td>
<td>Goth</td>
</tr>
<tr>
<td>2010-NL extra</td>
<td>NEPP3</td>
<td>MFR</td>
</tr>
<tr>
<td>2030</td>
<td>quality target</td>
<td>Proport. reduction</td>
</tr>
</tbody>
</table>

Goth = Gothenburg Protocol, NEC = Commission's NEC proposal, MFR = MFR scenario.

### Potential acid and nitrogen deposition

The difference between the current situation (1997) and the variants in 2010 is considerable, but there are still significant problem areas (Tables B and C). The 2010 deposition targets set out in NEPP3 of 1400 mol potential acid/ha/year and 1000 mol nitrogen/ha/year will not be achieved during the next 10 years (Table B). The Gothenburg Protocol and the original NECs are not sufficient to meet these deposition targets. Further Dutch policy measures in addition to the Gothenburg Protocol are also insufficient. Over 75% of ecosystem hectares will remain unprotected against potential acid and nitrogen deposition (or have deposition levels above the critical deposition levels) during the next 10 years in all variants in large parts of the Netherlands, and particularly in the south-east. The impact of extra reductions in emissions in the Netherlands over and above the Gothenburg Protocol nevertheless has a significant effect on lowering the total exceedances of the critical deposition levels and reduces the risks to ecosystems. These are 20-35% and 25-45% lower than the Gothenburg Protocol for potential acid and nitrogen respectively. More drastic Dutch policy measures in the form of a shift in agricultural ammonia emissions from habitat\textsuperscript{1} to agricultural land (as compared with the 2010-basis variant) leads to an additional reduction of approximately 30% in the total exceedances of the critical nitrogen deposition in the Netherlands.

Only if the emission targets set out in NEPP3 are implemented, and if similar efforts are made abroad, will it be possible to achieve the NEPP3 deposition targets before 2010. In that case it is calculated that 60% of the area covered by terrestrial ecosystems will be protected against excessively high potential acid deposition; the corresponding figure for nitrogen deposition is 80%. The target situation is intended to be a significant improvement. At that level of emissions it is calculated that approximately 90% of the area covered by terrestrial ecosystems will be protected against excessively high potential acid deposition; the corresponding figure for nitrogen deposition is also 90%. Large areas of vulnerable higher-

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\textsuperscript{1} Habitat is defined here as the 1 x 1 km\textsuperscript{2} grid cells in which more than 25% of the surface area is habitat. By making these grid cells free of NH\textsubscript{x} emissions, an area (ranging from 0-1000m) around habitat can implicitly be kept free of emissions.
lying sandy soils and dunes will also be protected against the adverse effects of potential acid and nitrogen deposition. There will still be several instances of exceedance, however. The deposition calculations do not contain any correction for the 'ammonia gap': the difference that has been found between measured and calculated ammonia concentrations. Information about the size of the gap indicates that the deposition of potential acid and nitrogen in 1997, for example, was underestimated by several hundred moles. It is not completely clear what causes the difference and how it will develop in the emission variants under consideration. In order to be able to compare the reference years and emission variants in terms of changes in emissions, no correction has been made in this study.

Table B. The total and average deposition of potential acid and nitrogen on terrestrial ecosystems. All figures have been calculated, including those for 1980, 1990 and 1997.

<table>
<thead>
<tr>
<th>reference year / emission variant</th>
<th>total deposition</th>
<th>average deposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>potential acid (Mmol.y(^{-1}))</td>
<td>nitrogen (Mmol.y(^{-1}))</td>
</tr>
<tr>
<td>1980</td>
<td>23730</td>
<td>11290</td>
</tr>
<tr>
<td>1990</td>
<td>17550</td>
<td>11020</td>
</tr>
<tr>
<td>1997</td>
<td>11970</td>
<td>8330</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>8640</td>
<td>6290</td>
</tr>
<tr>
<td>2010-basic</td>
<td>7960</td>
<td>5600</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>7460</td>
<td>5360</td>
</tr>
<tr>
<td>2010-NL-extra</td>
<td>7430</td>
<td>5150</td>
</tr>
<tr>
<td>2020-NEPP3</td>
<td>4870</td>
<td>3200</td>
</tr>
<tr>
<td>2030</td>
<td>3340</td>
<td>1990</td>
</tr>
</tbody>
</table>

Table C. The total and average exceedance of the critical values for potential acid and nitrogen deposition on terrestrial ecosystems\(^{1,2}\). Values for the Netherlands.

<table>
<thead>
<tr>
<th>reference year / emission variant</th>
<th>total exceedance</th>
<th>average exceedance</th>
<th>acreage of terr. ecosystems with no exceedance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>potential acid (Mmol.y(^{-1}))</td>
<td>nitrogen (Mmol.y(^{-1}))</td>
<td>potential acid (mol.ha(^{-1}.y^{-1}))</td>
</tr>
<tr>
<td>1980</td>
<td>6280</td>
<td>2550</td>
<td>4910</td>
</tr>
<tr>
<td>1990</td>
<td>4110</td>
<td>2470</td>
<td>3370</td>
</tr>
<tr>
<td>1997</td>
<td>2390</td>
<td>1620</td>
<td>2090</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>1180</td>
<td>830</td>
<td>1150</td>
</tr>
<tr>
<td>2010-basic</td>
<td>950</td>
<td>600</td>
<td>970</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>800</td>
<td>530</td>
<td>850</td>
</tr>
<tr>
<td>2010-NL-extra</td>
<td>790</td>
<td>460</td>
<td>850</td>
</tr>
<tr>
<td>2020-NEPP3</td>
<td>200</td>
<td>100</td>
<td>420</td>
</tr>
<tr>
<td>2030</td>
<td>50</td>
<td>20</td>
<td>270</td>
</tr>
</tbody>
</table>

1) Critical values are a combination of critical values for the protection of soil, groundwater, root growth, woodland and habitats (biodiversity) (Albers et al., 2001).
2) Exceedances relate to the 1 x 1 km² grid cells in which a critical value has been defined. These grid cells cover approximately 80-90% of the national ecological network.

**Ozone**

In this study the ambient air quality in terms of ozone has been tested against the target values and objectives in the draft EU Daughter Directive (COM(99)125). The long-term objective for health protection (no exceedance of the 8-hour daily maximum of 120 µg.m⁻³) is not achieved in any of the variants (Table D). Tighter Dutch policy measures over and above the Gothenburg Protocol produce only a slight improvement. As far as ozone abatement policy is concerned, a European approach is most appropriate. In the 2010 variants the EC proposal for the intermediate objective for the year 2010 (average over three years of less than 20² days on which the 8-hour daily maximum of 120 µg.m⁻³ is exceeded) may be achieved. Compared to the present situation, the AOT40 (sum of all hourly values greater than 80 µg.m⁻³ during daylight hours in May, June and July) in Dutch habitats will fall by approximately 25% over the next 10 years.

The peak concentrations of ozone will be lower: over the next 10 years the 95th percentile will fall by 5 µg.m⁻³. The peaks will then be further reduced; the 95th percentile will fall in the two lowest emission levels by 10 and 20 µg.m⁻³ compared to the present situation. On the other hand, the average concentration of ozone in the variants will rise to approximately 10 µg.m⁻³ compared to recent years. This is relevant because of the debate on the form of exposure-response relationships: where there is a linear relationship the effect of a reduction in peak concentrations can be compensated for by the rising average. Where there is an exponential relationship it is mainly 'trimming peaks' that yields benefits in health terms.

**Table D. Environmental indicators for 1990, 1997 and emission variants for 2010-2030. All data have been calculated.**

<table>
<thead>
<tr>
<th>emission variant</th>
<th>ozone, sunny year²</th>
<th>PM₁₀</th>
<th>NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>number of days</td>
<td>AOT₄₀</td>
<td>annual average concentration, average for Netherlands predators (µg/m³)</td>
</tr>
<tr>
<td></td>
<td>exceeding 120 µg/m³ - 8 h daily max., NL average</td>
<td>(µg.m⁻³.h) average in NL habitats</td>
<td>µg/m³</td>
</tr>
<tr>
<td>1980</td>
<td>34</td>
<td>26500</td>
<td>49</td>
</tr>
<tr>
<td>1990</td>
<td>39</td>
<td>28500</td>
<td>40</td>
</tr>
<tr>
<td>1997</td>
<td>28</td>
<td>22500</td>
<td>40</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>22</td>
<td>18000</td>
<td>32</td>
</tr>
<tr>
<td>2010-basic</td>
<td>22</td>
<td>18000</td>
<td>32</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>20</td>
<td>17000</td>
<td>31</td>
</tr>
<tr>
<td>2010-NL-extra</td>
<td>22</td>
<td>18000</td>
<td>32</td>
</tr>
<tr>
<td>2020-NEPP³</td>
<td>13</td>
<td>12500</td>
<td>no calculation</td>
</tr>
<tr>
<td>2030</td>
<td>3</td>
<td>7500</td>
<td>no calculation</td>
</tr>
</tbody>
</table>

1) In the 2010-basic to 2030 variants, no exceedances are calculated on a 5 x 5 km² scale. Emission peaks alongside roads and in towns and cities may, however, lead to exceedances locally.

2 The European Environment Council on 10 October 2000 adopted a common position on a maximum of 25 days in excess of the WHO target and an AOT₄₀ of 18000 µg.m⁻³.h by 2010.
2) These ozone figures apply to a sunny year. In the Daughter Directive, the 2010 intermediate targets for health and ecosystems are presented as a three-year and a five-year average respectively.

When the Gothenburg Protocol is implemented, the five-year AOT40 average is lower than the EU proposal for 2010 (17000 μg.m⁻³.h⁻¹) in approximately 90% of habitats. The goal of achieving an AOT40 of less than 14000 μg.m⁻³.h⁻¹ by 2020 seems to be achievable if the NEPP3 emission targets are implemented. In the lowest variant the AOT40 falls to 7500 μg.m⁻³.h⁻¹. This means that the ozone load for 75% of habitats is still above the sustainable level (6000 μg.m⁻³.h⁻¹). The target of complete protection of the national ecological network by 2030 is within sight, but has not yet been achieved.

The number of exceedances of the hourly average of 180 μg.m⁻³ (the information threshold in the Ozone Directive) will fall sharply over the next 10 years to less than five per year. In the variants for 2020 and 2030 no more exceedances are found.

Particulate matter
The variation in the 2010 calculations for particulate matter is only caused by secondary acidic aerosol. In the case of emissions of primary PM₁₀, the emissions in accordance with current and proposed policy are always used. The annual average concentration of particulate matter in the Netherlands will fall from 40 μg.m⁻³ in 1997 to approximately 30 μg.m⁻³ in 2010 (Table D). This annual average value of 30 μg/m³ corresponds to approximately 35 exceedances of the daily average standard of 50 μg.m⁻³, which will come into force as early as 2005. By 2010 the daily standard should not be exceeded more than seven times a calendar year. The latter is an indicative limit value. The differences between the 2010 variants are small (approximately 1 μg.m⁻³). This is partly due to the fact that the bulk of particulate matter concentrations are accounted for by other countries and that in three out of the four 2010 variants for other countries the Gothenburg Protocol is applied. It is clear from the 2010 calculations that the indicative EU limit value of 20 μg.m⁻³ will be significantly exceeded during the period up to 2010. No calculations for particulate matter have been carried out for 2020 and 2030.

NO₂
In all emission variants a fall in concentrations of NO₂ (weighted average for the population and by area) is calculated in relation to 1997. The 2010 Gothenburg variant falls the least; in calculations of long-term average meteorological conditions, the limit value is still exceeded (40 μg.m⁻³). Under unfavourable meteorological conditions (in terms of ambient air quality) an exceedance is found for 2010 for each of the variants, whereby the variant involving additional Dutch policy measures results in the lowest number of people being exposed. In the emission variants for 2020 and 2030, no exceedances are found at a 5 x 5 km² scale. Emission peaks alongside roads and in towns and cities may, however, lead to exceedances locally.

Health risk assessment of ambient air quality: ozone and particulate matter
The effects of ozone and particulate matter (as estimated below) and the results of the calculations in terms of health are uncertain because there is still insufficient insight into the plausibility and causality of the associations observed in the population and also concerning the form of the concentration-effect relationships and models that can be used to carry out calculations. For ozone the following are used here: a) a linear relationship, which means that an increase or decrease in the concentration of a substance in the air gives rise to an equal increase or decrease in the effect, and b) an exponential relationship, where the
concentration-effect ratio of an increase or decrease is smaller at lower concentrations than at higher concentrations.

Over the next 10 years an ongoing reduction in additional risk of death and emergency admissions to hospital has been calculated for PM$_{10}$, on the basis of the composition of the population in 1997. Taking into account the increasing age of the population, however, the absolute numbers in 2010 will be comparable to those in 1997 (Table E). The differences between the 2010 variants are small.

For ozone, on the basis of a linear exposure-response relationship (given the same population composition as in 1997), virtually no change is expected in the number of extra deaths / emergency admissions to hospital between now and 2010. With an exponential relationship between the ozone concentration and total daily mortality, the number of deaths is estimated to be lower. In the case of ozone, taking the ageing of the population into account, there will be an increase in the absolute numbers of extra deaths and admissions to hospital (Table F).

**Table E. Summary of the results of the risk assessment for particulate matter**

<table>
<thead>
<tr>
<th>PM$_{10}$</th>
<th>number of extra deaths</th>
<th>number of extra emergency admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>given the same population composition as in 1997</td>
<td>taking ageing into account</td>
</tr>
<tr>
<td>1980</td>
<td>1690</td>
<td>1130</td>
</tr>
<tr>
<td>1990</td>
<td>1360</td>
<td>1260</td>
</tr>
<tr>
<td>1997</td>
<td>1330</td>
<td>1330</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>970</td>
<td>1320</td>
</tr>
<tr>
<td>2010-basic</td>
<td>970</td>
<td>1310</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>950</td>
<td>1300</td>
</tr>
<tr>
<td>2010-NL-extra</td>
<td>920</td>
<td>1250</td>
</tr>
</tbody>
</table>

**Table F. Summary of the results of the risk assessment for ozone**

<table>
<thead>
<tr>
<th>Ozone</th>
<th>number of extra deaths</th>
<th>number of extra emergency admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>given the same population composition as in 1997</td>
<td>taking ageing into account</td>
</tr>
<tr>
<td></td>
<td>exponential model</td>
<td>linear model</td>
</tr>
<tr>
<td>1980</td>
<td>820</td>
<td>1800</td>
</tr>
<tr>
<td>1990</td>
<td>870</td>
<td>1860</td>
</tr>
<tr>
<td>1997</td>
<td>710</td>
<td>1950</td>
</tr>
<tr>
<td>2010-Gothenburg</td>
<td>630</td>
<td>1960</td>
</tr>
<tr>
<td>2010-basic</td>
<td>620</td>
<td>1960</td>
</tr>
<tr>
<td>2010-NEC</td>
<td>610</td>
<td>1990</td>
</tr>
<tr>
<td>2010-NL-extra</td>
<td>640</td>
<td>1950</td>
</tr>
</tbody>
</table>
With the help of dose-effect relationships obtained from clinical toxicological research it is estimated that the number of days per year on which lung function is reduced by more than 10% (expressed in days per year per 100 people) has fallen during the past two decades from approximately 45 to approximately 22 in 1997. In the next few years this will fall further to approximately 18 by 2010 and less than five by 2030.