OCTOBER 2021

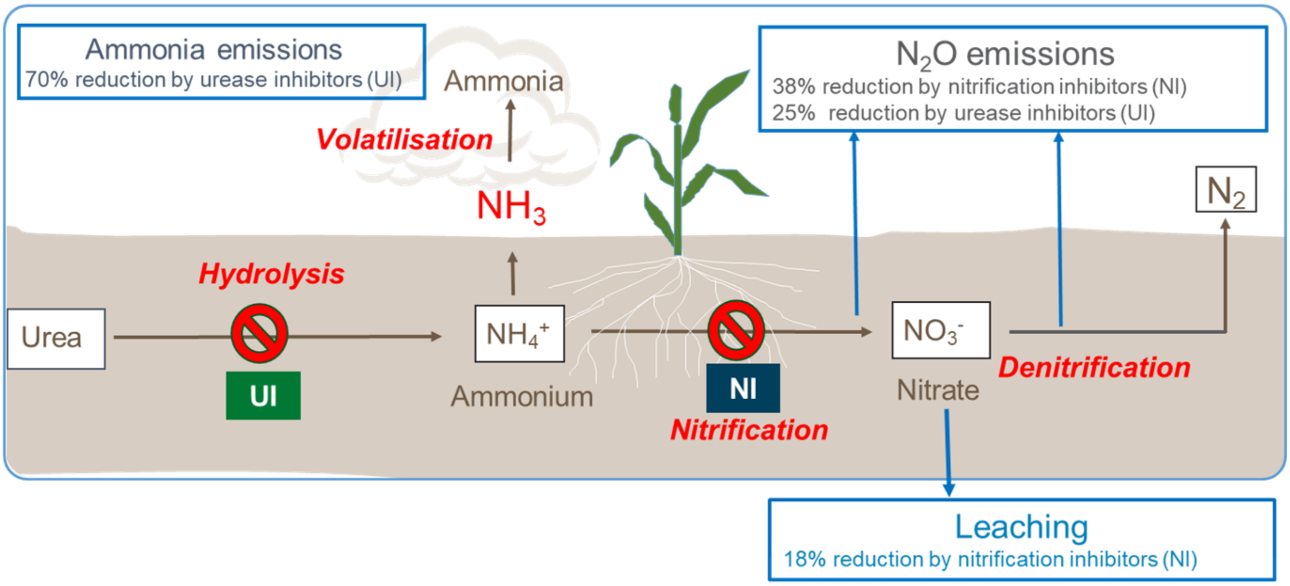
Annex to: "Urease and Nitrification Inhibitor technologies contribute to the European Green Deal"

Urease and Nitrification Inhibitors: contributing to reduce nitrogen losses from fertilisers

➢ Mode of action

The use of nitrogen is essential for agricultural production but only about 50% of nitrogen applied through fertilisers is absorbed by plants. Nitrogen fertiliser comprises either urea, ammonium or nitrate and their mixtures. Urea nitrogen is not readily plant available and must undergo hydrolysis via the naturally occurring urease enzyme to ammonium (NH_4). Hydrolysis occurs when urea is applied to the soil surface leading to regular losses of 10-30% of ammonia to the atmosphere through ***ammonia volatilization*** (Figure 1).

Figure 1



To slow down the hydrolysis of urea, **urease inhibitors (UIs)** can be applied thereby reducing ammonia emissions by close to 70% (Bittman et al. 2014). As a result, less nitrogen is released into the environment and this nutrient remains available for growing crops. While ammonium nitrogen (NH_4^+) is effectively retained by the soil and resistant to loss, naturally occurring soil bacteria convert it to nitrate (NO_3^-) and release nitrous oxide (N_2O) through **nitrification**. Nitrous oxide is a very potent greenhouse gas (298[1]x CO_2) with an atmospheric lifetime of over 100 years.

Nitrate can be reduced to nitrous oxide (N_2O) and nitrogen gas (N_2) through **denitrification**. In addition, nitrate is very mobile and can easily leach into ground and surface water, resulting in eutrophication - the formation of toxic algal blooms and the loss of biodiversity. One of the solutions to minimize nitrogen losses is the use of **nitrification inhibitors (NIs)**, which specifically inhibit the activity of microorganisms in the soil

[1] Understanding Global Warming Potentials | Greenhouse Gas (GHG) Emissions | US EPA

responsible for the conversion of ammonium to nitrate. Consequently, nitrous oxide emissions and nitrate leaching are reduced leading to ammonium being available to plants longer and in a form that best suits their needs.

- **Potential impact on emissions of ammonia, CO_2 equivalents and nitrate leaching**

In the EU27 + UK, urea fertiliser makes up 22% of the commercial nitrogen consumed in forage and crop production. Readily available, it is an attractive fertiliser for farmers due to its high N content, low cost and good water solubility. Nevertheless, ammonia volatilisation potential after field application represents a challenge to the use of urea. Furthermore, ammonia can be transported over long distances causing eutrophication and acidification in non-agricultural areas, e.g. rain forests. This can be mitigated to a large extent via urease inhibitor usage, as urea treated with UIs can contribute to a 42.5% and 9%[2] reduction of ammonia emissions and nitrous oxide emissions from mineral fertilisers, respectively (Table 1).

Fertiliser	Annual Consumption*	Pathways of nitrogen losses: Emission – Ammonia emisison factor**	Pathways of nitrogen losses: Emission – Ammonia	Pathways of nitrogen losses: Emission – Nitrous oxide	Pathways of nitrogen losses: Leaching – Nitrate	Urease inhibitor impact (UI): Reduction – Ammonia emission	Urease inhibitor impact (UI): Reduction – Nitrous oxide emission	Urease inhibitor impact (UI): Reduction – Nitrogen consumption	Nitrification inhibitor impact (NI): Reduction – Nitrous oxide emission	Nitrification inhibitor impact (NI): Reduction – Nitrate leaching	Nitrification inhibitor impact (NI): Reduction – Nitrogen consumption	UI+NI – Nitrogen consumption
	kt nitrogen	% N	kt NH_3-N	kT N_2O-N	kt N	kt NH_3-N	kt N_2O-N	kt N	kt N_2O-N	kT NO_3-N	kt N	kt N
				1%	12%	70%	25%		38%	18%		
Ammonium nitrate	2056	1,7	35	20,6	246,7				-7,81	-44,4	-52,2	-52,2
Ammonium phosphate:	344	6,4	22	3,4	41,3				-1,31	-7,4	-8,7	-8,7
Ammonium sulfate	385	11,5	44,3	3,9	46,2				-1,46	-8,3	-9,8	-9,8
Calcium ammonium nit	2557	1,1	28,1	25,6	306,8				-9,72	-55,2	-64,9	-64,9
NK compounds	53	2,2	1,2	0,5	6,4				-0,2	-1,1	-1,3	-1,3
NP compounds	248	6,6	16,4	2,5	29,8				-0,94	-5,4	-6,3	-6,3
NPK compounds	1214	6,6	80,1	12,1	145,7				-4,61	-26,2	-30,8	-30,8
Nitrogen solutions (UAI	1534	8,7	133,5	15,3	184,1	-53,4	-3,8	-57,2	-5,83	-33,1	-39	-96,2
Urea	2590	14,4	373	25,9	310,8	-261,1	-6,5	-267,5	-9,84	-55,9	-65,8	-333,3
other straight nitrogen	600	1,2	7,2	6	72				-2,28	-13	-15,2	-15,2
Grand total	11581		741	116	1390	-314	-10	-325	-44	-250	-294	-619
Reduction (%)					12	42,5	9	2,8	38	2,2	2,5	5,3
CO_2 equivalents (kt)	*40534*			*54183*			*-4824*	*-1519*	*-20589*	*-1170*	*(1376)*	*-2166*

Table 1

*IFAdata Average 2015-2018 EU27+UK

** EMEP/EEA air pollutant emission inventory guidebook 2019

On the other hand, NIs applied to urea and ammonium containing fertilisers like ammonium nitrate, calcium ammonium nitrate, ammonium sulphate and NPK compounds reduce nitrous oxide emissions and nitrate leaching. Research shows using urease and NIs with urea and ammonium containing fertilisers can mitigate nitrous oxide emissions by 47%[3], leading to significant carbon abatement of crop production systems. Taking into account the effect of saving nitrogen losses of about 619 kT nitrogen and average CO_2eq emissions of 3.5 t per ton of fertilisers nitrogen produced in Europe the overall potential impact of inhibitor technology on emissions from nitrogen fertilisers sums up to about 32 million tons of CO_2 equivalents or about 33% reduction of the carbon footprint of current nitrogen fertiliser use.

[2] IFA data – average 2015-18 EU 27+UK and EMEP/EEA air pollution emission inventory guidebook 2019

[3] IFA data – average 2015-18 EU 27+UK and EMEP/EEA air pollution emission inventory guidebook 2019

- **UI and NI usage outlook**

Today, Fertilisers Efficiency Enhancers estimates urease inhibitor use in the EU27 + UK is around 15% of available urea fertiliser, while use of NIs is less than 5% of available urea or ammonium-based fertiliser. These figures lag behind some regions of the world, such as the U.S., where inhibitors are used much more frequently by growers. Relatively low use of UIs and NIs in the EU27 + UK may be driven by either farmers not fully recognising the benefits of using inhibitors or by farmers recognising a loss of nitrogen which is just below the economic threshold to justify the purchase of inhibitors. In fact, the cost of either producing more crop with the same nitrogen fertiliser application or increasing crop yield with the same amount of nitrogen fertiliser is slightly below the cost of the inhibitor. Nevertheless, this merely economic analysis fails to consider the environmental benefits of the reduction of nitrogen losses and a more sustainable and effective nutrients management which could be enhanced using UIs and NIs.

- **Compliance to EU legislation**

In the EU, all registered UIs and NIs fulfil the requirements of REACH[4] and the EU Fertiliser Regulation[5], ensuring that their handling, storage and use do not pose unreasonable risks to users or the environment when used in accordance with labelling and approved uses.

[4] Regulation (EU) 1907/2006/EC
[5] Regulation (EU) 2003/2003/EC