

# AIR QUALITY AND THE NITROGEN CYCLE





# FACTSHEET

## Air Quality and the nitrogen cycle

Nitrogen is essential to life on earth. Its availability often limits crop yield. Over the past century, human activities have massively altered the nitrogen cycle and globally doubled or Europe-wide even tripled the production of reactive nitrogen mainly through the manufacture of nitrogen fertilizer (Haber-Bosch-Process), increasing the rate of biological nitrogen conversion and the burning of fossil fuel or biomass. The intensification of the nitrogen cycle forms the basis for supplying a growing world population with protein-rich food. There is ample evidence however that planetary boundaries for the so intensified nitrogen cycle have already been transgressed with considerable adverse effects on the environment and human health. International researchers (ROCKSTRÖM ET AL., 2009) suggest that the flow of new reactive nitrogen into the global nitrogen cycle should be limited to about 25% of its current value. The European Nitrogen Assessment (SUTTON ET AL., 2011) highlighted five societal core topics significantly impacted by excess reactive nitrogen

- ➔ air quality
  - ➔ ecosystems and biodiversity
    - ➔ soil quality
      - ➔ greenhouse balance
        - ➔ water quality

Excess reactive nitrogen is thus responsible for non-compliance with important environmental quality objectives. The adverse effects of reactive nitrogen do already lead to a significant loss of economic and social welfare, and will even more in the future.

### Emission trends and effects

Nitrogen emissions in the form of nitrogen oxides ( $\text{NO}_x$ ) or ammonia ( $\text{NH}_3$ ) contribute to the formation of **ground-level ozone** and **secondary fine particulates**, which, together with **nitrogen dioxide**, are major air pollutants with significant impacts on **human health**. In addition, ammonia and ground-level ozone cause damage to crops and natural ecosystems. Excess reactive nitrogen lost to the environment disrupts natural cycles and results in eutrophication and acidification of ecosystems, which are among the leading causes of **biodiversity loss**. The release of reactive nitrogen also jeopardizes **groundwater quality**. Furthermore, the increased nitrogen availability in ecosystems as well as the application of fertilizers lead to emissions of nitrous oxide which is increasingly contributing to **climate change**.

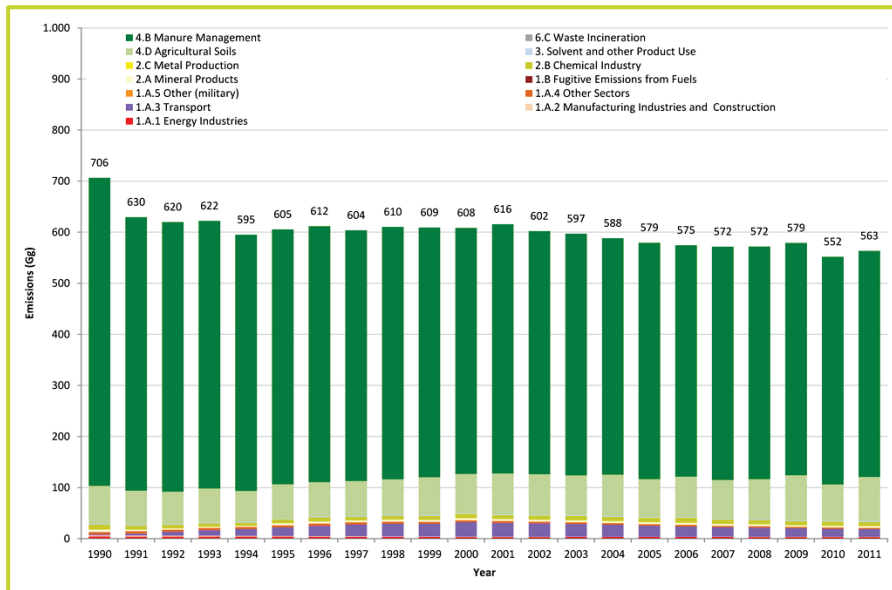


Figure 1: Trend in ammonia emissions to air since 1990. Agriculture is the major source (>95%) of ammonia emissions into the atmosphere. In Germany ammonia accounts for 2/3 of nitrogen deposition and eutrophication of ecosystems.

Figure 2: Trend in annual mean nitrogen dioxide (NO<sub>2</sub>) concentrations in the atmosphere in Germany based on the average of measuring stations in the pollution regimes "rural background", "urban background", and "urban traffic" in the period from 2000 to 2012. Year 2012: preliminary, not finally validated data.

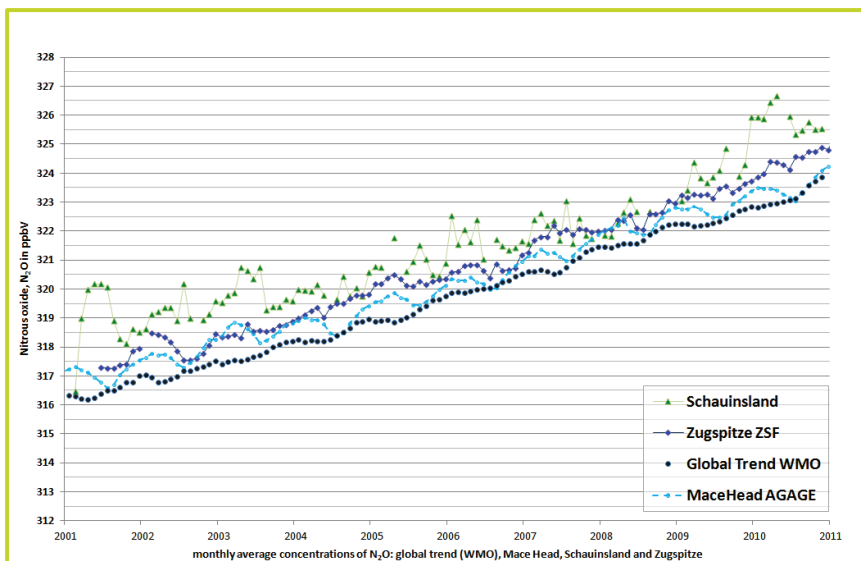
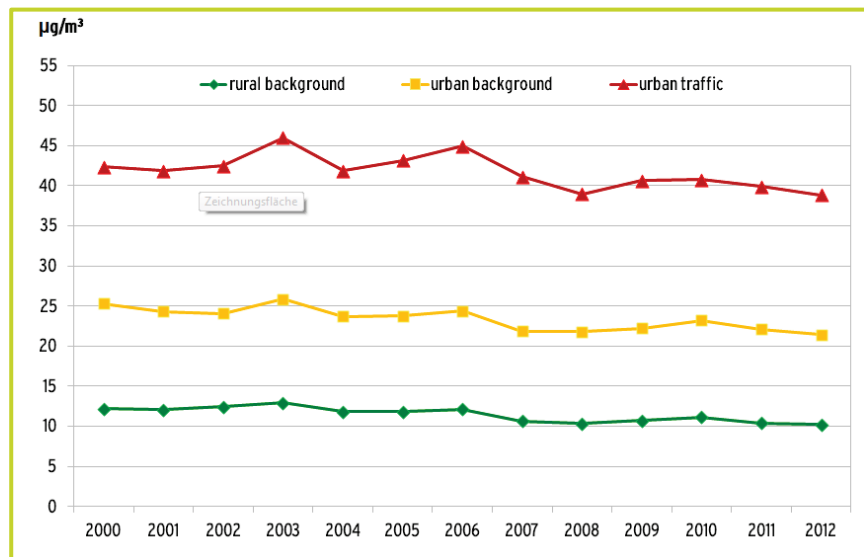


Figure 3: Monthly averaged nitrous oxide ("laughing gas") concentrations in the atmosphere measured in Germany and in Mace Head (Ireland); the global trend is shown in addition. Nitrous oxide is a major greenhouse gas and plays an important role in stratospheric ozone (O<sub>3</sub>) depletion. It has both natural and anthropogenic sources.

### Critical Load Exceedance 2007

#### Exceedance of CL for Nutrient Nitrogen (Eutrophication)

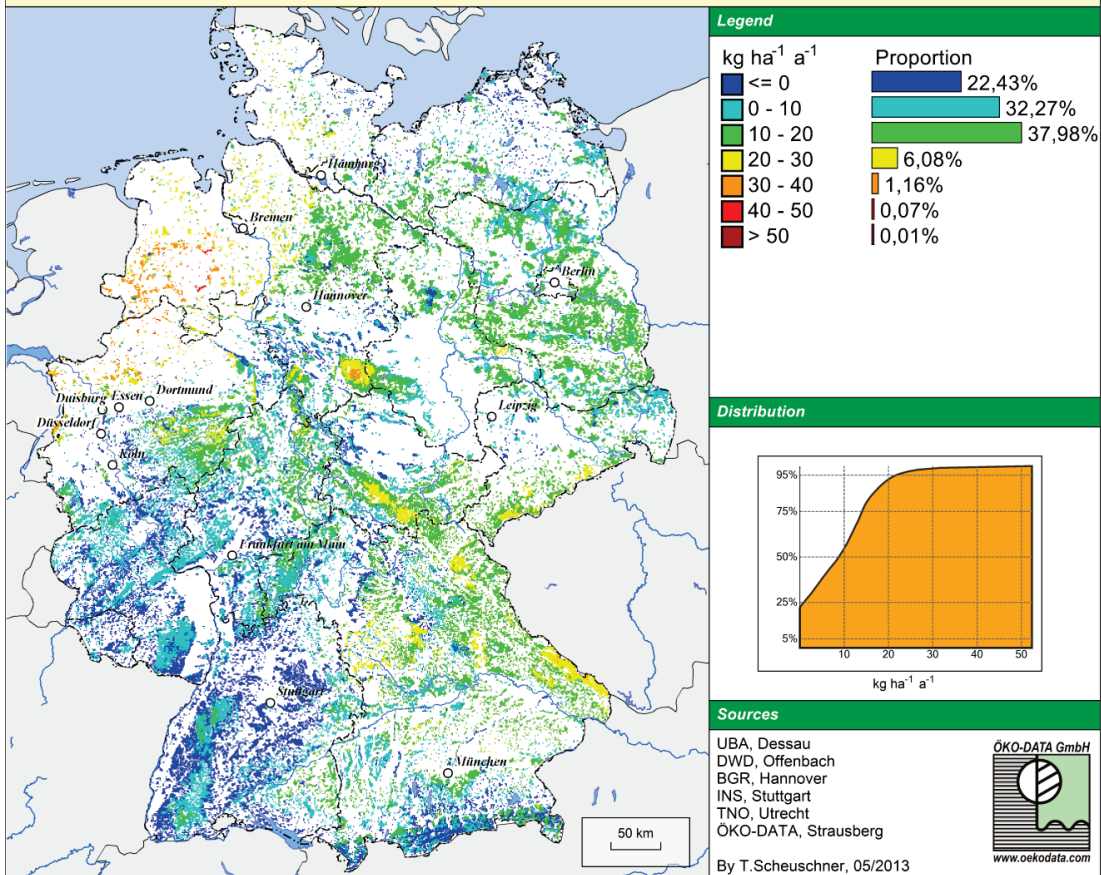


Figure 4: Exceedance of critical loads for eutrophication of natural and semi-natural ecosystems by the actual (2007) atmospheric nitrogen deposition. The exceedance indicates the risks for biodiversity loss through eutrophication in terrestrial ecosystems.

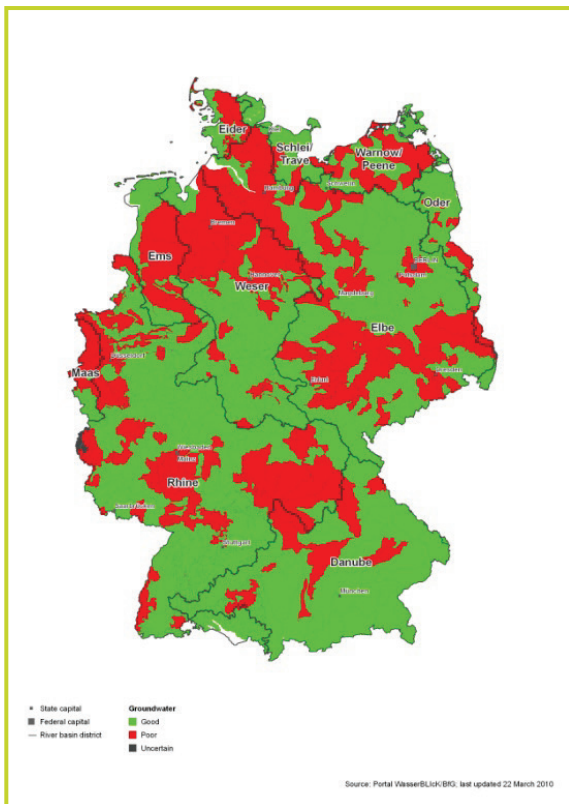


Figure 5: Groundwater quality: 63 percent of Germany's groundwater bodies currently achieve "good chemical status", whereas the remaining 37 percent do not. The main culprits are diffuse pollution from nitrate ( $NO_3^-$ ): 27 percent of groundwater bodies exceed the respective quality standard. In addition, a substantial portion of nutrients in groundwater is input into surface waters, causing additional pollution there.

Source: Portal WasserBLICK/BfG.

## The need for an integrated approach to reducing nitrogen emissions

The effects of reactive nitrogen occur on different spatial and temporal scales. For instance, high local concentrations of ammonia cause acute damage to plants on a small scale whereas globally elevated nitrous oxide concentrations affect the climate over a century.

- ⇒ Action must be taken at the global and continental as well as at national and local levels.

Reactive nitrogen compounds are highly mobile. In the so-called nitrogen cascade, they may undergo chemical reactions to sequentially exert different effects at different locations.

- ⇒ Regulations focusing on a single emission source category or environmental compartment, or on reducing a single effect, may shift problems to another environmental compartment (“pollution swapping”).

Hence, an integrated approach must be applied in the assessment of measures to achieve optimum effectiveness and cost efficiency.

## The German nitrogen cycle

Nitrogen budgets - at regional, national and international levels - are an important basis for the development, assessment and selection of measures to reduce reactive nitrogen emissions and to mitigate their overall adverse environmental impact. A brief summary of the German nitrogen cycle is given below:

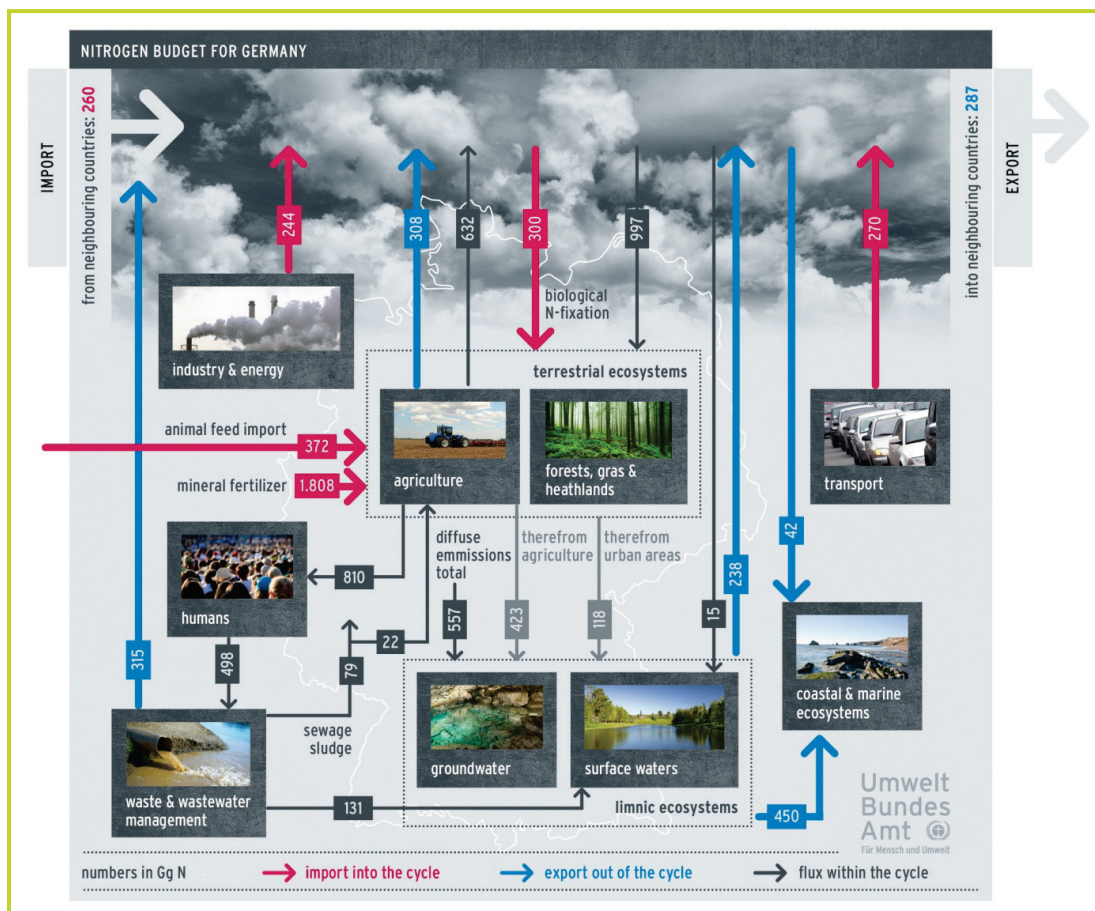


Figure 6: Annual input of reactive nitrogen compounds (red arrows) into Germany’s nitrogen cycle amounts to about 3200 gigagrams (Gg) of nitrogen. The most important fluxes are: sales of mineral fertilizers in Germany (1800 Gg N/a), emissions of reactive nitrogen from combustion processes at stationary and transport sources (510 Gg N/a), import of feedstuffs (370 Gg N/a), biological nitrogen fixation in agriculture and terrestrial ecosystems (300 Gg N/a) and transboundary atmospheric transport of nitrogen compounds into Germany (260 Gg N/a). The most important quantifiable removal pathways (blue arrows) are: denitrification and transboundary atmospheric and hydrological transport. 1 Gg = 1 billion grams.

Contribution of sectors to the overall emissions of reactive nitrogen [Gg N a <sup>-1</sup> ]						
Sector	Air			Water	Environment	
	NO <sub>x</sub>	NH <sub>3</sub>	N <sub>2</sub> O	NO <sub>3</sub> <sup>-</sup> / NH <sub>4</sub> <sup>+</sup>	total	share [%]
Agriculture	31	517	84	423	1055	57
Transport	258	9	3		270	15
Energy and Industry	187	18	39		244	13
Waste and Wastewater	1	10	5	265	281	15
<b>Total</b>	<b>477</b>	<b>554</b>	<b>131</b>	<b>688</b>	<b>1850</b>	<b>100</b>
Share [%]	26	30	7	37	100	
	63			37	100	

Table: In Germany 63 % of total reactive nitrogen emissions are released to the air, only 37 % to ground- and surface-waters. Agriculture is the main source of emissions of reactive nitrogen to all environmental compartments, contributing about 57 %. Transport, industry and energy generation as well as wastewater discharges and non-agricultural surface runoff each account for about 15 % of total emissions of reactive nitrogen to the environment.

### Emission reduction potential and policy recommendations

Environmental policies at the national, EU and international level have contributed significantly to decreasing the loss of reactive nitrogen to the environment. Further emission reductions are needed to achieve a number of different environmental quality targets. This also reduces the costs of unwanted environmental impacts.

An integrated consideration of measures and instruments for the reduction of emissions of reactive nitrogen must be based on their specific emission reduction potential and cost efficiency. Key fields for cost-efficient measures include:

- Agriculture is the sector with the largest emission reduction potential. Intensive livestock farming is currently one of the main drivers of the European nitrogen cycle. Increasing nitrogen efficiency in fertilization and feeding will significantly reduce the overall input of reactive nitrogen compounds into the N cycle. The full implementation and possible further adjustment of the German fertilizer ordinance is a very efficient measure to improve nitrogen efficiency in fertilization.
- Instruments aiming at energy saving and improved energy use have significant synergies, generally resulting in a reduction of NO<sub>x</sub> emissions.
- In the transport sector, the implementation of ambitious emission standards has the potential to further reduce the specific reactive nitrogen emissions. Integrated traffic management may reduce both total emissions and hot-spot pollution.

Regarding the atmospheric emissions of reactive nitrogen, the National Emission Ceilings Directive 2001/81/EC as well as the Industrial Emission Directive 2010/75/EC offer the possibility to trigger further emission reductions. This is also true of the Ambient Air Quality Directive 2008/50/EC (the second pillar of EU Air Policy), setting limit values to protect mainly human health.



Besides changes to the legal framework, encouraging a change in societal consumption patterns in areas showing high environmental impact is a complementary strategy to reduce releases of reactive nitrogen and to support sustainability-oriented policy-making. A promising tool for this sustainability communication is the calculation of nitrogen footprints, showing reactive nitrogen losses associated with individual choices.

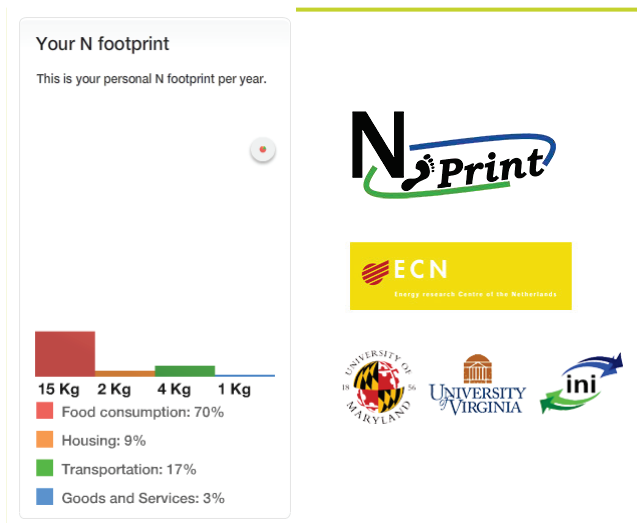


Figure 7: Calculation of the nitrogen footprint (loss of reactive nitrogen to the environment) based on individual consumption patterns (an example is shown). The tool also allows calculation of national average per capita nitrogen footprints for a number of countries. The nitrogen footprint calculator is developed by the N-print team (LEACH ET AL., 2012; <http://n-print.org>).

## References and further information:

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