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Agriculture, Ammonia, and Air Pollution

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Agriculture is probably not the first thing that springs to mind when considering the major sources of air pollutants. However, emissions from agriculture are significant contributors to particulate matter. More specifically, agriculture is the largest source of ammonia emissions. This important contributor to particulate matter concentrations in the atmosphere is released during the decomposition of manure and other organic matter. A recent report on air quality within EU Member States attributed around 400 000 premature deaths to long-term exposure to particulate matter pollution.[1] Measures to reduce ammonia emission exist but lack implementation.

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* This IASS Fact Sheet is a joint initiative of the IASS, Deutsche Umwelthilfe (DUH), Freie Universität Berlin (FU Berlin), and Netherlands Organisation for Applied Scientific Research (TNO).

What is ammonia?

Ammonia (NH_3) is a toxic gas with a pungent smell that irritates the eyes and respiratory system. Once emitted, ammonia reacts quickly with other air pollutants to form ammonium sulfate and ammonium nitrate, contributing to the overall particulate matter burden. However, ammonia and its subsequent particulate ammonium salts are important sources of nitrogen in soils and contribute to plant growth. The use of ammonia-based synthetic fertilisers has boosted agricultural productivity, which in turn has led to dramatic increases in emissions of ammonia. The overabundance of nitrogen caused in many ecosystems by these emissions results in adverse effects such as eutrophication.

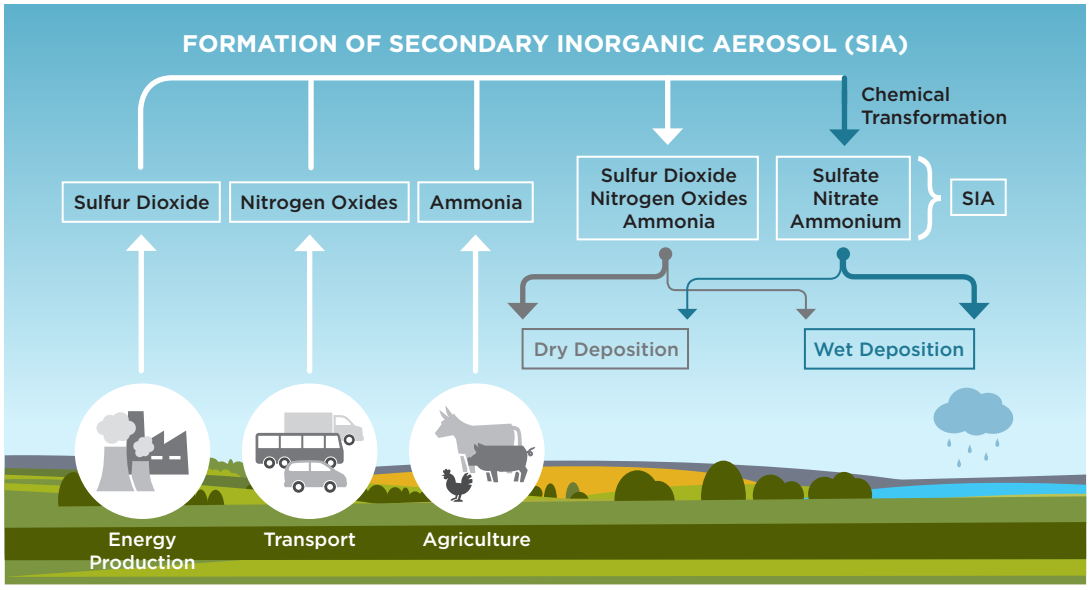
What are the sources of ammonia?

More than 90 per cent of ammonia emissions in Europe originate from the agricultural sector.[2] These emissions are released to the air during the decomposition of manure and organic matter. While the majority originates from animal farming and its associated manure processes, the use of synthetic fertilisers in farming also contributes to emissions to a lesser extent. The remaining ammonia emissions can be attributed to waste, industrial processes, combustion processes, denitrification units installed to reduce nitrogen oxides emissions from power stations, and catalytic converters in motor vehicles.

How does ammonia contribute to the formation of particulate matter?

Two-thirds of particulate matter can typically be attributed to particles of secondary nature, which are formed in the atmosphere from a variety of precursor gases. Ammonia is an important precursor gas in the formation of Secondary Inorganic Aerosol (SIA), which are often a significant factor in particulate matter episodes. Under typical ambient conditions, ammonia (NH_3) reacts with other inorganic species, in particular sulfuric acid (H_2SO_4) and nitric acid (HNO_3), to form salts (see figure). Ammonium nitrate, originating from the reaction of ammonia with nitric acid, is a main source of fine particulate nitrate in urban areas over large parts of Western Europe. Specifically, agricultural ammonia emissions often represent 10 to 20 per cent of fine particulate matter mass in urban areas in Europe and more in areas with intensive livestock farming.[3]

Ammonium sulfate and ammonium nitrate remain in the atmosphere as particulate matter on the order of days and for up to a week. As a result, SIA formed from ammonia can be transported over great distances and can influence human health and ecosystems on the regional scale.



Contribution of agriculture to the formation of inorganic aerosols and atmospheric particulate matter. © IASS/Adapted from APIS

How harmful is particulate matter?

The World Health Organization (WHO) has determined that there is no safe threshold level for exposure to particulate matter.[4] The adverse effects of air pollution result from both acute and chronic exposure. Ambient particulate matter pollution has been linked to increased respiratory and cardiovascular mortality, reduced lung function, and chronic obstructive pulmonary disease.

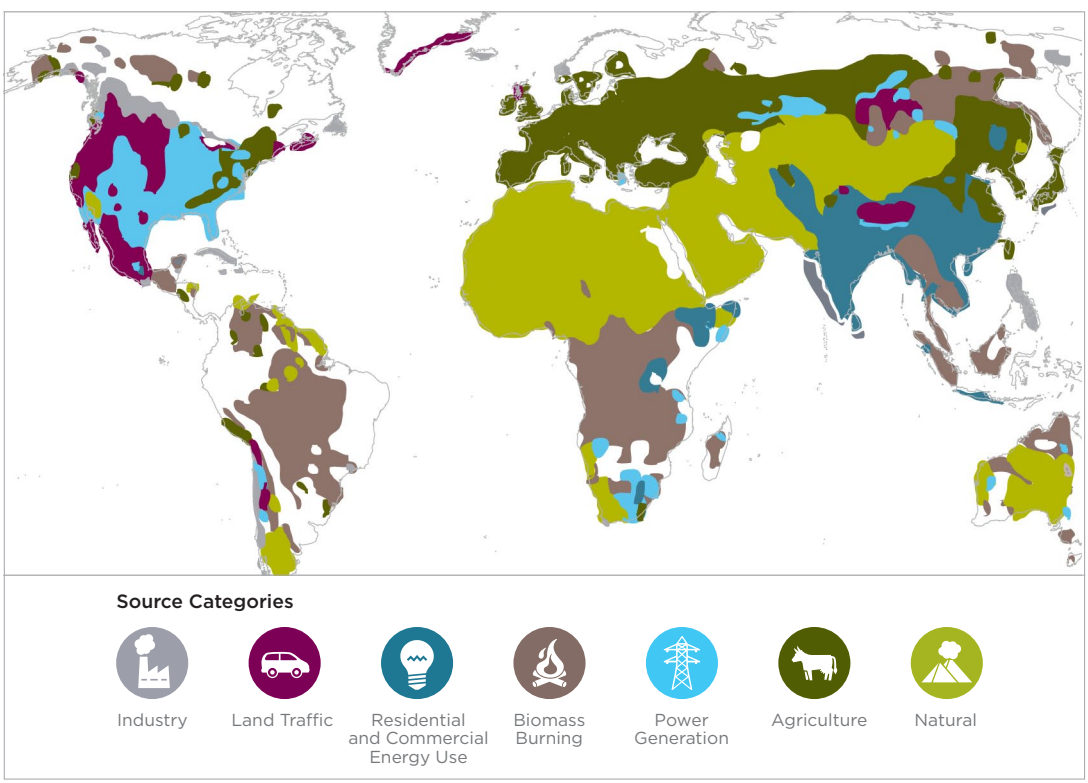
Depending on their size, particles can penetrate deep into a person's lungs and travel throughout the bloodstream. Size and chemical composition largely determine how dangerous particulate matter is for human health. However, information on the relationship between toxicity and chemical composition is extremely limited.

A recent study investigated the sectoral attribution of mortality owing to air pollution and found that emissions from agriculture – the largest relative contributor to particulate matter – were identified as the leading cause of mortality in Europe.[5] In some European countries, including Germany, Russia, and Ukraine, over 40 per cent of air pollution related mortality can be attributed to emissions from agriculture.

At the global level, approximately 3.3 million deaths are attributed to premature mortality from outdoor air pollution in the study. 380 000 of these deaths occurred in the European region, with 34 000 occurring in Germany – 45 per cent of which were attributed to contributions from agricultural emissions to air pollution. Other leading sources include transport (20 per cent), and power generation and industry (13 per cent respectively).

The study also tested the uncertainty around toxicity by considering alternative scenarios. While the balance between premature deaths attributable to emissions from traffic and agriculture shifts within these scenarios, agricultural emissions – and therefore ammonia – remain among the top two contributors to air pollution related mortality in Europe and are clearly a lynchpin for reductions in particulate matter to protect human health.

AIR POLLUTION: SOURCES WITH THE LARGEST IMPACT ON MORTALITY



Source categories responsible for the largest impact on mortality linked to outdoor air pollution in 2010 as per Lelieveld et al (2015). © IASS

Are current ammonia emissions targets being met?

In 2015, the European Commission updated its methods for estimating emissions of ammonia from agriculture. Previously reported estimates of emissions in Germany were raised significantly as a result of these changes (by roughly 100 kilotons per year). Under the former reporting regime, Germany had already exceeded its National Emission Ceiling (NEC) of 550 kilotons in almost every year between 2005 and 2013, with national emissions reaching around 671 kilotons in the latter year.

Germany has failed to meet the long-term targets of the European Union for emissions limits, and in light of the insufficient implementation of the EU Nitrates Directive, the European Commission launched an infringement procedure against the country in 2013. Provisional emissions data for 2013 show that five other Member States (Austria, Denmark, Finland, the Netherlands, and Spain) also exceeded ammonia emissions ceilings set by the National Emission Reduction Commitments (NERC). The highest exceedance in 2013 was reported for Germany, which ranks among the largest emitters of ammonia together with France and Italy. Only 16 of 27 EU Member States reported emission reductions.

What measures exist to reduce ammonia emissions?

As ammonia abundance is often a limiting factor in the formation of particulate matter, reducing emissions could contribute significantly to air pollution abatement. Since the 1990s, efforts to reduce emissions of precursor nitrogen oxides and sulfur dioxide have been relatively successful. However, emissions of ammonia have not been targeted substantially to date. Achieving effective reductions in particulate matter exposure requires reductions across all three precursor species and – specifically – ammonia.

Cost-effective measures for the reduction of ammonia emissions from agriculture exist and have been assessed. A variety of measures have been documented and evaluated in a number of reports, and various policy option analyses have been submitted to the European Commission. Many of these assessments focus exclusively on technical options, however non-technical options such as reducing meat consumption should also be investigated.

While the choice of measures implemented at the farm level depends on a variety of factors, the following measures are provided as examples.[6]

Improved manure storage

Ammonia emissions from manure can be reduced by decreasing the exposed surface area of manure slurry in storage. Potential measures to achieve this include:

- Adding a cover to manure storage containers such as a lid, roof, or tent structure
- Implementing floating covers such as plastic sheeting or 'low-technology' floating covers (for example, chopped straw, peat, or bark)
- Allowing a natural crust to form on the surface of the manure slurry
- Replacement of lagoons with covered tanks or tall open tanks with greater depth
- Storage bags

Improved application of manure to soil

Emissions of ammonia can be reduced by application techniques that bury the manure or decrease the exposed surface area of the manure slurry when applied to the surface soil. These techniques include:

- Band-spreading slurry at the soil surface using trailing hose or trailing shoe methods
- Slurry injection
- Incorporation of surface-applied solid manure and slurry into soil
- Dilution of slurry by at least 50 per cent in low pressure water irrigation systems

Low-protein feed

Animal feed composition and feed management have a strong influence on the resulting emissions of ammonia. The use of low-protein feedstock is one of the most cost-effective and strategic ways of reducing ammonia emissions. Provided that the requirements for all amino acids are met, low-protein feedstock has no animal health or welfare implications. Techniques include:

- Using low-protein feedstock (with or without supplementation)
- Increasing the non-starch polysaccharide content of feedstock
- Using feedstock supplements to lower pH levels

SUMMARY

Increasing the awareness of the role of agriculture as a major contributor to particulate matter concentrations is crucial to improving action.

- Agriculture is the dominant source of ammonia emissions in Europe and accounts for over 90 per cent of emissions.
- Ammonia is an important contributor to atmospheric particulate matter concentrations.
- Particulate matter is the largest cause of mortality related to air pollution.
- While efforts to reduce emissions of the SIA precursors nitrogen oxides and sulfur dioxide have been relatively successful, ammonia emissions have not been targeted substantially to date.
- Only by addressing the emissions of all the precursor gases simultaneously will an effective reduction of particulate matter concentrations result.
- Ammonia emission mitigation measures exist and will need to be implemented to effectively reduce particulate matter concentrations.

[1] European Environment Agency (EEA) (2015). *Air quality in Europe – 2015 report. EEA Report No 5/2015.* Available at: http://www.eea.europa.eu/publications/air-quality-in-europe-2015 (last accessed on 10.05.2016).

[2] Ammonia (NH_3) emissions, available at: http://www.eea.europa.eu/data-and-maps/indicators/eea-32-ammonia-nh3-emissions-1/assessment-4 (last accessed on 10.05.2016).

[3] Brunekreef, B. et al. (2015). Reducing the health effect of particles from agriculture. – *The Lancet, 3*, pp. 831–832.

[4] World Health Organization (2013). *Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report.* Available at: http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/air-quality/activities/evidence-on-health-aspects-of-air-pollution-to-review-eu-policies-the-revihaap-project (last accessed on 10.05.2016).

[5] Lelieveld, J. et al. (2015). The contribution of outdoor air pollution sources to premature mortality on a global scale. – *Nature, 525*, pp. 367–371.

[6] These examples are drawn from the following publications:

- Oenema, O. et al. (2012). *Emissions from agriculture and their control potentials. TSAP Report #3, Version 2.1. ENV.C.3/SER/2011/0009.* Available at: http://ec.europa.eu/environment/air/pdf/TSAP-AGRI-20121129_v21.pdf (last accessed on 11.05.2016).
- Bittman, S. et al. (2014). *Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen.* Centre for Ecology and Hydrology, Edinburgh, United Kingdom.

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Founded in 2009, the IASS is an international, interdisciplinary hybrid between a research institute and a think tank, located in Potsdam, Germany. The publicly funded institute promotes research and dialogue between science, politics, and society on developing pathways to global sustainability. The IASS focuses on topics such as sustainability governance and economics, new technologies for energy production and resource utilisation, and earth system challenges such as climate change, air pollution, and soil management.

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