

Modelling assumptions – ammonia emissions from pig and poultry installations

Purpose

This fact sheet is for farmers who have improvement conditions in their permits, which require:

- a reduction in ammonia emissions from the farm installation;
- or, a reduction in their impact on a sensitive conservation site.

We require these farms to provide an Emission Reduction Plan (ERP) for us to approve. The timetable for submitting and implementing the ERP is set out in the permit

The fact sheet is divided into two parts:

1. guidance aimed at farmers and consultants;
2. further technical information on the modelling assumptions aimed primarily at consultants carrying out modelling to support ERP's.

The purpose of this fact sheet is to set out how we modelled the emissions from intensive farming installations as part of the permitting process during 2007/8.

Part 1: Critical levels and the modelling tools**Critical levels**

Ammonia is released from intensive pig and poultry units and can affect ecosystems in various ways. It may be toxic to some plants, either killing them outright or retarding their growth and development. Or, it may stimulate the growth and expansion of some plants by supplementing their nitrogen take-up (eutrophication), thereby eliminating more sensitive species. It is also an important component of acid rain.

The **Critical Level** is the pollutant concentration (in the atmosphere) above which direct adverse effects on vegetation or ecosystems may occur. Therefore, when pollutant concentrations exceed the critical level it is considered that there is risk of harmful effects. The pollutant concentration (in this case ammonia) is usually expressed in terms of micrograms per cubic metre ($\mu\text{g}/\text{m}^3$) averaged over a given time period, often a year.

The United Nations Economic Commission for Europe (UNECE) has recently adopted new Critical Levels for ammonia to protect sensitive vegetation. For general vegetation the Critical Level (annual average) is $3 \mu\text{g}/\text{m}^3$ with an uncertainty range of $2\text{--}4 \mu\text{g}/\text{m}^3$ (micrograms per cubic metre) and for particularly sensitive plants, such as lichens, it is $1 \mu\text{g}/\text{m}^3$. Previously, the United Nations Economic Commission for Europe had recommended a Critical Level for ammonia of $8 \mu\text{g}/\text{m}^3$ for all plants but new scientific evidence, mainly from the UK, suggested that lower Critical Levels were more appropriate.

The modelling tools – AFP1 and AFP2

The first stage of the assessment process involved identifying those farms with the potential to impact on sensitive wildlife sites. Farms within 10km of a European site (Special Areas for Conservation, Special Protection Areas and Ramsar sites), 5 km of Sites of Special Scientific Interest and 2km of other wildlife sites such as Ancient Woodland were identified. For these farms the potential impact was assessed using the AFP1 and AFP2 tools as described below. If there were no such sites within these distances from the farm, determination of the application was completed without further consideration of impact on wildlife sites.

In order to speed up and give greater consistency to the permitting process for intensive farming, we developed tools to model the potential impact of ammonia from farm installations on sensitive locations e.g. Special Protection Areas (SPAs), Special Areas for Conservation (SACs), Sites of Special scientific Interest (SSSIs) and non-statutory conservation areas. These tools are called AFP1 and AFP2. AFP1 is a basic screening tool, which was used on all farms which came under the Pollution Prevention and Control regime (PPC). We used data from the PPC application and generic emission factors to calculate ammonia emissions from each facility. The level of ammonia concentration and deposition at any sensitive location e.g. at SSSIs within 5km or SPAs/SACs within 10km of the farm was then modelled. Where AFP1 screening indicated an installation had the potential to impact on a sensitive site then further modelling was carried out using AFP2.

AFP2 uses the US Environmental Protection Agency's modelling software – AERMOD PRIME. The outputs from AFP1 were used with 3 years worth of meteorological data from the closest available weather station. The modelling was used to indicate whether the critical level or relevant threshold for ammonia was likely to be exceeded at the sensitive sites. Where we predicted an exceedance of the critical level or relevant threshold, a more detailed assessment was undertaken which took into consideration other factors such as background concentrations of ammonia and local information on the wildlife site. The outcome of this more detailed assessment was then reflected in improvement conditions within the permit.

Many farmers will have received reports which have been derived using the modelling tools described above and the assumptions set out in Part 2. These outputs also include an error, which resulted from an unnecessary conversion factor being applied to the emission factors used within the tools. To correct the error in permit improvement conditions, the process contribution has been recalculated using the correct emission factors that are set out in Appendix 1. Remodelling has not been undertaken, therefore revised output reports are not available. Letters informing farmers of their revised improvement conditions based on the corrected emission factors will be sent to all affected operators in August 2008. Please note that the AFP2 report also shows the

Modelling assumptions – Cont.

original Critical Level of $8 \mu\text{g}/\text{m}^3$ rather than the revised Critical Levels of $1\mu\text{g}/\text{m}^3$ or $3 \mu\text{g}/\text{m}^3$, which were proposed by the UNECE too late to be included in our model.

Tools AFP1 and AFP2 were developed for specific assessment purposes and are not available outside of the Environment Agency.

Modelling assumptions – Cont.

Part 2: Modelling assumptions**AFP1 screening tool assumptions:**

- generic emission factors
- release height, 3m
- surface roughness, 0.5m
- meteorological station data from Cardiff airport was used to produce a standardised concentration/distance curve which could be scaled by the release to estimate the maximum annual average downwind concentration at a particular point.
- The use of meteorological data from a single location is justified given the application of the model output for screening purposes.

AFP2 detailed modelling tool assumptions:

- point sources assumed
- release diameter, 1m
- release height, 3m
- surface roughness, 0.5m
- 46 met stations (three years met data for each station) stored in the tool.
- low momentum assumed (exit velocity, 0.001 m/s)
- AFP2 tool uses the US EPA AERMOD PRIME model. AERMOD PRIME is a regulatory model recommended by the US EPA and is also widely used in the UK for regulatory purposes
- terrain and buildings not considered
- plume depletion considered
- wet deposition of ammonia not considered significant for short range modelling.

Further information

An Aermod PRIME Model Formulation Document is available from the US EPA website:
http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod

Appendix 1: Table of emission factors for estimating ammonia emission rates

Emission Source (animal housing / manure storage / slurry storage)	Emission Factor (kg NH ₃ /place/year)
Poultry	
Layers: Cage with deep pit manure storage beneath	0.29
Layers: Ventilated Deep Pit	0.15
Layers: Manure removal twice a week by manure belt	0.09
Layers: Vertical tiered cages with forced air drying once a week removal	0.09
Layers: Vertical tiered cages with whisk forced air drying once a week removal	0.09
Layers: Vertical tiered cages with manure belt with drying tunnel over cage 24-36 hour removal	0.04
Layers: Enriched cage	
Barn & free range: Perchery with deep litter	0.29
Barn & free range: Litter system with forced air drying	0.13
Barn & free range: Litter system with perforated floor & forced air drying	0.13
Barn & free range: Aviary system	0.09
Broilers & Pullets: Naturally ventilated, fully littered floor, non-leaking drinkers	0.05
Broilers & Pullets: Fan ventilated, fully littered floor, non-leaking drinkers	0.05
Turkeys: Male	0.44
Turkeys: Female	0.22
Ducks	0.11
Pigs	
Sows: Fully Slatted Floor (FSF)	3.01
Sows: Solid Floor - straw system	4.57
Sows: Part-slatted floor (PSF) with reduced manure pit	2.5
Sows: FSF with vacuum system for frequent slurry removal	2.34
Farrowers: Fully Slatted Floor (FSF)	5.84
Farrowers: Solid Floor - straw system	8.88
Farrowers: FSF/PSF with combination of water & manure channel	4.18
Farrowers: FSF/PSF with flushing system with manure gutters	3.48
Farrowers: FSF/PSF with manure pan underneath	3.05
Weaners: Fully Slatted Floor (FSF)	0.29
Weaners: Solid Floor - straw system	0.21
Weaners: Pen/flatdeck with FSF/PSF with vacuum system for frequent slurry removal	0.42
Weaners: Pen/flatdeck with FSF beneath where there is concrete sloped floor to separate faeces or urine	0.4
Weaners: Pen with PSF (2-climate system)	0.34

Modelling assumptions – Cont.

Emission Source (animal housing / manure storage / slurry storage)	Emission Factor (kg NH ₃ /place/year)
Weaners: Pen with PSF and sloped or convex solid floor	0.26
Weaners: Pen with PSF with triangular slats & manure channel with sloped side-walls	0.17
Growers: Fully Slatted Floor (FSF)	1.59
Growers: Solid Floor - straw system	1.14
Growers: FSF with vacuum system for frequent slurry removal	1.79
Growers: PSF with reduced manure pit including slanted walls & vacuum system	0.96
Growers: PSF with central convex solid floor at front and manure gutters with slanted sidewalls and sloped manure pit	0.96
Finishers: Fully Slatted Floor (FSF)	4.14
Finishers: Solid Floor - straw system	2.97
Finishers: FSF with vacuum system for frequent slurry removal	2.25
Finishers: PSF with reduced manure pit including slanted walls & vacuum system	1.2
Finishers: PSF with central convex solid floor at front and manure gutters with slanted sidewalls and sloped manure pit	1.2
Manure Storage (see footnote)	(kg NH ₃ /tonne/year)
Poultry - Manure - belts	2.38
Poultry - Manure - deep pit	2.38
Poultry - Other litter	1.74
Pigs - Manure heap	1.49
Slurry Storage (see footnote)	(kg NH ₃ /m ² /year)
Slurry - circular store: No cover	1.4
Slurry - circular store: Rigid cover	0.28
Slurry - circular store: Floating cover	0.7
Slurry - circular store: Low tech cover	1.05
Slurry - lagoon: No cover	1.4
Slurry - lagoon: Rigid cover	0.28
Slurry - lagoon: Floating cover	0.7
Slurry - lagoon: Low tech cover	1.05

Manure – Tonnes of fresh manure stored per year.

Slurry – Floor area of slurry store (m²).

Emission rate calculations

Example emission rate calculations using the above emission factors:

Example 1 – Layer farm: If an installation consists of 60,000 layer places in a housing system utilising cages with deep pit manure storage beneath, and no external manure storage at the installation, then the emission rate of ammonia is calculated by:

$$\begin{aligned}
 \text{Emission rate due to 60,000 layer places} &= \text{number of animal places} * \text{emission factor} \\
 &= 60,000 * 0.29 \\
 &= 17,400 \text{ kg NH}_3 / \text{year} \\
 \text{To convert from kg/year to g/s then apply the factor } 1,000 / 31,536,000 & \\
 &= 17,400 * 1,000 / 31,536,000 \\
 &= 0.55 \text{ g NH}_3 / \text{s}
 \end{aligned}$$

Example 2 – Pig farm: If a finishing unit has 3,000 places for Finishers and also has accommodation for 1,700 Growers, both on a fully slatted floor system. Slurry is stored at the installation in an uncovered circular store with a base area of 50m², then the emission rate of ammonia is calculated by:

$$\begin{aligned}
 \text{Emission rate from growers} &= \text{number of animal places} * \text{emission factor} \\
 &= 1,700 * 1.59 \\
 &= 2,703 \\
 \text{Emission rate from finishers} &= \text{number of animal places} * \text{emission factor} \\
 &= 3,000 * 4.14 \\
 &= 12,420 \\
 \text{Total from livestock} &= 15,123 \text{ kg NH}_3 / \text{year} \\
 \text{Emission rate from slurry store} &= \text{floor area of store} * \text{emission factor} \\
 &= 50 * 1.4 \\
 &= 70 \text{ kg NH}_3 / \text{year} \\
 \text{Total emission} &= 15,193 \text{ kg NH}_3 / \text{year} \\
 \text{To convert from kg/year to g/s then apply the factor } 1,000 / 31,536,000 & \\
 &= 15,193 * 1,000 / 31,536,000 \\
 &= 0.48 \text{ g NH}_3 / \text{s}
 \end{aligned}$$