# Annexes to the Assessment report on ammonia (ECE/EB.AIR/2021/7)

## Annex 1: Future research needs

Despite trends and results presented in this report, it should not be neglected that the assessment of ambient ammonia remains a scientific challenge. For example ambient ammonia concentrations are highly variable on the small spatial scale and influenced by meteorological conditions. Also, the real life emission factors remain an ongoing scientific debate. Therefore, continued and increased observation of ammonia is needed to form a robust scientific basis for assessing ammonia in the future. This includes increased measurements of ammonia concentrations and fluxes in sensitive nature areas.

1. There is a need for more monitoring ammonia and ammonium concentrations, both in the proximity of sources and at longer distance. Observations from background stations in Europe and North America are not representative for areas with high livestock density. Methods for taking into account satellite observations in future assessments look promising means.

Given that the dispersion of ammonia and ammonium, the nitrogen deposition and the formation of secondary particulates depend on the interaction with other compounds and with meteorological conditions, the atmospheric modelling requires the use of short timesteps (e.g. three hours). The accuracy of this modelling depends in part on having reliable estimates of the ammonia emission at high spatial and temporal resolution. In that connection, there is a need to improve the spatial and temporal activity data and modelling.

2. Prolonged or continuous monitoring of ammonia emissions from animal housing and manure storage. The emissions vary according to the type of housing and manure storage and the meteorological conditions.
3. Better monitoring of event-driven ammonia sources (field-application of manure and fertilizer). These emissions mainly occur during the period 1 to 3 days following application and depend on the type of manure or fertilizer, soil conditions and meteorological conditions.
4. Better monitoring of emissions from living crops and crop residues. Ammonia emissions occur when the concentration within the leaf exceeds the concentration in the air, when crops are damaged by disease, when crop foliage is deliberately killed by the farmer, from severed leaves and stems after forage harvesting, from above ground crop residues and during grain filling in cereals. Our understanding of these crop ammonia emissions varies from good to poor, depending on its exact nature.

The quality of ammonia emission projections could be further improved using sensitivity analysis.

5. The effectiveness of abatement measures derived from model farms could be too optimistic compared to real life practices. Projections with less (of more) optimistic assumptions could give a better picture of the sources that will be dominant in the future and of the potential benefits of innovative breakthroughs in housing, precise farming or diets. Sensitivity analysis could also indicate which new ammonia sources might become relevant, e.g. due to the production of energy crops or the use of ammonia as a fuel in shipping.
6. The synergies and trade-offs between ammonia emission abatement measures and the reduction of methane and nitrous oxides requires further empirical studies.

Also, the modelling of future impacts for health and ecosystems can be improved.

7. Analysis of the impact of envisaged $NO_x$ and $SO_2$ reductions on the formation of secondary inorganic aerosols and on future ammonia concentrations and transboundary fluxes. E.g. what will be the impact on exceedances of critical levels for ammonia in remote areas such as Fennoscandia?
8. Further research into to sensitivity of ecosystems to ammonia exposure. There are indications that vegetation can be more sensitive to exposure to ammonia than to ammonium aerosols[1]. This would justify more policy attention to ammonia emission reduction near sensitive ecosystems.

Last but not least, questions remain about the optimal policy level to take action:

9. Are additional local ammonia measures sufficient to protect nature areas, or is (inter-) national co-ordination to further reduce background deposition levels more cost-effective?
10. What is reliability of models used for permitting individual farms and projects that estimate the nitrogen deposition on nearby and remote nature areas? How can such models be improved?

[1] Mark A. Sutton, 2020, Alkaline air: changing perspectives on nitrogen and air pollution in an ammonia-rich world, Royalsocietypublishing.org, https://doi.org/10.1098/rsta.2019.0315

## Annex 2: Background information

### *Ammonia and methane: synergies and trade offs*

European climate policy is set for further ambition and action on the time horizons to both 2030 and 2050 as part of the European Green Deal proposals. Renewables and electrification offer a challenging but comparatively clear path for many sectors to decarbonise. In contrast, agriculture and biogenic methane remain comparatively unconstrained. Whilst reducing herd sizes and changing global diet patterns would have a direct impact, the former is highly contentious politically, and the latter would require a coordinated global population response. As outlined in this report, ammonia is also a particular challenge in an air pollution context for many member states, and, as with biogenic methane, is something which should be addressed within the agriculture sector. Choices, co-benefits and trade-offs between ammonia and biogenic methane abatement are researched and merit more direct analysis and policy attention.

As an example promising feed measures for biogenic methane control may be available to herds in feedlot systems, but what are the trade-offs for ammonia and animal welfare? What options are there for grass fed herds? At present countries such as New Zealand have introduced ranges for their biogenic methane target in direct acknowledgment of the uncertainty around plausible pathways for the future. They also recognise the value of reductions in a comparatively short-lived climate forcer as part of efforts to keep global temperature increase well below 2 degrees C.

Anaerobic digestion is a measure that contributes to replacing fossil fuels by biogas, but will not automatically reduce ammonia emissions, as the nitrogen will remain in the sludge.

The use of energy crops could also replace fossil fuels use, and could increase the use of mineral nitrogen fertilizers. The extent to which energy crops will lead to increased use of fertilizer will depend on whether the crops they replace will have received more or less fertilizer.

The integrated assessment of ammonia and climate policies offers the opportunity to build the evidence base for what is possible, or indeed not possible with respect to simultaneously meet ammonia and climate goals in future policy preparations.

### *Urea fertilizer*

Low emission manure application can have a large contribution to reducing ammonia emissions, especially when combined with less mineral fertilizer use. One of the types of mineral fertilizer that contributes relatively much to ammonia emission is urea fertilizer. This type of fertilizer is relatively cheap and widely used in Germany, where the share of fertilizer use in the total ammonia emissions is around 25%. Substitution of this type of fertilizer is a cost-effective measure (€ 0.1-2.8 per kg ammonia ) (Wulf, et al. (2017) – see footnote 38). In Germany, since January 2020, all urea fertilizer must be immediately incorporated into the soil or incorporate special compounds to slow urea break down (‘urease inhibitors’), both of which substantially reduce ammonia emissions.

*The nitrogen debate in the Netherlands*

From 2016 non-governmental organizations challenged the existing nitrogen policy in the Netherlands in legal courts. In May 2019 the supreme court of the Netherlands blocked new permits for all activities that cause additional nitrogen deposition. In November 2018 the European Court of Justice had judged that permitting in the Netherlands was not in line with the Habitat Directive of the EU and would lead to further increase of nitrogen deposition, although all permits included European emission limit values, the obligations under the National Emissions Ceilings Directive were met, as well as the obligations under the Nitrate Directive. The construction of new animal housing, roads, houses and other buildings had to stop at once. This caused massive protests of both farmers and construction workers. Highway blockades caused traffic chaos across the country for several days. Farmers put the conclusion that ammonia was a dominant cause of biodiversity loss into doubt. Committees were formed to develop a way out and to scrutinize the data and models. The lesson was that the Habitat Directive should be taken more serious. And that what happened in the Netherlands could also happen in courts in other EU-countries.

From now on, permits for new activities can only be given after a reduction of current nitrogen depositions. Of the reduced nitrogen deposition 70% can be used for new permits. The remaining 30% defines the speed of reduction in excess nitrogen deposition. The main problem in the Netherlands is the high density of livestock and traffic and the scattered pattern of small nature areas. The scope for additional technical measures is very limited. That means that most probably the solution will have to be found in reduction of activity levels. The first easy measures were taken were the reduction of the speed limits on highways, additional funding for nature conservation and financial incentives to voluntary close pig stables. But the reduction of the cattle stock is still debated heavily. Some farmers promote new high tech solutions (e.g. cows with a higher milk productivity, additives to cattle feed and ‘innovative’ housing systems). Other farmers choose low tech solutions: lower cattle densities and more grazing would mean less ammonia, less methane, healthier cows, but with a lower productivity.[2] However they would also require less cattle feed, less fertilizers and less antibiotics.

Lessons from the Netherlands and Flanders learn that enforcement of regulation is essential for an effective implementation of ammonia abatement measures. E.g. the installation of air scrubbers itself proved to be insufficient as they were not always operational and additional measures had to be taken to guarantee its use. Recording of manure transport also remains to be a challenge to prevent groundwater pollution or illegal export and dumping. Transboundary co-operation is needed to make national import and export data of manure consistent. Current inconsistencies indicate that ammonia emissions might be underestimated. Better recording would increase the effectiveness of ammonia emission reduction measures and could avoid increased concentrations of nitrate in groundwater.

[2] According to the Emission Inventory Guidebook both ammonia and methane emission factor is substantially lower for manure excretion in meadows than in stables.