Discussion paper, Task 7

NH_3 emission from mineral fertilisers NFR 4D

The ammonia emission from mineral fertiliser depends primarily on the fertiliser type, the temperature under which the fertiliser is applied, humidity, pH of the soil, Cat ion Exchange Capacity of the soil, crop cover and urease activity in the soil. A methodology for estimating NH_3 emissions from mineral fertilisers has been included in the emission inventory guidebook for many years. During time the methodology has changed slightly as well as it has been updated from the 2006 guidebook (EMEP 2006) to the 2009 guidebook (EMEP/EEA 2009) with more stringent definitions of the temperature regimes where fertiliser application takes place. The methodology has been criticized for overestimating the NH_3 emission especially from urea. The purpose of Task 7 is to search the literature and update the current methodology and parameters.

It has to be recognized that for the last 10-15 years there hasn't been published much work on emissions from mineral fertilisers, except for urea where some work on introducing urea inhibitors and in this way increase the utilization of N in urea and at the same time reduce the ammonia emission.

The temperature conditions in the EMEP area

The EMEP area covers a wide range of climatic conditions, from boreal to subtropical climates and from coastal to continental climates, which all has to be fit into a simple Tier 2 model. In figure 1 temperature curves are shown for the more extreme parts of the EMEP area. Malaga in Spain and Dublin in Ireland has coastal climates with relatively high temperatures all year round and a relatively uniform temperature throughout the year with amplitude of the temperature function from minimum to maximum of 10-15°C. Moscow in the Russian Federation is the opposite with continental climate and amplitude of 28°C. In continental climates the maximum temperature is reached earlier than in coastal climates due to the heat buffer capacity of the surrounding water.

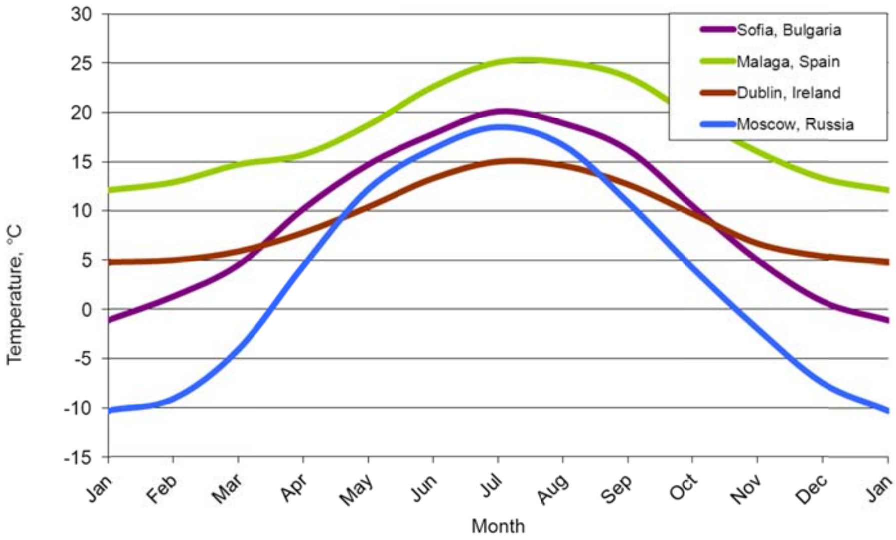


Figure 1: Temperature conditions in the EMEP area. Data from www.worldclimate.com

Mineral fertiliser application

Mineral fertilisers are in comparison to nitrogen in animal manure bought by the users. Therefore the farmers have an economic interest to use mineral fertilisers in an optimum way and only apply when there is a plant need and growth. Plant growth depends on temperature and light. Depending on which plants is grown and the intensity of the agriculture, the application may be spread over spring and summer. Regions with a long growth period or several intensive crops (horticulture and 5-6 grass cuts per year) may have applications over a longer period with a higher percentage of the total amount applied in summer and in autumn than other regions. But still the most important period of fertiliser application is March to May (EMEP 2006). Preliminary data from a questionnaire to emission inventory compilers in the EMEP area has shown the share of fertilisers applied in summer varies from 10 to 40%.

In Malaga the temperature is high in winter and spring but there is a lack of light and plant growth is slow despite of the high temperature. In such areas a long application period can be assumed covering both applications in the autumn and in spring because the optimum time covers a long period. This is in contradiction to the northern regions as well as continental climates where spring is approaching very fast and covers only a short period before it is summer. In these regions the farmers are more likely to apply mineral fertilisers later, when the temperature is ambient and where the light radiation is high enough to promote plant growth. In these regions a later but more uniform application will take place within a very short period to get most out of the short and intensive growth period.

The split between fertilisers applied early in the year, in “summer” and in autumn will clearly also differ between the regions. Regions having a short intensive growth period will most likely have a high percentage applied at growth start compared to areas where multi cropping is possible. For fertiliser types having a positive temperature emission coefficient this should be taken into account. This is not the case with the Tier 2 methodology in the current version of the GB.

In practical farming and partly because of the fertiliser application cost, most crops are only fertilised once in the growth period. However, some cereal crops and in certain regions split application of fertilisers may be common to increase the utilization rate of the fertiliser or to enhance the protein content in the kernel. Split application can either be made with pellets or dissolved nitrogen solutions applied on the leaves by foliar application, however normal practice is only a single application. Fertiliser application in spring is normally applied around 250-350 DD°C in the more cold climates with average temperatures below 2-3 °C (The definition of DD, Day Degrees, differ according to the species of interest and its activity. For most agricultural plants in the EMEP area 0°C is often used as a reference. DD is here the sum of the average daily temperatures > 0°C). For the Mediterranean areas growth start measured in DD °C will be higher because there are positive temperatures throughout the year.

Where multi cropping is possible and in cut grass and grass for grazing 2-5 applications per year may occur leading to higher emissions because the of the higher temperature conditions during the different applications.

Four different methodologies

In the following four different methodologies are discussed:

1. The Tier 2 version in the current GB (http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009)
2. The Tier 2 version in EMEP 2007 GB (http://www.eea.europa.eu/publications/EMEPCORINAIR5/page019.html)
3. An updated Tier 2 version of the 2009 GB
4. An updated Tier 2 version of the 2007 GB

As the emission from fertilisers to a certain extend depends on temperature it is recommended that a future methodology is based on a regionalization in different temperature regimes combined with temperature dependent emission factors, as it is today. A Tier 1 EF will be developed based on the agreed Tier 2 approach.

1. The Tier 2 version in the current GB

The current methodology is based on two parts:

- A methodology to estimate the temperature regime for a given area/country
- Linear emission coefficients in relation to temperature.

The model is given in Box 1 as well as the temperature functions for different nitrogen fertilisers.

The current version from EMEP/EEA guidebook 2009:

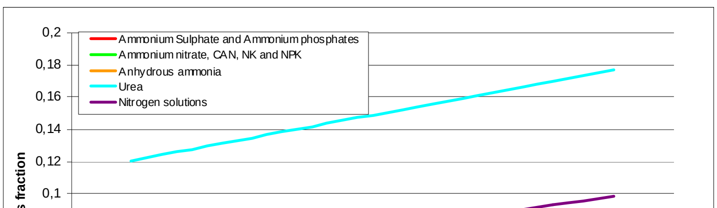
$EF^{a} = x + y * ts$

where ts = mean spring temperature is defined as

$spring,_{start} = \sum DD\ \ >0+° \ = 400\ DD$

$spring,_{end} = \sum DD\ \ >0+° \ = 400\ DD + 3\ months$

[a] if soil pH > 7 and fertilser = Ammonium sulphate and Ammonium phosphates then EF is multiplied with 10. If fertiliser = Anhydrous ammonia EF is multiplied with 4.



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after 400 DD °C and summed for the following three months. In table 1 is given the approximate start dates for spring for the four locations in figure 1 and the average spring temperature.

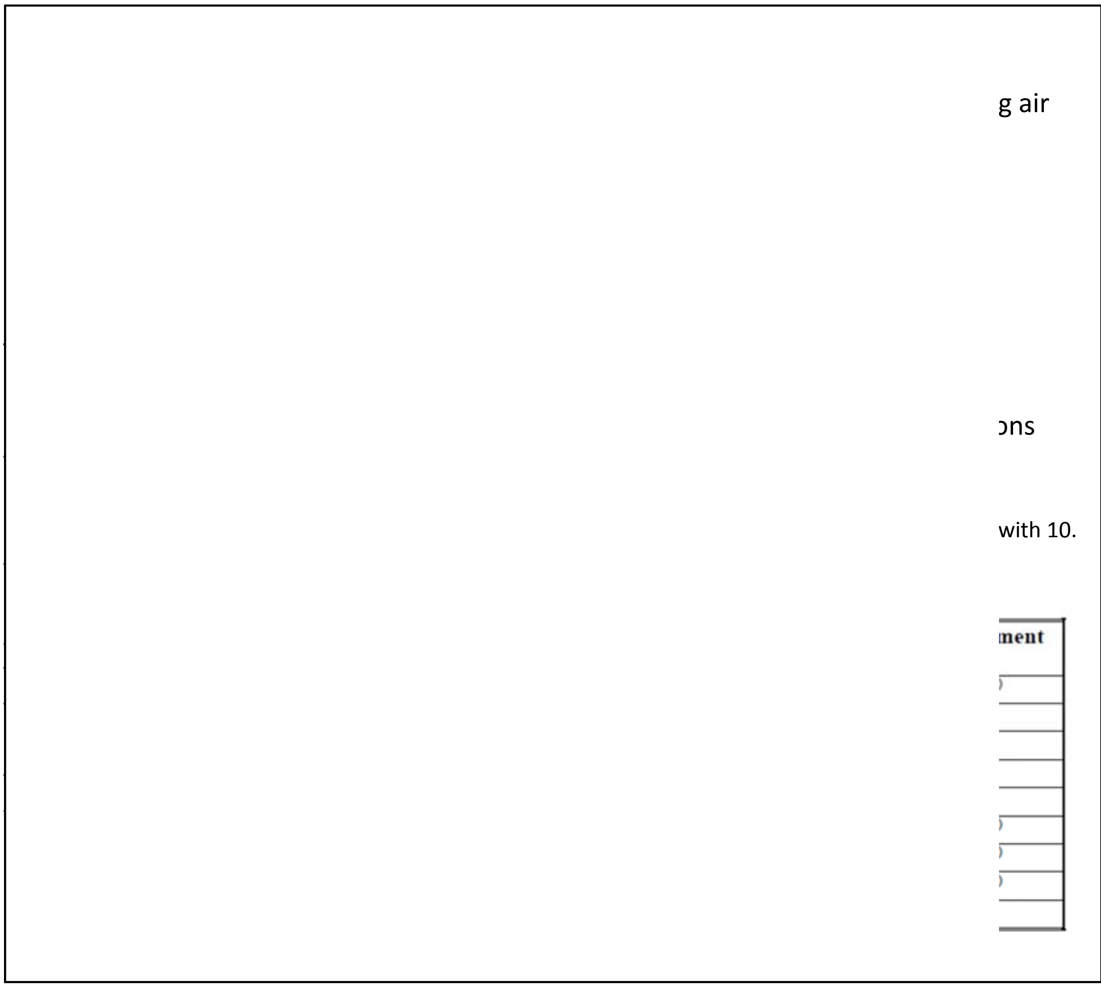
Table 1. Approximate spring start and average spring temperature for four locations based on the current 2009 GB methodology

	Spring start	Avg. spring temp, °C	Spring period
Malaga, Spain	5. Feb	15	5.Feb - 5.Apr
Dublin, Ireland	20. March	12	20.March – 20.June
Sofia, Bulgaria	20. April	16	20. April – 20.July
Moscow, Russia	15. May	16	15.May - 15. Jul

From Table 1 it can be seen that the defined spring temperature is 12-16 °C in the whole EMEP area despite that spring application normally takes place when the average is around 6-7 °C in the cold, temperate and continental areas. This leads to an overestimation of the emission in some areas. Furthermore, there can be an underestimation in warm areas where large parts of the application is taking place during summer, because the model only use “the average spring temperature” and not the summer temperature, which can be up to 10 °C higher than the average spring temperature. These possible over- and underestimation are highest for regions, which are using a high share of urea and other fertilisers having high temperature coefficients. In regions using only ammonium nitrate and other fertilisers with low temperature coefficients the potential error is of less significance.

2. The Tier 2 version in the 2006 GB

The 2006 GB detailed methodology is given in Box 2:



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The model could therefore be improved with a more specific definition of "mean spring air temperature", but this do not solve the problem that for the warm regions up to 40% of the fertiliser are applied in warmer periods of the year.

3. An updated Tier 2 version of the 2009 GB

The Tier 2 version of the 2009 GB could be updated with a more precise definition of spring. The simplest version could be that spring is defined at a certain DD°C. According to a Danish plant growth model (Denmark is located in a cold climate) 362 DD °C after 1. March is the time where the start of stem elongation (GS 31) takes place in winter wheat (Olesen and Plauborg 1995). Fertilisation of most annual crops in single cropping systems is *before* this time. For spring grown crops like spring barley fertilisation is taking place either before sowing or after the germination. For spring barley stem elongation is starting at 294 DD°C after sowing. Based on this it can be concluded that spring fertilisation in colder climates which have a cold defined winter period with no crop growth is around 250-350 DD°C.

For warmer regions the Danish plant growth model is not applicable because here the growth is restricted by light deficit. The DD approach therefore needs to be updated with local data on different DD where the main spring fertiliser application is taking place. E.g. in Malaga it is most likely that the main spring application takes place at 700-900 DD from 1. January. Knowledge on this can only be obtained from the different regions. We have therefore made a questionnaire where we have asked different inventory compilers in the EMEP area for information on when spring application is taking place in an attempt to establish such a relationship. The questionnaire is found in Appendix A.

4. An updated Tier 2 version of the 2006 GB

An update of the detailed methodology in the 2006 GB seems to be superior for a simple Tier 2 methodology. The model should be combined with two or three distinctive application periods: Spring, summer and autumn application to account for the differences in the share of spring, summer and autumn application.

For colder regions having a winter with no crop growth will spring application take place regardless of the winter temperature. It is therefore recommended that all cold regions use an EF for 6-8 °C for their spring application and the average summer temperature defined as the average temperature in main three summer months for the summer application.

For regions having an average winter temperature in January-March > 7-8 °C the methodology should use the actual spring temperatures.

Temperature regions

The 2009 GB and the 2006 GB recommends three temperature regions: <6 °C, 6-13 °C and >13 °C. The importance of having different regions depends on the temperature coefficients for each fertiliser type. If the fertiliser has no temperature coefficient there is no need to divide the EMEP area into regions. In box 1, which is the temperature function from the 2009 GB, is shown that urea has the highest temperature coefficient:

$EF_{urea} = 0.1067 + 0.0035\ Ts$

The largest difference in temperature in spring and summer between the extremes in figure 1 is 20 °C, giving a span in the emission factor from urea of 12.4 % (at 5 °C) to 19.4 % (at 25 °C). The 2009 GB recommends that the temperature range within each region should not exceed 7 °C equal to a difference in the EF of 2.5 %. It is not possible to discuss this approach before an in-depth analysis of the temperature coefficients has been completed based on literature data. But taking into account the high variability and the uncertainty in the measured ammonia emission data it probably gives no meaning to have a regionalization with less than 7 °C.

Update of the emission factors

Collection of old and new emission data is taking place in an attempt to update the current EF with new knowledge. Currently, it is not possible to give any discussion or recommendation on this topic. The analysis will also show, if there should be a split in the emission factors between annual crops and grassland as in the 2006 GB.

Current recommendation for discussion

The current recommendation for a Tier 2 model is to return to an updated version of the 2006 GB methodology with defined temperature regions with a split of the model into a fraction applied in the spring, a fraction applied in summer and probably a fraction applied in autumn. As fertiliser application will not take place at temperatures below 5-7 °C, areas having an average temperature in January-February <5-7°C all should use an EF of $EF_{6°C}$ (recommended actual temperature range has not been decided yet, but 6°C is used in the formula below). For summer temperature, the average temperature of the three summer months should be used.

Information from the EMEP countries shows that the fraction applied in autumn may be large in some countries (up to 40% in Southern Italy). If the temperature regime in the autumn differs substantially from spring and summer applications, there may be a need to include autumn application as a third variable. Although the uncertainty of the EFs and the fractions are large and overriding the overall uncertainty it could be reasonable to implement an autumn application fraction for a more complete picture.

IF T_{spring} <= 6°C: $$Emis = \sum A_{spring,i} * (x_i + y_{i,z°C}) + \sum A_{summer,i} * (x_i + y_{i,Tsummer}) + \sum A_{autumn,i} * (x_i + y_{i,Tautumn})$$

ELSE $$Emis = \sum A_{spring,i} * (x_i + y_{i,T_{spring}°C}) + \sum A_{summer,i} * (x_i + y_{i,Tsummer}) + \sum A_{autumn,i} * (x_i + y_{i,Tautumn})$$

Where:
Emis = Total ammonia emission, kg N yr^{-1}
T_{spring} = Average of the temperature in January, February and March
i = fertilizer type *i*
x = constant for fertilizer *i*
y = temperature coefficient for fertilizer *i*
z = the average temperature when spring application takes place, probably 7-8 °C, but not settled yet.
A_{spring} = amount of fertilizer *i* applied in spring
A_{summer} = amount of fertilizer *i* applied in summer, equal to the total sold amount minus spring applied amount
A_{autumn} = amount of fertilizer *i* applied in autumn

Literature

EMEP/EEA, 2009. EMEP/EEA air pollutant emission inventory guidebook 2009. Technical guidance to prepare national emission inventories. EEA Technical report No. 9/2009. ISSN 1725-2237. http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009

EMEP 2006, Atmospheric Emission Inventory Guidebook, Second edition, http://www.eea.europa.eu/publications/EMEPCORINAIR4/page001.html

Olesen, J.E. and Plauborg, F. 1995, MVTOOL version 1.10 for developing MARKVAND. Danish Institute of Plant and Soil Science, SP report No. 27 pp 64. ISSN 0908-2581.

Annex I

Questionnaire

NH_3 from mineral fertilisers

Location 1:

Country: ________________________________

Location (Nearest largest City, county): ________________________________

Altitude if mountainous area: ________________________________

Eventually contact person: ________________________________

Eventually E-mail: ________________________________

1. How many % of the mineral fertilisers are applied when?

	Urea	Pellets (AN, CAN, AS, NP, NPK, etc.)	Fluent nitrogen solutions (N32, N40)
Beginning of crop growth			
During summer			
Early Autumn			
SUM	100 %	100 %	100 %

2. What is your definition of fertiliser seasons, given in dates?

Definition

Spring			Summer			Autumn		
Start date	Optimal application time, date	End date	Start date	Optimal application time, date	End date	Start date	Optimal application time, date	End date