Knowledge grows

Reducing Ammonia Emissions from Agriculture

PURE NUTRIENT | Ammonia Emissions

Clean Air, Strong Crops

Ammonia lost to the air is nitrogen lost for plant growth. At the same time, ammonia volatilization is an environmental burden, affecting human health, natural ecosystems and biodiversity. Mitigating ammonia emissions therefore benefits farmers and society. Solutions are available and the recent European directive on emission ceilings, by consequence, sets national reduction commitments for ammonia.

This Pure Nutrient Fact deals with ammonia emissions from agriculture in general and fertilizer application in particular - and how to mitigate them.

Ammonia emissions – what's the problem?

Ammonia emissions are an environmental burden and a loss of valuable nitrogen for plant growth. Mitigating ammonia losses from fertilizer application thus provides a double benefit. What exactly are the causes and consequences of ammonia volatilization?

About ammonia

Ammonia is a highly reactive, pungent gas formed of nitrogen and hydrogen. Its chemical formula is NH_3. Ammonia occurs in essential biological processes and is not a problem in low concentrations. However, ammonia volatilization into the atmosphere has negative consequences for agriculture, ecosystems and human health:

- Ammonia volatilization from agricultural land is a loss of nitrogen for plant growth. It therefore comes at a cost for the farmer that needs to be minimized.
- Ammonia reacts with air humidity to form ammonium (NH_4). Ammonium depositions contribute to acidification of land and water.
- Deposition of ammonium degrades the biochemistry of natural ecosystems and causes eutrophication (i.e. excess nutrient supply leading to e.g. algae proliferation).
- Ammonia combines with other air pollutants such as sulfuric acid and nitric acid to form secondary particulate matter (PM10). It stays in the air over several days and travels long distances. Particulate matter contributes to respiratory diseases.

Ammonia pollution from agriculture represents a high cost to society. According to the European Nitrogen Assessment, it is estimated at 12 € per kg of emitted nitrogen for health damages and 2 € for ecosystem damages [1].

Where does it come from?

Agriculture

94 % of all ammonia emissions in the EU result from agriculture. The remaining 6 % come from waste handling, road transportation and industrial applications.

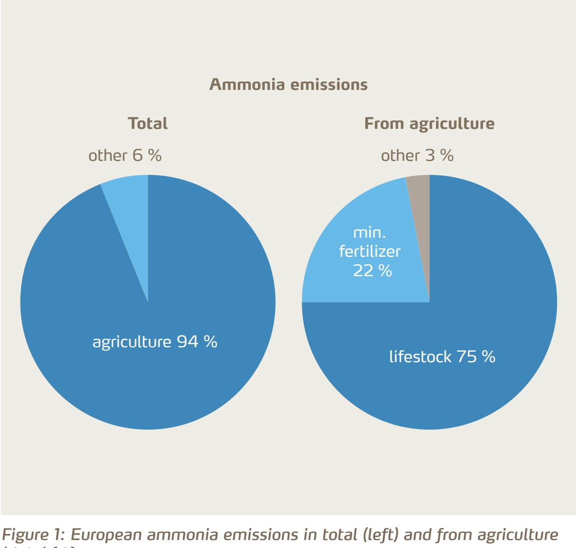

Figure 1: European ammonia emissions in total (left) and from agriculture (right) [4].

Animal husbandry and manure

Livestock excreta contain high amounts of ammonia. They are at the origin of 75 % of all ammonia emissions from agriculture in the EU (figure 1). Emissions from livestock can be reduced but are beyond the scope of this Pure Nutrient Fact which is dedicated to mineral fertilizer.

Mineral fertilizer

Mineral fertilizer application accounts for 22 % of all ammonia emissions from agriculture in the EU (figure 1). These emissions are due to the transformation of ammonium solved in the soil to gaseous ammonia. The rate of transformation depends on the soil pH level. The higher the soil pH level, the more ammonium is converted to ammonia. The higher the temperature, the more ammonia is then lost to the atmosphere.

Mineral nitrogen fertilizers either directly contain ammonium (ammonium sulfate, ammonium sulfate nitrate, ammonium nitrate, CAN) or are converted to ammonium in the soil subsequent to spreading (urea and UAN). Urea and ammonium containing fertilizers are therefore subject to potential ammonia losses. Urea, however, is specifically prone to ammonia volatilization (figure 4).

The impact of nitrogen form

The case of urea

Hydrolysis of urea to ammonium temporarily increases the pH level in the direct vicinity of the application location. The increased pH level spurs the formation of ammonia, even on acidic soils (figure 2).

With temperatures above 15 °C, urea hydrolysis is fast and local ammonia concentrations in the soil rise, and thus volatilization. Temperatures below 8 °C slow down the transformation of urea to ammonia, but also the subsequent nitrification of ammonia to nitrate, leading again to high ammonia concentrations and volatilization.

Dry conditions reduce diffusion of ammonia in the soil and therefore also increase volatilization. Rainfall after application, in contrast, reduces volatilization.

Field trials conducted in different European regions have demonstrated average ammonia volatilization losses from urea of 13.1 % [2].

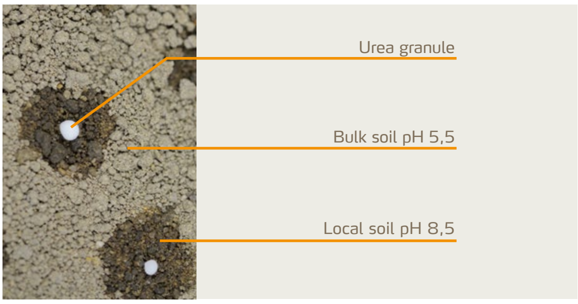

Figure 2: Hydrolysis of urea temporarily and locally increases soil pH, resulting in increased ammonia losses.

Comparing mineral fertilizers

Figure 3 summarizes the estimated ammonia volatilization from different fertilizer types. CAN and AN offer the lowest emission factors of all nitrogen fertilizers.

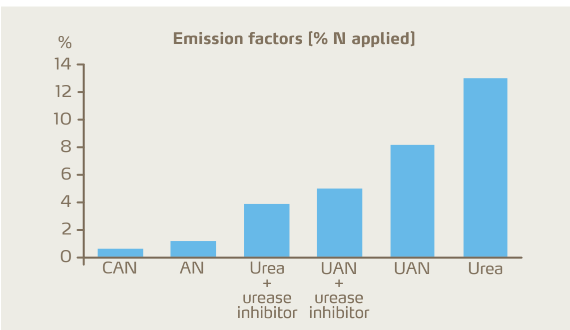

Figure 3: Ammonia emission factors for different nitrogen fertilizers applied to normal soils (pH ≤ 7) [3][4].

Table 1 shows the ammonia emissions from main mineral fertilizers according to the emission factors defined by the European Environmental Agency. Urea (53.7 %) and UAN (18.4 %) together account for 72 % of these emissions, while CAN and AN amount for only 2,9 and 4,6 % respectively.

	Applied N [kt]	N lost as NH_3 [%]	N lost as NH_3 [kt]	Loss share [%]
CAN	2713	0.7	18	2.9
AN	2119	1.3	28	4.6
Urea	2473	13.1	324	53.7
UAN	1354	8.2	111	18.4
AS	364	7.6	28	4.6
Other	1504	5.5	83	13.7
DAP/MAP	299	4.2	13	2.1
Total	10826		605	100

Table 1: Ammonia losses in 2014 from mineral fertilizer in Europe according to standard emission factors. 72 % of overall ammonia losses from fertilizer are caused by urea and UAN. Ammonia emissions from NPK fertilizers (line "Other" in above table) depend on composition (compounds or blends, urea or nitrate based) with nitrate based compounds offering the lowest emissions. [3].

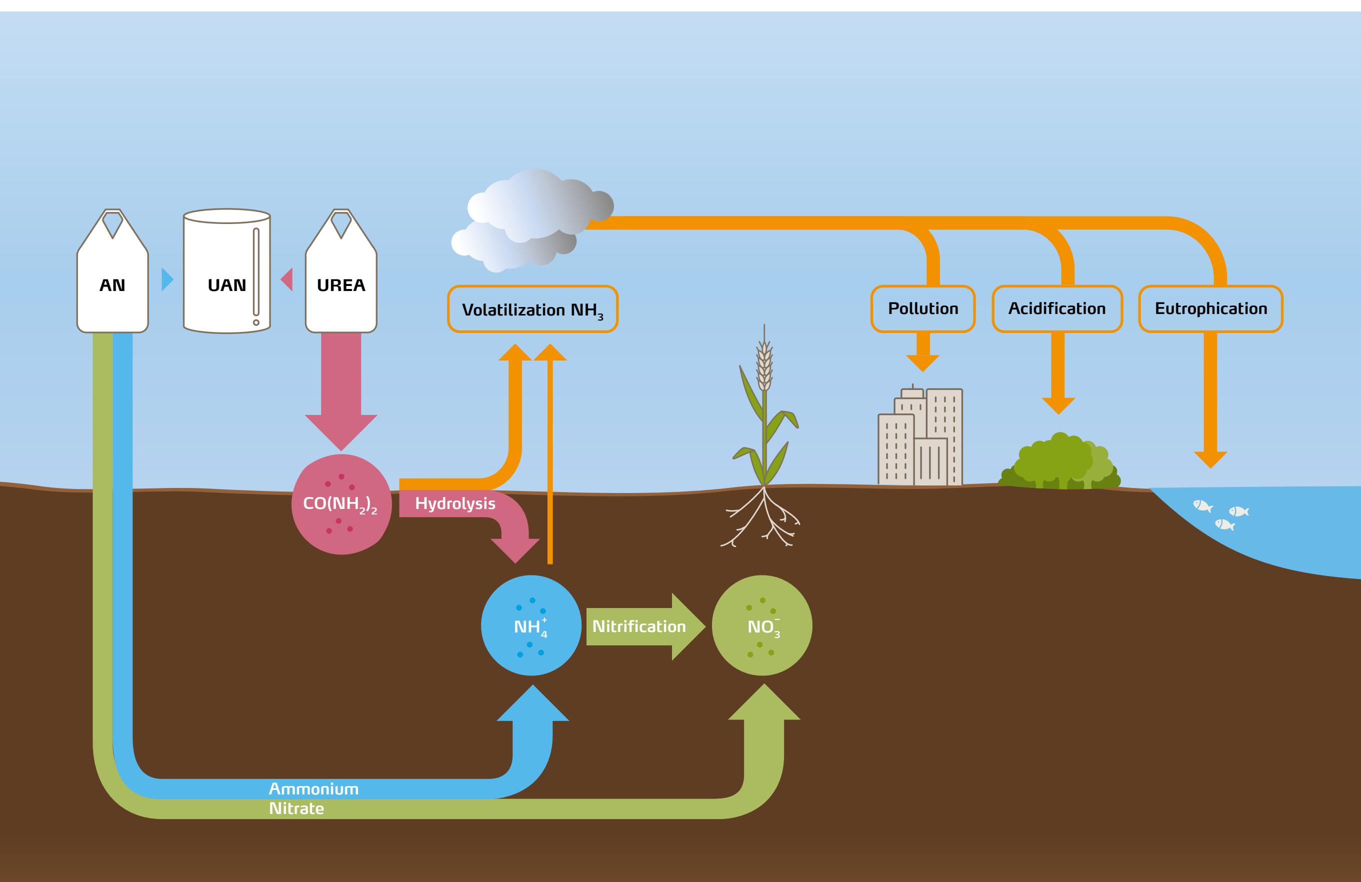

Figure 4: All mineral nitrogen fertilizer is ultimately transformed into nitrate (NO_3^-) before it is taken up by plants. Ammonium (NH_4^+) is an intermediate compound which is either directly applied (as ammonium nitrate NH_4NO_3) or converted in the soil from urea ($CO(NH_2)_2$). Ammonium is in equilibrium with ammonia (NH_3) in the soil solution. The higher the pH, the more the balance shifts in favor of ammonia.
UAN is a mix of AN and urea and thus activates all the pathways in the above diagram.

New NEC directive: what does it say?

Air pollution travels long distances and does not stop at national boundaries. It affects health of the most vulnerable and is responsible for acidification and eutrophication.
What does Europe do to tackle the problem?

Setting emission ceilings

The European Union has put legislation in place to control air pollution. In 2001, the NEC (National Emission Ceilings) directive has set emissions ceilings per country for main pollutants (see table 1). In 2016, the NEC directive sets additional reduction targets per country. The reference for the reductions to be achieved at the horizon of 2020 and 2030 are calculated based on actual emissions recorded in 2005 (figure 5).

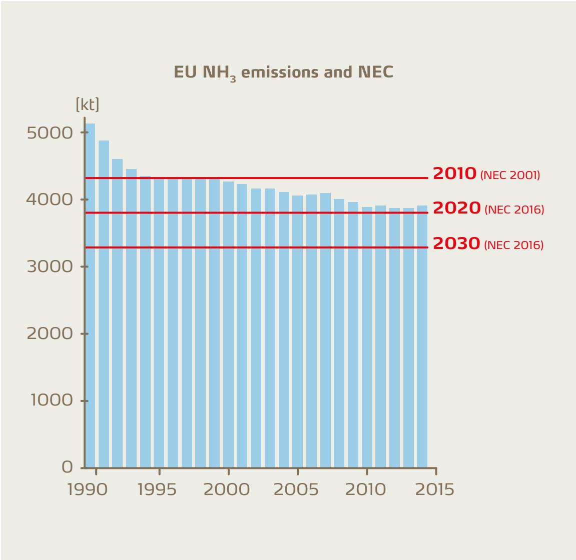

Figure 5: Ammonia emissions in the EU have decreased slowly in the past two decades. The 2016 NEC directive sets national reduction targets for 2020 and 2030, respectively.

The current status and the goals set out by the NEC directive are summarized in table 2.

Country	Actual Emissions	Reduction Targets	
	2005	2020 vs. 2005	2030 vs. 2005
France	659 kt	- 4 %	- 13 %
Germany	678 kt	- 5 %	- 29 %
Belgium	68 kt	- 2 %	- 13 %
Netherlands	156 kt	- 13 %	- 21 %
EU	3818 kt	- 6 %	- 19 %

Table 2: Actual emissions, ceilings and reduction targets for ammonia according to the NEC 2016 [3].

It is worth noting that in some countries (e. g. France) ammonia emissions have increased since 2005 due to the extensive use of urea and UAN.

Best fertilizer practice

Nitrogen compounds at a glance:

NH_3
Ammonia: a pungent smelling gas and air pollutant causing soil acidification, eutrophication, ground level ozone and a precursor of secondary particulate matter.

NH_4^+
Ammonium: a cation found in low concentration in soil solution and fixed by clay mineral.

NO_3^-
Nitrate: an anion found in the soil solution. Preferred nitrogen form taken up by plants.

N_2O
Laughing gas: a 300 times more powerful greenhouse gas than CO_2.

NOx
Nitrous oxides: an abbreviation designating both, NO and NO_2. Important air pollutant causing ground level ozone and a precursor of secondary particulate matter.

N_2
Dinitrogen: an unreactive gas that is abundant in the atmosphere

Ammonia emissions from fertilizer application can be significantly reduced. Each kg of nitrogen kept in the soil increases nitrogen efficiency and plant uptake.
What are the practical measures to put in place?

Nitrogen forms make a difference

Ammonia from urea?
More than 72 % of ammonia emissions from fertilizer application are caused by urea and UAN. Ammonium nitrate generates 90 % less ammonia emissions per unit of nitrogen than urea. Replacing all urea and UAN by ammonium nitrate could save 63 % of overall ammonia losses from fertilizer application in Europe. With a potential emission reduction of about 470 kt NH_3, this is the single most efficient measure to reduce ammonia volatilization. When volatilization risk is high, only CAN or AN shall be used.

Urease inhibitors
Urease inhibitors slow hydrolysis of urea. More time therefore is available for diffusion into the soil, reducing ammonia concentrations and increasing the soil volume available for buffering pH. Urease inhibitors can mitigate ammonia losses from urea by about 70 % and from UAN by about 40 %. For this reason the new German fertilizer ordinance requires either use of urease inhibitors or incorporation of urea when urea is applied from 2020 on. However, ammonia emissions still remain more than 3 times higher then those from CAN/AN. Urease inhibitors can improve environmental and agronomic outcome but do not overcome other weak points of urea such as lower spreading accuracy and lower reliability. Furthermore, degradation of the inhibitor on urea bears the risk of much lower ammonia emission control than claimed.

Applying fertilizer optimally

Incorporation upon spreading
Incorporation of urea into the soil immediately upon spreading, either by closed-slot injection or by cultivation, reduces potential volatilization losses by up to 70 %. However, also in this case, ammonia emissions still remain more than 3 times higher than those from CAN/AN. Depth of injection and soil texture influence reduction efficiency.

Weather conditions
Spreading urea under hot and windy conditions with no rainfall expected upon spreading shall be avoided. With dry soils, diffusion of ammonium and urea in the soil is slow and volatilization losses are high. Humid soils improve diffusion. Rainfall upon fertilizer application significantly reduces ammonia emissions by better distribution of fertilizer in the soil and mitigation of pH peaks.

Cool weather (< 15 °C) curbs formation of ammonia in the soil and subsequent volatilization losses from urea. However, low temperatures often observed in early spring slow down the nitrification process. More ammonia thus remains in the soil, again increasing potential volatilization losses.

Soil conditions
Alkaline soils (high pH) result in higher volatilization losses. Urea and UAN therefore shall not be spread on such soils.

Split application
Split application reduces ammonia concentrations and volatilizations risks.

Conclusion

Use of nitrate-based fertilizers and split application are the most efficient means to mitigate ammonia losses to the atmosphere. Urease inhibitors reduce ammonia volatilization from urea but remain less performant than ammonium nitrate.

Yara offering

Good returns for farmers combined with environmental sustainability are the cornerstones of Yara's vision and mission. We offer farmers premium fertilizers and agronomic advice. What makes the difference?

Quality first

YaraBela and YaraMila nitrate-based fertilizers are produced in our European plants which are amongst the most efficient worldwide. Close control over the entire production process, highly trained employees, the latest technology and a century of experience ensure that we set and meet the highest standards.

Clean production

Yara is committed to produce in plants operating under best practices. All our plants are certified ISO 9001 and 14001. We intend to lead the sector in adopting and communicating common high standards. Our constant pledge for safety is reflected by our low rate of incidents.

Pure Nutrients

YaraBela and YaraMila nitrate-based fertilizers are pure nutrients, offering farmers the reliability, precision and efficiency to meet the requirements of modern agriculture under economic, agronomic and environmental aspects.

Knowledge grows

Volatilization can be made visible. Yara has developed a kit (figure 6) for educational and other demonstration purposes. It can also be used to compare and measure semi-quantitatively ammonia losses from different nitrogen fertilizers.

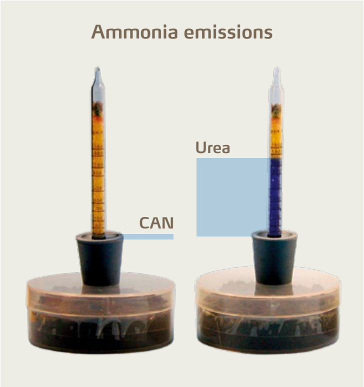

Figure 6: The Yara volatilization kit indicates volatilization losses by turning the yellow indicator to blue when it gets in contact with ammonia emitted from fertilizer.

LITERATURE

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[2] Bouwman A F, Boumans L J M, Batjes N H (2002): Estimation of global NH_3 volatilization from mineral fertilizer and animal manure applied to arable land and grasslands, Global Biochemical Cycles, 16, 1-15

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[4] Bittman S, Dedina M, Howard CM, Oenema O, Sutton MA (2014): Options for Ammonia Mitigation. Guidance from the UNECE Task Force on Reactive Nitrogen, chapter 8, Centre for Ecology and Hydrology, Edinburgh, UK

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YARA NITRATE FERTILIZER PURE® nutrient

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For further information about nitrate fertilizers and farming

YARA WEBSITE

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About Yara

Yara's knowledge, products and solutions grow farmers', distributors' and industrial customers' businesses profitably and responsibly while protecting the earth's resources, food, and environment.

Our fertilizers, crop nutrition programs and technologies increase yields, improve product quality and reduce the environmental impact of agricultural practices. Our industrial and environmental solutions improve air quality by reducing emissions from industry and transportation, and serve as key ingredients in the production of a wide range of goods. Throughout our organization, we foster a culture that promotes the safety of our employees, contractors and societies.

Founded in 1905 to solve emerging famine in Europe, today Yara has a worldwide presence with close to 15,000 employees and sales to about 160 countries.