Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

Nitrogen input in the biosphere

First nitrogen report from the Federal Government

Contents

Introduction ... 3
1 Nitrogen and its effects ... 4
2 Impacts of high nitrogen emissions ... 6
2.1 Ecological impacts ... 6
2.2 Health impacts ... 8
2.3 Impacts on businesses and the economy ... 9
3 Nitrogen emission causes ... 10
3.1 Agriculture ... 10
3.2 Transport ... 11
3.3 Industry and energy ... 11
4 Balance sheet, targets, fields of action ... 12
4.1 Measures to date ... 12
4.2 Targets and implementation ... 13
4.3 Fields of action ... 15
5 Conclusion: Integrated policy approaches ... 19
Bibliography ... 20
Abbreviations ... 23

Introduction

This report from the German government draws attention to the significance of nitrogen for our society and to the consequences and causes of high nitrogen emissions. It is intended to provide information to the public and increase awareness. In this document, the German government positions itself within the national and international conversations about the health, environmental and economic risks connected to excessive inputs of reactive nitrogen into the environment.

The intent is to highlight goals, fields of action and policy approaches relevant to the topic. The report makes clear the cross-sector need for action to reduce inputs of reactive nitrogen into the air, soil, water and other ecosystems at local, national and global levels. Reactive nitrogen is a general term used for a variety of nitrogen compounds such as nitrogen oxides (nitrogen dioxide and nitrous oxide/laughing gas), ammonia and nitrate.

In order to solve the nitrogen problem, the government relies on an integrated approach to reduction. This takes into account all emission-producing sectors and all affected media.

The aim is to reduce reactive nitrogen emissions because excess reactive nitrogen is harmful to people, the environment and the economy.

1 Nitrogen and its effects

A key substance cycle in modern industrialised societies

Almost all of the nitrogen on earth is in the form of inert gas in the atmosphere. Only about 1% of the earth's nitrogen exists in the form of reactive nitrogen compounds in organisms, soils and sediments or can be found distributed in the water and air. Reactive nitrogen, like carbon and water, is an essential building block of life.

The nitrogen cycle is a key biogeochemical cycle for modern life. At global level, annual reactive nitrogen emissions linked to human activity have increased ten-fold since the middle of the 19th century (SRU, 2015), with particularly strong growth in industrialised countries and countries with economies in transition. The increase secures the food supply for a growing world population; however, it also has significant consequences for people, the environment and the economy. Nitrogen is connected to a number of important areas of life, including transport, mobility, energy, health, food, recreation and tourism. It is strongly influenced by production patterns and also indirectly influenced by individuals' consumer behaviour. Inputs of reactive nitrogen – better known as nitrate, ammonia or nitrogen oxides – into the air, water and soil are connected to local, regional, national and global substance flows and value chains.

Consumption, use and disposal of products and services impact the environment. Due to the global interconnection of production processes, which can cause their impacts, e.g. on the environment, to cascade in multiple directions, consumption patterns in Germany generally have an effect on how people living in other countries meet their needs (Federal Government, 2016a). In relation to nitrogen emissions, this means that the global trade in raw resources and commodities including agricultural products (e.g. fodder, cotton, dairy products, meat, leather), fuels (in particular brown coal) and basic substances and goods (mineral fertiliser, polyamides, explosives, etc.) leads to shifts in nitrogen volumes that create unequal balances. According to a study by Oita et al. (2016) on nitrogen footprints and trade, Germany is second place among 188 countries in the list of the world's biggest net importers of nitrogen. National action on this issue has international impacts, and Germany is taking on its responsibility to act. The consequences can have many dimensions: local and global, individual and societal, and impacts on health, environment and even economies.

Producers and those affected by inputs

Nitrogen emissions are primarily produced in agriculture, food production, mobility, transport and energy generation and use. A clear picture of these emissions has to take into account the entire value chain, from raw material extraction to production, trade to consumption and, finally, disposal or recycling.

Increased nitrogen emissions have negative impacts on water resource management, drinking water supply, forestry, agriculture, nature conservation, recreation, tourism, the healthcare system and other areas. High nitrogen emissions also affect people, especially small children (due to water quality) and the people living in urban areas (due to air quality).

Increasing nitrogen pollution endangers ecosystems

Even though certain sectors have successfully reduced emissions – mostly thanks to technological innovations – worldwide trends in population growth, increasing consumption levels, high-resource diets, increase in private travel and growing energy requirements due to increasing mechanisation and industrialisation all lead to growth in nitrogen emissions. When reactive nitrogen compounds build up in the air, water or soil due to human activity (e.g. burning of fossil fuels or intensive agriculture), they can damage ecosystems, the environment and the climate, reduce biodiversity and affect the health of people and animals.

An intact nitrogen cycle is a key systemic requirement for the earth's ecosystems to retain functionality within planetary boundaries, as identified by an international team of scientists (Rockström et al., 2009; Steffen et al., 2015; de Vries et al., 2013).

“The boundaries of our planet's resilience, [...], define a ‘safe operating space’ within which development, global justice, prosperity and a ‘good life’ can be achieved and permanently secured. According to this research, humanity has already left the safe operating space with regard to loss of biological diversity, the disruption of biogeochemical cycles of nitrogen and phosphorous, climate change and land-system change.” (Federal Government, 2017).

Taking interactions into consideration

Reactive nitrogen compounds can become different chemical compounds and have varying impacts on water, air, soil and various ecosystems. Nitrogen compounds can be found in water and soil as ammonium, nitrate and nitrite, and in the air as ammonia, nitrogen oxides or particulate matter. Studies and approaches focussing on isolated aspects of the nitrogen issue (for example, tackling nitrate in groundwater or nitrogen oxides in the air) fail to take into account the chemical and ecosystemic interactions of these compounds. At the same time, measures focussing exclusively on one sector fail to take into account nitrogen pollution swapping between environmental media (e.g. from soil to air).

Greater problem awareness is required

Public awareness is primarily focussed on individual aspects of the nitrogen issue. For example, awareness focusses on nitrogen dioxide levels in urban areas that exceed limit values and are caused by traffic and in particular by diesel-powered vehicles. Separately, attention might be given to the impacts nitrogen application (in the form of organic and mineral fertilisers) has on nitrate concentrations in groundwater. The interactions between the individual aspects, the overall context and the dimensions of systemic problems are not made clear. It is difficult to communicate these issues because they are so complex and because immediate individual impact is, in large part, absent. In addition, systemic nitrogen pollution loads have a wide range of causes that are not obvious. This information deficit gives rise to a situation in which individuals are not very conscious of the extent of their complicity or ability to influence the problem through their own consumer choices.

2 Impacts of high nitrogen emissions

A variety of policy measures have led to a significant reduction in reactive nitrogen emissions in Germany in the last twenty years. Total annual emissions sank between 1995 and 2010 alone by around 40%, from 2.75 to 1.57 million tonnes of reactive nitrogen (see Table 1, p. 12). This is a clear success, especially with regard to air quality, nature, water and soil conservation and immission control.

And yet, the inputs of reactive nitrogen compounds into the environment are still too high in some regions, meaning that compliance with limit values and environmental quality standards for water, air and soil in these regions cannot be guaranteed. These inputs have grave consequences for ecological systems:

- Pollution of the air with nitrogen oxides, ammonia and the formation of secondary particulate matter,
- Pollution of groundwater with nitrate,
- Eutrophication of inland waters and seas,
- Eutrophication and acidification of soils and land ecosystems (for example forests),
- Loss of biodiversity due to eutrophication and acidification,
- Laughing gas pollution and its contribution to climate warming.

The eutrophication and acidification of ecosystems have a variety of national and transboundary impacts, such as contamination of drinking water sources with nitrate, losses in forestry due to reduced tree resilience, and additional health expenditures due to respiratory and circulatory ailments caused by nitrogen.

2.1 Ecological impacts

Biodiversity

Excessive inputs of reactive nitrogen into the air, water and soil are a major factor in the loss of biodiversity. Eutrophication and acidification change the species composition of ecosystems, especially in nitrogen-sensitive ecosystems. These changes can harm various species and reduce their numbers. Nitrogen inputs give nitrogen-tolerant plants a growth advantage, ousting regionally distinct, more sensitive and oftentimes endangered species. In Germany and the EU, 65% of natural and near-natural ecosystems are at risk of nitrogen-caused eutrophication (CCE, 2015). A significant percentage of the species and habitats protected EU-wide under the Habitats Directive were assessed as having an unfavourable conservation status due to excessive inputs of reactive nitrogen compounds from the air (Balla et al., 2013).

Groundwater

Fertiliser use that exceeds plants' needs can lead to problematic amounts of the nitrogen compound nitrate entering groundwater. In the past and currently, the limit value of 50 mg nitrate/l is exceeded at 18% of groundwater monitoring stations (BMUB, BMEL, 2016). Contaminated groundwater cannot be used as drinking water without further treatment; it must be diluted or conditioned biologically or chemically. Figure 1 illustrates the regional focal points of nitrate pollution problems in groundwater. Over the last few years, no tangible reduction of nitrate pollution in groundwater or of the eutrophication of coastal waters could be measured (BMUB, BMEL, 2016).

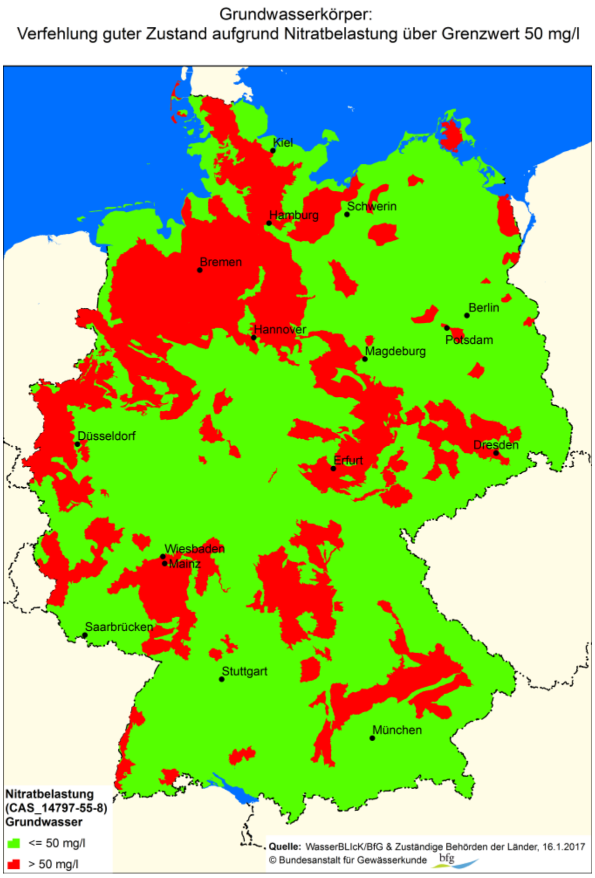

Figure1 Groundwater bodies that miss the Water Framework Directive's "good status" mark because they exceed the nitrate limit value of 50 mg/l (Source: WasserBLIcK & the Länder's competent authorities, 16 January 2017)

Eutrophication of water bodies

Nitrogen inputs from polluted groundwater close to the surface and direct inputs from intensively farmed land can lead to a nitrogen surplus in inland surface water bodies and the North and Baltic Seas. This can cause algal blooms and, in coastal areas, can give rise to what are called dead zones, areas of low oxygen. In the long term, these environmental changes can have significant adverse effects on biodiversity in these zones. Atmospheric nitrogen inputs from coastal agriculture, shipping and long-range transmission of air pollutants can intensify these effects. 20 to 25% of the nitrogen inputs into the North and Baltic Seas are introduced via air (SRU, 2015). Eutrophication caused by nitrogen is the primary reason that inland waters and all of the coastal water bodies in the German North and Baltic Sea regions failed to achieve the EU Water Framework Directive's (WFD) good ecological status in 2008. The initial assessment of German coastal and marine waters in accordance with the EU Marine Strategy Framework Directive (MSFD) identified eutrophication due to excessive nitrogen inputs from rivers and the atmosphere as one of the main ecosystem pressures on the North and Baltic Seas. A follow-up assessment is to be carried out in 2018.

2.2 Health impacts

Adverse effects on human health depend on the type of nitrogen compound and its pathway (air, water, soil).

Outdoors, **ammonia** contributes to the formation of **secondary particulate matter**. When inhaled, particulate matter with a diameter of less than 2.5 micrometres ($PM_{2.5}$) can make its way deep into the lungs and cause inflammation of the respiratory tract. At the same time, it can intensify allergic respiratory ailments. Particulate matter is also associated with the incidence of cardiovascular diseases and lung cancer (Royal College of Physicians, 2016). No concentration limit value can be set on particulate matter that will make adverse health effects unlikely; therefore, particulate matter pollution should be kept to an absolute minimum (Umweltbundesamt, 2009a).

Current findings from the Global Burden of Disease study (GBD, 2016) show that in 2015, 4.2 million premature deaths and around 103 million lost healthy life years could be attributed to the impacts of particulate matter ($PM_{2.5}$) on the world population (IHME, 2016). The German Environment Agency (UBA) estimates that in Germany, in 2014, ca. 41,000 premature deaths and around 308,000 lost healthy life years could be attributed to particulate matter pollution (Umweltbundesamt, 2016a).

The nitrogen oxide **laughing gas**, which has 265 times the impact on the climate as carbon dioxide (IPCC, 2013; Umweltbundesamt, 2015b), destroys the ozone layer in the upper layers of the stratosphere, reducing the layer’s ability to protect people from ultraviolet radiation. This causes increased skin cancer risk in humans. Laughing gas makes up 6% of global emissions that negatively impact the climate.

High concentrations of **nitrogen dioxide** irritate the eyes and the mucous membranes of the entire respiratory tract. This can cause shortness of breath, coughing, bronchitis, pulmonary oedema and pneumonia. Chronic exposure to nitrogen dioxide causes long-term damage to the respiratory and cardiovascular systems (EEA, 2013). Studies show a relationship between high nitrogen dioxide concentrations and increase in hospital admittances due to respiratory ailments (Kraft et al., 2005).

Nitrogen oxides are also major **precursors for ground level ozone**. Among other things, ozone causes significant respiratory and tissue damage in humans. According to the Global Burden of Disease study, around 254,000 premature deaths and 4.1 million lost healthy life years could be attributed to the impacts of ozone on the world population (IHME, 2016).

Figure 2 shows the location of local hot spots for particulate matter and nitrogen dioxide pollution in Germany.

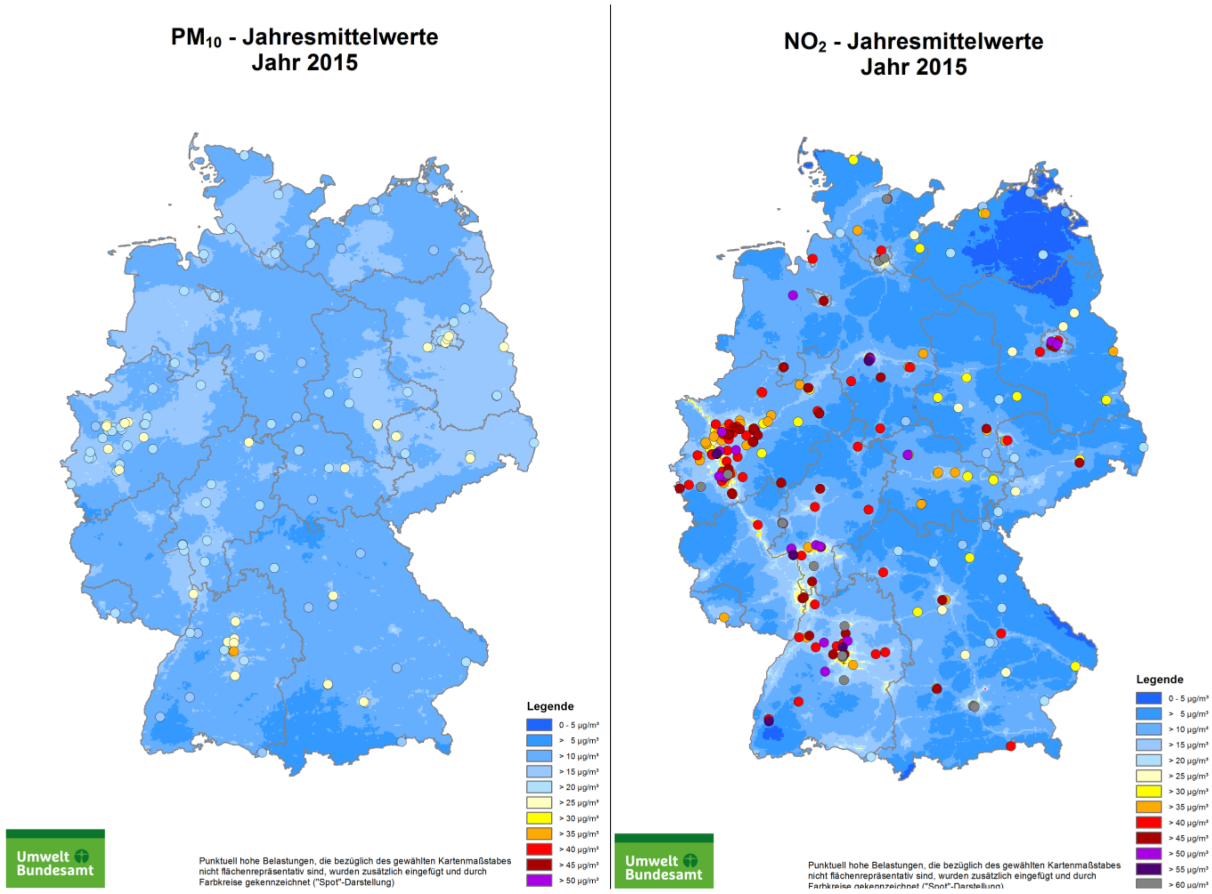

Figure 2 Annual median values in 2015 for particulate matter (PM_{10}) (left) and nitrogen dioxide (NO_2) (right). Sporadic high pollution levels are represented here with dots and are not to scale.

Two-thirds of Germany's drinking water comes from groundwater sources. When the **nitrate** concentration in groundwater is over the precautionary limit value of 50 mg/l, the water cannot be used directly as drinking water without processing. Processing is necessary because excessive intake of nitrate via drinking water can adversely affect human health. In the digestive system, nitrate can lead to the formation of carcinogenic compounds (nitrosamine) that can cause tumours to form or, in infants, can cause "blue baby syndrome," also known as methemoglobinemia (SRU, 2015). Germany's regulations require drinking water to comply with the nitrate limit value (BMG, UBA, 2014).

2.3 Impacts on businesses and the economy

Nitrogen emissions limit the use of environmental resources and increase the complexity and costs of use. This is true, for example, in the area of drinking water supply and in recreation and tourism (e.g. due to algal blooms). The more contaminated groundwater is, the more difficult and expensive processing in water treatment plants becomes. Yields in agriculture and forestry can be diminished due to reactions caused by nitrogen such as the formation of ground level ozone.

But first and foremost, the burdens of health impacts are most significant here. Nitrogen contamination leads to considerable negative impacts for individual businesses and national economies, although cost estimates of these impacts necessarily include a degree of uncertainty. Estimates produced for the EU put the costs of the adverse effects of current overall nitrogen emissions of all 27 EU member states (base year 2000) at an annual total of between €70 billion and €320 billion. Around 60% of this figure accounts for costs arising from human health impacts, 35% are costs arising from ecosystem impacts and 5% are costs arising from climate impacts (Sutton et al., 2011).

3 Nitrogen emission causes

3.1 Agriculture

Almost half of Germany's land area (47%) is used for agriculture. Nitrogen, in the form of ammonium and nitrate, has an important function in agriculture as an essential source of plant nutrients. The use of nitrogen in mineral and organic fertiliser (e.g. manure) is not problematic in and of itself. Rather, the problem lies in nitrogen input that exceeds plants' needs.

Agriculture is responsible for 63% of the total emissions of reactive nitrogen (see Table 1, p. 12). The main discharge routes for reactive nitrogen compounds are ammonia and laughing gas emissions into the atmosphere and nitrate input into ground and surface waters. In addition, some reactive nitrogen is transformed into inert atmospheric nitrogen.

When fertiliser use is inappropriate to plant needs or not in keeping with good professional practices, nitrogen not absorbed by the plants or stored in the soil can lead to environmentally harmful nitrogen surpluses. Regions where land is used for intensive livestock production often generate more manure than can be efficiently used locally.

If biogas plants use renewable raw materials in addition to manure, this can lead to an increase in the regional nutrient pressure. Because of this, the expansion of land used to produce crops for energy and industrial use – which more than tripled between 1999 and 2013 from 0.7 to 2.4 million hectares – has to be viewed in a critical light (SRU, 2015). Livestock production regions could, depending on the type of biogas facility available, process manure to increase the transportability of the resulting sludge, helping reduce the regional nutrient pressure.

Ninety-five percent of ammonia released into the air comes from fertiliser use and livestock production (Wissenschaftlicher Beirat Agrarpolitik, Ernährung und gesundheitlicher Verbraucherschutz und Wissenschaftlicher Beirat Waldpolitik at the BMEL, 2016). Agricultural ammonia emissions have decreased since the beginning of the 1990s in Germany. Although they remain under the 1990 level, since 2005 they have been on the rise again. In 2015 the mandatory national emissions ceiling of 550 kilotonnes per year was exceeded by 27%. The revision of the Fertiliser Application Ordinance (Düngeverordnung), to be completed in 2017, can facilitate a reduction of agricultural emissions in the medium term. Several documents articulate the need for additional action: the new edition of the German Sustainable Development Strategy (Federal Government, 2017) and its nitrogen targets (see Chapter 4); the National Biodiversity Strategy; the Climate Action Plan 2050; and the EU Directive on the reduction of national emissions of certain atmospheric pollutants of 14 December 2016 (new NEC Directive), under which Germany must reduce its ammonia emissions by 29% by 2030 in comparison with 2005 levels.

3.2 Transport

Transport is responsible for 13% of total reactive nitrogen emissions. It gives rise almost exclusively to nitrogen oxide emissions (see Table 1, p. 12).

Due to road traffic emissions, and particularly due to those of diesel-powered vehicles, nitrogen oxide pollution is highest in urban and high traffic areas. Currently, 58% of the air quality monitoring stations in high traffic areas record emission levels in excess of the annual average limit value set out in the EU Framework Directive on Ambient Air Quality, 40 micrograms nitrogen dioxide/m^3 averaged over the year. In accordance with the 39th Ordinance on the Implementation of the Federal Immission Control Act (39. BlmSchV), the permissible nitrogen dioxide emission limit value is 40 micrograms/m^3, averaged over the calendar year, or 200 micrograms/m^3 if the value is averaged over a full hour (with 18 permitted exceedances per year). The alert threshold is 400 micrograms/m^3 (also averaged over a full hour) (BMJV, federal ordinance, 39. BlmSchV, 2010). Measures already adopted or planned for transport (Euro 6/VI standard for emission levels, update of limit values for non-road mobile machinery) can further reduce nitrogen oxide emissions from traffic.

Regulations limiting the nitrogen dioxide emissions of passenger vehicles in real-world use will begin having an impact on reduction of emission values at monitoring stations in high traffic areas in the coming years. Swift reduction also depends on replacing older diesel-powered vehicles with newer models, replacing diesel-powered vehicles with gas, electric and natural gas-powered vehicles and shifting a share of private motorised traffic to public transport. Scenarios modelled by the German Environment Agency (UBA) show that compliance with annual limit values on nitrogen dioxide in heavily impacted areas cannot be expected until after 2025 (Umweltbundesamt, 2017).

Compared to passenger vehicle transport, rail transport emits less than half the amount of nitrogen oxides.

3.3 Industry and energy

Although significant mitigation has been achieved in the past two decades, particularly in high emission industries, around 40% of nitrogen oxide emissions and thus around 15% of the total reactive nitrogen emissions in Germany are still caused by the industry and energy sectors (Umweltbundesamt, 2015a), with 85% of nitrogen oxide emissions coming from the energy sector and 15% from industry. Power plants, the manufacturing industry and private and commercial combustion installations are counted as part of the energy sector.

Nitrogen emissions from high emission industries – namely the chemicals, steel, cement, glass and lime industries – have seen significant reductions across the board over the period from 1995 to 2012. A 15% reduction was registered compared to 1990 levels, 8% compared to 1995 levels. This was achieved primarily through improved flue gas cleaning (Umweltbundesamt, 2015a).

Emissions from the energy industry decreased sharply between 1990 and 2000, but thereafter have shown a variable trend of slight increases and decreases (Umweltbundesamt, 2016b).

Emissions can be reduced by upgrading Germany's power plants, stepping up the expansion of renewable energies (especially wind farms and photovoltaic installations) and taking measures to reduce electricity demand. Nonetheless, it must be noted that burning biomass as a renewable energy source leads to higher specific nitrogen oxide emissions than burning coal.

4 Balance sheet, targets, fields of action

4.1 Measures to date

In the last few decades and during the current legislative period, the German government has taken a variety of policy measures to reduce reactive nitrogen inputs into the environment in coordination with the European Union, the Länder (federal states), local authorities and all relevant civic stakeholders. These efforts primarily focussed on specific nitrogen compounds, specific environmental media and specific input pathways.

Successful reduction in the last 20 years has been considerable (see Table 1, p. 12). From 1995 to 2010, reactive nitrogen emissions decreased by about 40%. However, 1.6 million tonnes of reactive nitrogen compounds still enter the environment annually (reference period 2005-2010). Two-thirds of emissions that enter the air, soil and water are produced by the agricultural sector. The sectors transport, industry/energy and wastewater treatment/surface water drainage are each responsible for 9 to 15% of the remainder. Inputs into soil and groundwater due to defective sewerage networks have not been measured to date. Transport and wastewater treatment have achieved high percentage mitigation of nitrogen emissions in the past two decades. The potential for further substantial emissions mitigation exists in all sectors. In future, transport, industry and energy will see additional emissions reductions due to measures that have already been adopted; in contrast, there is still work to be done in agriculture, including revision of the Fertiliser Application Ordinance and other measures.

Table 1 Absolute and percentage trends in total nitrogen emissions in the four main producer sectors

Base year and reference period	1995		2005-2010	
Source	Alfred Töpfer Akademie für Naturschutz 1997		German Environment Agency 2015a	
Scale	Emissions [tonnes of nitrogen per year]	Percent [%]	Emissions [tonnes of nitrogen per year]	Percent [%]
Agriculture	1,330,000	**48%**	980,000	**63%**
Transport	595,000	**22%**	207,000	**13%**
Industry/energy sector	354,000	**13%**	241,000	**15%**
Wastewater, surface run-off	474,000	**17%**	140,000	**9%**
Total	**2,753,000**	**100%**	**1,568,000**	**100%**

The German government has established various laws in the area of nitrogen reduction that set quality standards for the individual environmental media and action targets for specific producer sectors. These established limit values for water, air and soil and set out emission values and technical standards in immission control and other areas.

With regard to the protection of surface water, groundwater reserves and drinking water, the Federal Water Act (Wasserhaushaltsgesetz), the Surface Waters Ordinance (Oberflächengewässerverordnung), the Drinking Water Ordinance (Trinkwasserverordnung) and the Waste Water Ordinance (Abwasserverordnung) are of note. Fertiliser legislation – the Fertiliser Application Ordinance (Düngeverordnung) and the Fertiliser Ordinance (Düngemittelverordnung) – regulates the amount of nitrogen input into water and soil in agriculture.

Integrated environmental protection measures are most effective in the area of industrial emissions; examples of such measures include prevention of nitrogen emissions in production and processing (via process optimisation, use of alternative low-emission raw materials and machinery) and improvements in flue gas and wastewater treatment. Relevant legislation here includes the Federal Immission Control Act (Bundesimmissionsschutzgesetz, BImSchG) and the Circular Economy Act (Kreislaufwirtschaftsgesetz, KrWG). The Waste Water Charges Act (Abwasserabgabegesetz) is a steering instrument for water protection.

The Federal Nature Conservation Act also has a cross-sectoral impact on these issues.

In addition, there are other acts and ordinances that have a clear positive impact on emissions.

4.2 Targets and implementation

Despite all efforts and considerable mitigation successes, emissions continue to be far higher than health and environmental targets at UN, EU and national levels, as summarised in Chapter 2.

The German government's overall goal is to reduce nitrogen emissions to levels that are compatible with the environment and human health. In order to achieve this, the government is using an integrated reduction approach that is geared to targets and requirements agreed at EU and international levels. These include the goals of the **2030 Agenda** for Sustainable Development, adopted by the **United Nations (UN)** in 2015. The preamble of the 2030 Agenda names five areas of critical importance that are the guiding principles for the Agenda's 17 Sustainable Development Goals (SDGs): People, Planet, Prosperity, Peace and Partnership. Under its "protect the planet" guideline, the Agenda requires sustainable use of the seas and oceans, the preservation of ecosystems and biodiversity, efforts to combat climate change and sustainable use of natural resources. Reducing surplus nitrogen in the environment is a component of several SDGs. Some examples include:

Goal 3, "Ensure healthy lives and promote well-being for all at all ages," includes the target "By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination."

Goal 14, “Conserve and sustainably use the oceans, seas and marine resources for sustainable development,” includes the target “By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.”

In total, nine SDGs contain targets related to nitrogen pollution reduction, including Goal 2 “Achieve food security, promote sustainable agriculture,” Goal 6 “Sustainable water management,” Goal 13 “Combat climate change,” and Goal 15 “Protect terrestrial ecosystems.”

The Convention on Long-range Transboundary Air Pollution, a United Nations Economic Commission for Europe (UNECE) treaty adopted in Geneva, is an additional benchmark at international level. The related Gothenburg Protocol contains numerous provisions on reducing emissions of nitrogen oxides and ammonia, among other substances. This is intended to work against acidification, eutrophication and the formation of ground level ozone.

The United Nations Convention on Biological Diversity also adopted various targets for the reduction of surplus nitrogen in the environment; several can be found in its Strategic Plan for Biodiversity 2011-2020 and Aichi Biodiversity Targets. Target 8, for example, states: “By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.”

Implementation at EU level

The **European Union** has several nitrogen-related directive provisions that supplement international targets and make them more specific and legally binding.

In the area of air quality control, examples include the Ambient Air Quality Directive (with limit values for NO_2), various rules limiting emissions from installations and products and the new NEC Directive (Directive 2016/2284/EU on reduction of national emissions of certain atmospheric pollutants, formerly known as the NERC Directive). According to the new NEC Directive, German ammonia and nitrogen oxide emissions are to be cut by 29% and 65% respectively over the period from 2005 to 2030.

The EU Nitrates Directive, the Urban Waste Water Directive, the Water Framework Directive (WFD), the Groundwater Directive and the Marine Strategy Framework Directive (MSFD) are in place to cover issues in water pollution control.

In addition, there are cross-media directives related to nitrogen such as the Industrial Emissions Directive, the Habitats Directive and the Birds Directive.

The above-mentioned EU directives have achieved great progress in mitigating emissions. However, not all of the limit values have been reached in the stipulated timeframe. Because of this, the European Commission has started an infringement procedure (infringement of the Nitrates Directive and the Ambient Air Quality Directive’s NO_2 provisions) and EU Pilot procedures (inadequate transposition of WFD, NEC Directive with regard to ammonia) against Germany. Beyond specific directives, the EU seeks to comply with the World Health Organisation’s air quality guidelines for human health and the critical loads and levels for ecosystems in the EU’s seventh Environment Action Programme (European Commission, 2014).

Implementation in Germany

The international and EU targets and provisions on reducing the environmental nitrogen surplus are being implemented in Germany via a number of national targets, strategies, programmes and laws.

In particular, the targets of the 2030 Agenda for Sustainable Development mentioned above are a major challenge. The dimensions of the challenge are specified in the new 2016 edition of the German Sustainable Development Strategy, adopted by the Federal Cabinet in January 2017 (Federal Government, 2017). Reducing the nitrogen surplus in Germany in all areas is reflected as a priority in the strategy's various targets. The main, overall goal is to reduce the annual average agricultural nitrogen surpluses (total balance) to 70 kilograms per hectare of agricultural land between 2028-2032. But also of note are goals to reduce emissions of the air pollutants ammonia and nitrogen oxides, to lower the annual average values of total nitrogen in rivers that flow into the Baltic and North Seas and to reduce the percentage of sensitive ecosystems in which atmospheric inputs exceed ecological critical loads to 37% by 2030.

In addition to the Sustainable Development Strategy, the German government has also set specific nitrogen reduction targets in other strategies. For example, the overall nitrogen reduction goal is also a part of the National Biodiversity Strategy. It was also included in the Climate Action Plan 2050, adopted at the end of 2016. According to the Climate Action Plan 2050, "Nitrogen surpluses are to be cut and permanently reduced. To do this, ammonia emissions from agriculture must be substantially reduced, among other measures. The reduction obligations of the [old] NEC Directive are to be complied with as soon as possible and additional reductions are necessary so that the targets of the NERC Directive [new NEC Directive], which set emission reduction commitments for 2030, can be achieved. ..." (Federal Government, 2016b).

4.3 Fields of action

A variety of programmes, initiatives and strategies in various policy areas aim to reduce nitrogen emissions directly and indirectly.

Environment

Environmental policy works for nitrogen reduction in many areas. Water pollution control and other areas are supported through the implementation of the EU Water Framework Directive and the Marine Strategy Framework Directive. In nature conservation, the nitrogen reduction target is included in the National Biodiversity Strategy. Beyond this, combating the nitrogen pollution of ecosystems also plays a role in the implementation of the EU Habitats Directive.

Further, the Federal Cabinet adopted the National Programme for Sustainable Consumption in 2016, to be implemented jointly with the Federal Ministry of Justice and Consumer Protection (BMJV) and the Federal Ministry of Food and Agriculture (BMEL). The programme contains guidelines for a policy of sustainable consumption undergirded by specific measures. It also covers dietary issues with relevance to sustainable consumption and includes implementation measures.

The Technical Instructions on Air Quality Control (TA Luft) are a key instrument for limiting the atmospheric nitrogen oxide and ammonia emissions from around 50,000 installations that require emissions permits. The instructions are to be updated to reflect state-of-the-art technology in 2017.

The implementation of the new NEC Directive and other emissions control, fertiliser and transport measures will contribute to the reduction of airborne emissions.

Agriculture and food

Crop-appropriate use of nitrogen is necessary for sustainably securing the food supply and resources vital to life. But it is also important that agriculture and food consumption patterns are nitrogen-efficient, i.e. geared to products and processes that are sustainable in the long term and not to those based on disproportionately high nitrogen emissions.

Although as the producer responsible for almost two-thirds of Germany’s total emissions of reactive nitrogen, agriculture also offers the greatest and most cost-effective potential for emission reductions (Sutton et al., 2011, Umweltbundesamt, 2009b). This potential encompasses all agricultural nitrogen emissions; apart from nitrate, ammonia emissions should also be taken into account.

The major current approaches to nitrogen reduction in agriculture and food are based on the targets described above. Thus, for example, the BMEL is leading the revision of the Fertiliser Application Ordinance. This ordinance is a key element of the national action programme for the protection of water bodies against pollution caused by nitrates from agricultural sources pursuant to the EU Nitrates Directive. Predictions based on early drafts of the revision suggest it could lead to a 15% reduction compared to current inputs (LAWA 2014). The revised Fertiliser Application Ordinance will make a significant contribution to reducing nitrogen input into the water and air. This will also support achieving the targets of the Water Framework Directive (WFD), which promotes achieving a good chemical status for water bodies, and the obligations of the new NEC Directive. In the framework of talks to coordinate the revision, the German government is also in discussion with the Länder (federal states) about supplementary measures.

The Federal Ministry of Food and Agriculture (BMEL) published its “Organic Farming – Looking Forwards” strategy in February 2017; this is one way the German government is pursuing targets of its Sustainable Development Strategy. Under the farming strategy, 20% of agricultural land will be organically farmed. In 2016, 6.8% of agricultural land was organically farmed. Organic farming is, in particular, characterised by a nutrient cycle that is as closed as possible (using internal resources and inputs) and less intensive livestock production relative to land area. Mineral nitrogen fertilisers cannot be applied to the land.

In the framework of the Joint Task for the Improvement of Agricultural Structures and Coastal Protection, the German government is supporting measures to protect the environment and to conserve natural habitats. Examples of activities targeting the reduction of emissions include measures for introducing and maintaining organic cultivation processes, for extensive use and management of permanent grasslands, for low-emission organic fertiliser use with minimal impact on water bodies, and for maintenance of undersown crops over winter.

The German government also sees important potential in dietary policy for reaching nitrogen reduction targets. The BMEL “Too good for the bin” initiative campaigns against food waste; in turn, this contributes to nitrogen emission savings by encouraging the public to make prudent choices while shopping and by urging retailers and consumers not to waste useable products that are labour and resource-intensive. Currently, around 11 million tonnes of food are disposed of as waste by industry, retailers, large-scale commercial buyers and private households in Germany annually. What is most relevant here to nitrogen is the wasteful disposal of protein-rich and therefore nitrogen-rich foods such as dairy and meat products. The German government intends to tackle this by stepping up consumer education, with the potential involvement of retailers. In this area, the government is also reviewing, for example, whether there is a need for regulation with regard to best-by dates on food products while also bearing in mind health-related consumer protection.

Transport and energy

Transport and industry/energy are responsible for 13% and 15% of overall nitrogen emissions in Germany, respectively.

In the area of transport, the German government is pushing ahead with the transition to electric and natural gas mobility; this will lead to a reduction of nitrogen oxide emissions in particular, provided that the electricity used is generated using a low-nitrogen source. A key area here is providing relief to urban centres. Until the transition is complete, compliance with the EU emission standard for motor vehicles (Euro 6/VI) and the national implementation of the new EU NEC Directive will have an emission-reducing effect. Under the NEC Directive, nitrogen oxides must be reduced by 65% by 2030, particulate matter (less than 2.5 micrometres in diameter) by 43%. Shifting traffic to environmentally friendly modes of transport is also a central pillar of German transport policy in this regard. In particular, shifting traffic to rail transport, which is primarily powered by electricity, is an effective option for reducing nitrogen pollution.

In the energy sector, the German government is pushing ahead with developing renewable energies, improving energy efficiency and reducing energy consumption. The Federal Ministry for Economic Affairs and Energy (BMWi) compiled theses and guiding issues on the medium and long-term future development of energy efficiency policy in its Green Paper on Energy Efficiency (BMWi, 2016). These were also discussed in a public dialogue in 2016. The expiration of bonuses for the use of energy crop substrates in existing biogas plants and the plans to focus on the use of waste and scrap material in the course of the follow-up on the 2017 Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG 2017) could relieve nutrient pressure in regions with high inputs of organic fertilisers. In future it will also be easier to tap the full potential of technological and logistical possibilities for reducing nitrogen, particularly in the areas of private motor traffic, logistics (energy mix selection) and through advances in energy efficiency and technological emission reduction. One way to do so, for example, would be expanding and further developing incentives for switching to emission-free vehicles.

Health

Air and drinking water containing the lowest possible amount of reactive nitrogen and appropriate dietary intake of nitrogen are vital to public health and quality of life. The German government promotes consumer behaviour conducive to nitrogen reduction (mobility, diet, energy consumption, etc.) in this field of action.

The Federal Ministry of Health (BMG) and the Federal Ministry of Food and Agriculture (BMEL) have a joint initiative to promote healthy diets and physical activity, IN FORM, which endorses the basic nutrition principles of the German Nutrition Society (DGE). If the DGE's recommendations on the consumption of meat and meat products were followed, it would result in a reduction in reactive nitrogen, as long as production in Germany was reduced corresponding to demand. Protecting the public from reactive nitrogen compounds, especially air pollutants, can help lower the incidence of nitrogen-induced illnesses and lighten burdens on social security and healthcare systems.

Education and research

Successful nitrogen reduction policy requires widespread public awareness of the issue and systematic problem awareness among key actors. The German government promotes and supports educational and awareness-raising activities in various areas relevant to nitrogen. Activity areas have included energy savings and renewable energy use, environmentally conscious mobility, electromobility, nutrition, housing, recreational and consumer choices, and precautionary, comprehensive public information about the health and environmental risks of high nitrogen emissions.

Research programmes supported by the Federal Ministry of Education and Research (BMBF) are examining the impact of agricultural land use on soil functions. The BonaRes research group's goal is to study the many functions of soil and to develop new strategies, instruments and measures for the sustainable use and management of soils. In this way, BonaRes intends to significantly expand knowledge about soils used for agriculture. These soils not only have to produce commercially viable yields – they must also perform a variety of ecosystem services that go far beyond agricultural use. These services include water and carbon storage, filtration that ensures clean groundwater and maintenance of nutrient cycles and biodiversity. Some of the research also examines nitrogen.

Reduction of nitrogen pollution can also be achieved by ensuring that expert knowledge, examples of practical, sustainable approaches and innovative technologies are disseminated as quickly and as broadly as possible. The German government also supports programmes that promote application-oriented innovation and research such as the BMBF's framework programme FONA – Research for Sustainable Development and other scientific studies on a variety of nitrogen-related issues.

Options for cross-sectoral policy action

In order to further reduce nitrogen inputs, policies in environment, agriculture, nutrition, energy, transport, health, consumer protection, education and research must be coordinated more closely. This kind of integration between fields of action is the only way to successfully limit nitrogen emissions to a level that is safe for human health and the ecosystem. Developing an action programme on integrated nitrogen reduction could help identify and intensify synergies between existing, ongoing and planned government programmes targeting nitrogen reduction. This could also help prevent potential negative impacts of measures (unintended social, economic or ecological impacts) and ensure that risks of pollution swapping are identified. Generally, the polluter pays principle should be applied with more precision in dealing with the impacts of nitrogen emissions. In addition, a review should be conducted to determine whether legal or financial framework conditions work against nitrogen reduction.

The current dialogue about options for nitrogen reduction shows the great need for comprehensive information and exchange of knowledge on the overall nitrogen issue. The dialogue should include scientific and policy consultation, public actors (Federation, Länder and local authorities), the general public and businesses.

An integrated approach to nitrogen should also include the problem's international dimensions. This is why the German government is involved in many policy initiatives at EU, OECD and UN levels. These platforms are also striving for an integrated approach to the various aspects of nitrogen reduction. This was evident in the agenda of the OECD environment minister meeting in fall 2016. One of the four working group meetings focussed on nitrogen and the remaining three topics – water, biodiversity and air pollution from transport – had key links to nitrogen as well. The development of international cooperation programmes, such as the International Nitrogen Management System (INMS) coordinated by UNEP (United Nations Environment Programme), should be accelerated. Experience at national and international level shows that linking fields of action across the various political levels can increase efficiency and efficacy.

5 Conclusion: Integrated policy approaches

The successes in nitrogen emission reduction achieved by Germany to date are considerable. Nonetheless, further efforts are necessary to achieve nitrogen-related targets in German and EU environmental policy. This is why the German government is highlighting the need for an integrated policy approach to nitrogen reduction for all sectors and media. A consistent, integrated approach enables a big picture view of the total reactive nitrogen balance that goes beyond punctual or sector-specific reduction measures. Ecologically and economically appropriate and balanced solutions can be formulated and implemented on this basis. Such solutions can also give rise to innovative trends with positive effects for the economy.

Bibliography

Alfred Töpfer Akademie für Naturschutz (NNA) (1997). Stickstoffminderungsprogramm - Bericht der Arbeitsgruppe aus Vertretern der Umwelt- und der Agrarministerkonferenz. NNA-Berichte. Schneverdingen. 10

Balla, S., Uhl, R., Schlutow, A., Lorentz, H., Förster, M., Becker, C., Müller-Pfannenstiel, K., Lüttmann J., Scheuschner, T., Kiebel A., Düring I., Herzog W. (2013). Untersuchung und Bewertung von straßenverkehrsbedingten Nährstoffeinträgen in empfindliche Biotope. Forschung Straßenbau und Straßenverkehrstechnik, Volume 1099, BMVBS Abteilung Straßenbau, Bonn

BDEW (2017). Gutachten zur Berechnung der Kosten der Nitratbelastung in Wasserkörpern für die Wasserwirtschaft

bmel-statistik.de. http://www.bmel-statistik.de/landwirtschaft/statistischer-monatsbericht-des-bmel-kapitel-a-landwirtschaft/ MBT-0111290-0000, (Accessed 2 March 2017)

BMG, UBA (2014). Bericht des Bundesministeriums für Gesundheit und des Umweltbundesamtes an die Verbraucherinnen und Verbraucher über die Qualität von Wasser für den menschlichen Gebrauch (Trinkwasser) in Deutschland (2011 - 2013)

BMJV, Juris GmbH. Neununddreißigste Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes Verordnung über Luftqualitätsstandards und Emissionshöchstmengen (39. BImSchV), https://www.gesetze-im-internet.de/bundesrecht/bimschv_39/gesamt.pdf (Accessed 23 March 2017)

BMUB, BMEL (2016). Nitratbericht 2016, http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Binnengewaesser/nitratbericht_2016_bf.pdf

BMWi (2016). Green Paper on Energy Efficiency. Discussion Paper of the Federal Ministry for Economic Affairs and Energy, https://www.bmwi.de/Redaktion/EN/Publikationen/green-paper-on-energy-efficiency.pdf?__blob=publicationFile&v=3

Federal Government (2016a). Nationales Programm für nachhaltigen Konsum. Berlin: Press and Information Office of the Federal Government

Federal Government (2016b). Klimaschutzplan 2050. Berlin: Press and Information Office of the Federal Government

Federal Government (2017). German Sustainable Development Strategy: New Version 2016. Berlin: Press and Information Office of the Federal Government

CCE (2015). Modelling and Mapping the Impacts of Atmospheric Deposition of Nitrogen and Sulphur, CCE Status Report 2015. CCE Status Report. M. Posch, J. Slootweg and J.-P. Hettelingh. Bilthoven, Netherlands, Coordination Centre for Effects, RIVM http://www.rivm.nl/media/documenten/cce/Publications/SR2015/SR2015.pdf.pdf

de Vries, W., Kros, J., Kroeze, C., Seitzinger, S. P. (2013). Assessing planetary and regional nitrogen boundaries related to food security and adverse environmental impacts. Current Opinion in Environmental Sustainability, 5

DGE (2016), Vollwertig essen und trinken nach den 10 Regeln der DGE, https://www.dge.de/fileadmin/public/doc/fm/10-Regeln-der-DGE.pdf (Accessed 1 March 2017)

EEA (European Environment Agency) (2013). Air quality in Europe – 2013 report. Luxembourg: Publications Office of the European Union. EEA Report 9/2013

European Commission (2014). Living well, within the limits of our planet. 7th EAP – The new general Union Environment Action Programme to 2020, http://ec.europa.eu/environment/pubs/pdf/factsheets/7eap/en.pdf (Accessed: 23 March 2017)

GBD (2016). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015, DOI: http://dx.doi.org/10.1016/S0140-6736(16)31012-1

German Informative Inventory Report, accessed 12 December 2016, http://iir-de.wikidot.com/3-agriculture, Haenel, H.-D., Rösemann, C., Dämmgen, U., Freibauer, A., Döring, U., Wulf, S., Eurich-Menden, B., Döhler, H., Schreiner, C., Osterburg, B. (2016). Calculations of gaseous and particulate emissions from German agriculture 1990 - 2014: report on methods and data (RMD) submission 2016. Braunschweig: Johann Heinrich von Thünen-Institut, p. 73, Thünen Rep 39

Heinrich Böll Stiftung, BUND e.V. (2016), Fleischatlas, Daten und Fakten über Tiere als Nahrungsmitttel, 3. Auflage, https://www.boell.de/sites/default/files/fleischatlas_regional_2016_aufl_3.pdf (Accessed 1 March 2017)

IHME (Institute for Health Metrics and Evaluation) (2016). GBD Compare. http://vizhubhealthdataorg/gbd-compare/ 2016: (Accessed: 28 November 2016)

IPCC (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T. F. Stocker, D. Qin, G.-K. Plattner et al. Cambridge, United Kingdom and New York, NY, USA, Cambridge University: 1535 pp

Kraft, M., Eikmann, T., Kappos, A., Künzli, N., Rapp, R., Schneider, K., Seitz, H., Voss, J.-U., Wichmann, H. E. (2005). The German view: Effects of nitrogen dioxide on human health – derivation of health-related short-term and long-term values. International Journal of Hygiene and Environmental Health 208 (4), pp 305–318

LAWA (2014). Bund/Länder-Arbeitsgemeinschaft Wasser, Prognose der Auswirkungen einer nach Gewässerschutzaspekten novellierten Düngeverordnung auf die Qualität der Oberflächengewässer in Deutschland

Oita, A., Malik, A., Kanemoto, K. , Geschke, A., Nishijima, S. , Lenzen, M. (2016) Substantial nitrogen pollution embedded in international trade, Nature Geoscience, Vol. 9, pp 111-115 doi:10.1038/ngeo2635

Rockström, J., W. Steffen, K. Noone, Å. Persson, F.S. Chapin, III, E.F. Lambin, T.M. Lenton, M. Scheffer, C. Folke, H.J. Schellnhuber, B. Nykvist, C.A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P.K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R.W. Corell, V.J. Fabry, J.

Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J.A. Foley, 2009: A safe operating space for humanity. Nature, 461, 472-475, doi:10.1038/461472a

Royal College of Physicians (2016). Every breath we take: the lifelong impact of air pollution. Report of a working party. London: RCP

SRU (2015). Sondergutachten Stickstoff: Lösungsstrategien für ein drängendes Umweltproblem. Sachverständigenrat für Umweltfragen (SRU), Berlin

Steffen, W., K. Richardson, J. Rockström, S.E. Cornell, I. Fetzer, E.M. Bennett, R. Biggs, S.R. Carpenter, W. de Vries, C.A. de Wit, C. Folke, D. Gerten, J. Heinke, G.M. Mace, L.M. Persson, V. Ramanathan, B. Reyers, S. Sörlin (2015). Planetary boundaries: Guiding human development on a changing planet

Sutton, M. A., Howard, C. M., Erisman, J. W., Billen, G., Bleeker, A., Grennfelt, P., van Grinsven, H., and Grizetti, B. (2011). "The European nitrogen assessment: Sources, Effects and Policy Perspectives," Cambridge University Press, Cambridge, New York. http://www.nine-esf.org/node/360/ENA-Book.html

Umweltbundesamt (2009a). Feinstaubbelastung in Deutschland. Dessau-Roßlau: UBA

Umeltbundesamt (2009b). Hintergrundpapier zu einer multimedialen Stickstoff-Emissions-minderungsstrategie. Stand: April 2009. Dessau-Roßlau: UBA

Umweltbundesamt (2015a). Reaktiver Stickstoff in Deutschland - Ursachen, Wirkungen, Maßnahmen. Dessau-Roßlau: UBA

Umweltbundesamt (2015b). UBA Texte 39/2015, Ermittlung der Emissionssituation bei der Verwertung von Bioabfällen. Dessau-Roßlau: UBA

Umweltbundesamt (2016a).https://www.umweltbundesamt.de/daten/umwelt-gesundheit/gesundheitsrisiken-der-bevoelkerung-in-deutschland

Umweltbundesamt (2016b). Übericht zur Entwicklung der energiebedingten Emissionen und Brennstoffeinsätze in Deutschland 1994-2014 unter Verwendung von Berechungsergebnissen der Nationalen Koordinierungsstelle Emissionsberichterstattung. Dessau-Roßlau: UBA

Umweltbundesamt (2017). Verminderung der Stickstoffbelastungen: eine Schlüsselaufgabe der Umweltpolitik. Dessau-Roßlau: UBA

WasserBLIcK/BfG & Zuständige Behörden der Länder, Kartendarstellung der Nitratbelastung von Grundwasserkörpern

Wissenschaftlicher Beirat Agrarpolitik, Ernährung und gesundheitlicher Verbraucherschutz (WBAE)und Wissenschaftlicher Beirat Waldpolitik (WBW) beim BMEL (2016). Klimaschutz in der Land- und Forstwirtschaft sowie den nachgelagerten Bereichen Ernährung und Holzverwendung. Gutachten. Berlin

Abbreviations

BImSchG	Federal Immission Control Act (Bundesimmissionsschutzgesetz)
BImSchV	Ordinance implementing the Federal Immission Control Act (Bundesimmissionsschutzverordnung)
BonaRes	BMBF research initiative on soil as a sustainable resource
DGE	German Nutrition Society (Deutsche Gesellschaft für Ernährung)
DüV	Fertiliser Application Ordinance (Düngeverordnung)
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
EU	European Union
Euro 6	EU emission standard for light passenger and commercial vehicles
FONA	BMBF framework programme for research on sustainable development
g	gram(s)
GWD	Groundwater Directive
IED	Industrial Emissions Directive
INMS	International Nitrogen Management System
KrWG	Circular Economy Act (Kreislaufwirtschaftsgesetz)
l	litre(s)
mg	milligram(s)
MSFD	Marine Strategy Framework Directive
NEC Directive	National Emission Commitments Directive (EU Directive of 14 December 2016 on the reduction of national emissions of certain atmospheric pollutants; sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds, ammonia and particulate matter less than 2.5 micrometres in diameter)
NO_2	Nitrogen dioxide
OECD	Organisation for Economic Co-operation and Development
PM_{10}	Particulate matter (solid) less than 10 micrometres in diameter
$PM_{2,5}$	Particulate matter (solid) less than 2.5 micrometres in diameter
SDG	Sustainable Development Goals
t	tonne(s)
TA Luft	Technical Instructions on Air Quality Control
UBA	German Environment Agency
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
WFD	Water Framework Directive