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Review

Towards an integrated nitrogen strategy for Germany

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ABSTRACT

The release of reactive nitrogen compounds into the atmosphere, soil and water belongs to one of the biggest environmental challenges in Germany. Consequences are the loss of biodiversity due to eutrophication and acidification of terrestrial and aquatic ecosystems, impaired groundwater quality and impacts on human health. Responsible for the emissions of reactive nitrogen compounds are primarily agricultural activities and combustion processes. A number of European environmental targets and objectives in the context of nitrogen are clearly being missed. It is urgently necessary to increase the efforts to reduce nitrogen emissions and to protect biodiversity and human health. Important processes are a further development of European clean air policies and the implementation of the European Nitrate Directive and Water Framework Directive in Germany. A national nitrogen strategy could be a good starting point to increase efforts to solve the nitrogen problem and for a better integration of existing protection policies.

1. Introduction

The excessive release of reactive nitrogen compounds into the environment is one of the biggest ecological challenges of our time. Reactive nitrogen compounds, such as nitrogen oxides (NO and NO_2), nitrous oxide (N_2O), ammonia (NH_3), ammonium (NH_{4+}) and nitrate (NO_3), pollute the environment and endanger human health in numerous ways.

The nitrogen cycle is essential to the existence of all living organisms. But anthropogenic activities are seriously impacting the natural nitrogen cycle. Responsible are emissions from agricultural activities and combustion processes. A major driver for the nitrogen cycle was the development of industrial fertilizer production about a century ago, in which non-reactive atmospheric nitrogen is converted into reactive nitrogen compounds. Reactive nitrogen compound emissions, mainly linked to fertilizer use, livestock farming, and combustion processes, have increased almost ten-fold since the dawn of the industrial revolution.

While certain types of nitrogen emissions have been successfully rolled back, they remain unacceptably high as a whole. In Germany, the release of reactive nitrogen emissions into water, soil and air has led to severe pollution in some areas. As a consequence, 48% of Germany's natural and semi-natural terrestrial ecosystems are exceeding eutrophication limits. Around 27% of all groundwater bodies fail to reach a good chemical status according to the European Water Framework Directive (2000/60/EC) owing to elevated nitrogen concentrations, which also impact the production of drinking water. Especially the south part of the North Sea and a large part of the Baltic Sea are adversely affected by eutrophication (HELCOM, 2014; OSPAR Commission, 2010). Public health in densely populated areas is threatened by nitrogen oxide emissions and nitrogen-containing particulate matter.

Existing and partly legally binding clean air, water protection and nature conservation targets are clearly being missed. Germany has failed to adequately implement and enforce key environmental standards, leading the European Commission to introduce an infringement procedure against Germany for its failure to take actions against nitrate pollution in water (European Commission, 2014). Accordingly, the German advisory council on the environment (SRU) sees the urgent need to intensify the efforts and for a

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more integrated approach to solve the nitrogen problem in Germany.

The present article is based on a special report published by the SRU in January 2015 and addresses three of the main political challenges in the context of the nitrogen problem: a further development of European clean air policies, water protection and an integrated nitrogen strategy (SRU, 2015).

2. Clean air policies

2.1. Air pollution emissions

In Germany more than half of the releases of reactive nitrogen into the environment occur via emissions into the atmosphere. Expressed in terms of the nitrogen content, these emissions were equivalent to a total of 958 kt in 2012. The main source of emissions of reactive nitrogen into the atmosphere in Germany is the agricultural sector, which accounts for 57% of all nitrogen emissions into the atmosphere or 94% of total ammonia emissions. This is followed by stationary combustion installations, which emit 19% of all nitrogen air emissions or 43% of total nitrogen oxides emissions and transport sector with 18% of all nitrogen air emissions or 41% of total nitrogen oxides emissions. The principle generator of emissions of nitrous oxide is agriculture (77%), with 94% of these emissions originating from soils used for agricultural purposes (Table 1).

A comparison of the developments of emissions of nitrogen oxides from both the stationary combustion installations in the energy sector and the transport sector, and of ammonia emissions from agriculture since 1990 shows that the largest reductions were achieved in the transport sector (Fig. 1). The emissions stemming from the energy sector initially declined, but over the second half of the period showed a slight upward trend. The reductions in emissions of ammonia from the agricultural sector until about 1995 were mainly due to the reduction in livestock levels (Osterburg and Rösemann, 2012). The emissions of nitrous oxide have been reduced by 34% since 1990 (UBA, 2013b), although more recently there could only be noticed a slight downward trend.

2.2. Depositions and impacts

Nitrogen compounds emitted into the atmosphere impact in part on the area near the source of emissions, but some emissions may be transported over considerable distances before being deposited and having harmful effects. In Germany it can be assumed that ammonia itself leads to increased ammonia concentrations and depositions within a few kilometres of the source. In contrast, emissions of nitrogen oxides are transported over longer distances and depositions close to the source of the emissions are less frequent. Both ammonia and nitrogen oxides can react with other atmospheric components, forming or attaching to aerosols. These tiny aerosol particles have a very low rate of deposition and can therefore be transported for thousands of kilometres before they are removed from the atmosphere in the process known as wet deposition, i.e. mainly by precipitation (Hertel et al., 2011). For example, ammonia reacts with acids in the atmosphere to form ammonium salts, which in Central Europe accounts for a considerable proportion of atmospheric particulate matter (Dämmgen et al., 2013).

Table 1
Sources of emissions of NO_x, NH_3 and N_2O in Germany for 2012.

Source of emissions	NO_x (kt)	NH_3 (kt)	N_2O (kt)	% of total N
Stationary combustion installations	549	6	14	18.9
Transport[b]	521	14	5	18.1
Industrial processes	87	12	10	4.5
Agriculture	107	512	141	57.4
Waste and wastewater treatment	0.4	0	9	0.6
Others[a]	5.5	1.8	3	0.5
Total	1269	545	182	
Total N (air emissions)				100 (958 kt)

[a] Sum of emissions from: "Military and other small sources", "Diffuse emissions from fuels", "Solvent and other product uses" and "Land use, land use change, forestry".
[b] Emissions from international air traffic and shipping not included.
SRU (2015); data source: UBA (2013a,b).

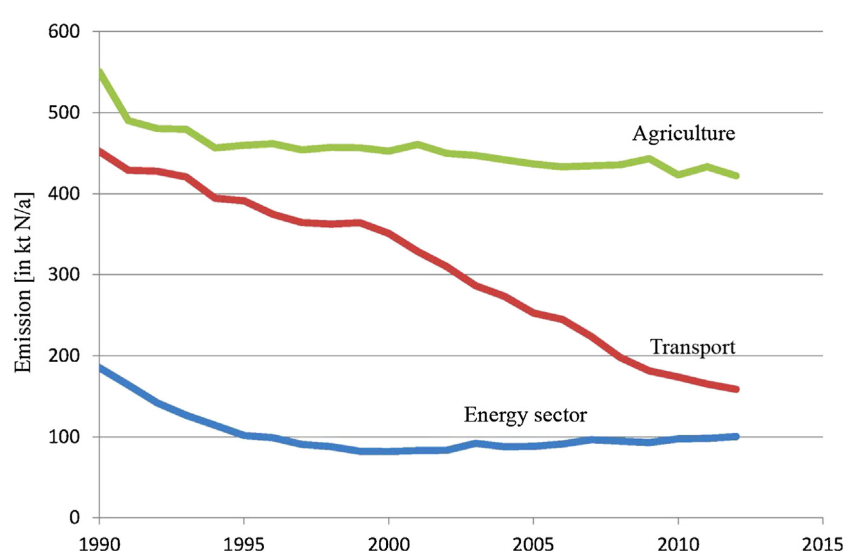

Fig. 1. Changes in NO_x emissions from the energy and transport sectors and of NH_3 emissions from the agricultural sector (in kt N/a).