PERGAMON

Atmospheric Environment 34 (2000) 871–880

ATMOSPHERIC ENVIRONMENT

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Ammonia emission factors for UK agriculture

T.H. Misselbrook[a,*], T.J. Van Der Weerden[a,1], B.F. Pain[a], S.C. Jarvis[a], B.J. Chambers[b], K.A. Smith[c], V.R. Phillips[d], T.G.M. Demmers[d]

[a]*Institute of Grassland and Environmental Research, North Wyke, Okehampton, Devon, EX20 2SB, UK*
[b]*ADAS Gleadthorpe, Meden Vale, Mansfield, Nottinghamshire, NG20 9PF, UK*
[c]*ADAS Wolverhampton, Wergs Road, Wolverhampton, WV6 8TQ, UK*
[d]*Silsoe Research Institute, Wrest Park, Silsoe, Bedford, MK45 4HS, UK*

Received 9 December 1998; received in revised form 2 July 1999; accepted 16 July 1999

Abstract

Ammonia (NH_3) emission inventories are required for modelling atmospheric NH_3 transport and estimating downwind deposition. A recent inventory for UK agriculture, estimating emission as 197 kt NH_3–N yr^{-1}, was constructed using 1993 statistical and census data for the UK. This paper describes the derivation of the UK-based emission factors used in the calculation of that emission for a range of livestock classes, farm practices and fertiliser applications to agricultural land. Some emission factors have been updated where more recent information has become available. Some of the largest emission factors derived for each farming practice include 16.9 g NH_3–N dairy cow^{-1} d^{-1} for grazing, 148.8 g NH_3–N liveweight $unit^{-1}$ yr^{-1} for housed broilers and 4.8 g NH_3–N m^{-2} d^{-1} for storage of solid pig and poultry waste as manure heaps. Emissions for land spreading of all livestock waste were 59% of the total ammoniacal nitrogen (TAN) applied as a high dry matter content slurry and 76% of TAN applied as farm yard manure. An updated estimate of emission from UK agriculture, using updated emission factors together with 1997 statistical and census data, is presented, giving a total of 226 kt NH_3–N per year. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Ammonia; Inventory; Agriculture; Emission factors

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1. Introduction

Atmospheric ammonia (NH_3) transport models and derived estimates of deposition rely on emission data which are often assembled as inventories. Previous NH_3 emission inventories from several countries, including the UK, have shown that agriculture produces approximately 90% of the total emission of NH_3 to the atmosphere. Earlier estimates for the UK suggest that emissions from agriculture range from 186 to 405 kt NH_3–N yr^{-1} (Buijsman et al., 1987; Ryden et al., 1987; Kruse et al., 1989; Jarvis and Pain, 1990; Asman, 1992; Eggleston, 1992; Klaassen, 1992; Sutton et al., 1995). Such a large range in emissions from this major source suggests there are large differences in the emission factors used for each source of NH_3. Unfortunately, in a number of published inventories it has not always been obvious how some emission factors were established. Similarly, the use of average values, or those inappropriate for UK agriculture, may give unreliable estimations.

A recent, detailed inventory for UK agriculture, which estimated NH_3 loss to be 197 kt NH_3–N per year (Pain et al., 1998), was based on emission factors derived primarily from measurements in the UK and, where these were not available, on best estimates from the literature, with, again, UK literature being used wherever possible. This inventory, constructed on a computer spreadsheet, calculated the emission by combining the estimated contribution of each livestock class, farming practice and fertiliser applications. The present paper describes how the emission factors were derived and

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* Corresponding author.

[1] Present address: Department of Soil Science, Lincoln University, Canterbury, New Zealand.

E-mail address: tom.misselbrook@bbsrc.ac.uk (T.H. Misselbrook)

PII: S1352-2310(99)00350-7

gives details of the statistical and census data, experimental results and assumptions used in the construction of the inventory. Recent experimental data have been included in the estimate of emission factors in this paper, some of which differed from those used in the inventory of Pain et al. (1998).

2. Derivation of emission factors

The construction of the inventory is illustrated in Fig. 1, which shows the main components of UK agriculture for which census or survey data and emission factors were required. The emission factors used in the inventory are given in Table 1. Values used for each livestock type and for fertiliser applications are discussed below.

2.1. Emission factors for cattle

Cattle were split into four sub-classes to include dairy cows, beef cattle, bulls and others less than 2 years of age, which were further sub-divided to reflect the availability of census data.

2.1.1. Outdoor cattle emissions

Ammonia emissions from grazing cattle are known to be related to inorganic N input to the grassland (Jarvis and Bussink, 1990). An updated version of this relationship was used in which emission estimates from complete grazing seasons in the UK (Jarvis et al., 1989; van der Weerden, unpublished), the Netherlands (Bussink, 1992,1994) and New Zealand (Ledgard, 1996) were incorporated (Fig. 2). A linear relationship was fitted between NH_3–N loss, expressed as g per liveweight unit per day (where a liveweight unit, or lu, is equivalent to 500 kg) and inorganic fertiliser N input (kg ha^{-1} yr^{-1})

$$\text{Nloss} = 2.27 + (0.0683 \times \text{Ninput})$$

with an r^2 value of 0.63. All measurements were made directly using the micrometeorological mass balance technique (Jarvis et al., 1989). The most recent measurements in the UK (van der Weerden, unpublished) were

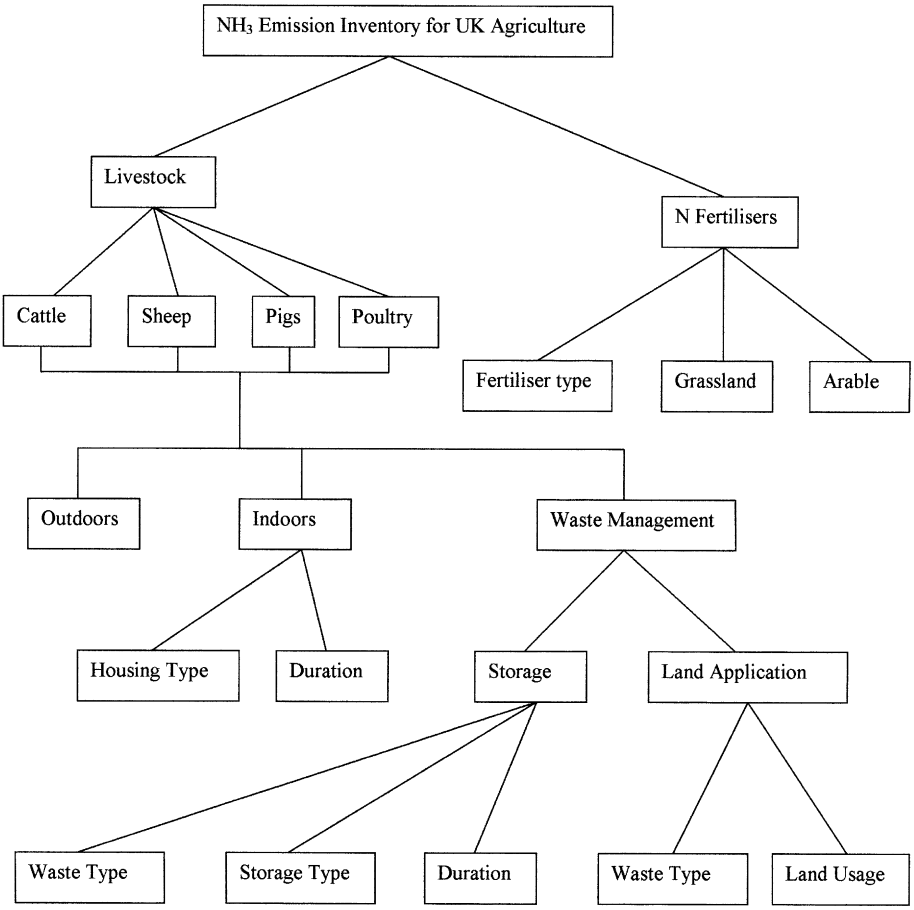

Fig. 1. Main sources of ammonia emission included in the inventory.

Table 1
Emission factors for livestock

Livestock class	Grazing/Outdoor emission factor (g N $\mathrm{animal^{-1}\,d^{-1}}$)	Housing emission factor[a] (g N $\mathrm{lu^{-1}\,d^{-1}}$)		Waste storage emission factor (g N $\mathrm{m^{-2}\,d^{-1}}$)		Land spreading emission factor[b] (% of TAN applied)	
Cattle							
Dairy cows and heifers	16.9	Dairy-cubicles	34.3	Slurry:		Slurry (based on %DM):	
		-litter	17.2	Circular stores/Lagoons:		Aug–Apr < 4%	15%
Heifers in calf	12.3			Crusted	2.1	4–8%	37%
				Not crusted	4.4	> 8%	59%
		Beef-cubicles	34.3	Weeping walls	2.1	May–Jul all DMs	60%
Beef cattle	4.7	-litter	17.2	Solid manure	2.5	Solid manure	76%
Calves	1.9	Calves-litter	10.6	Dirty water	0.4	Dirty water	15%
				Yard emission (dairy)	8.3 g N $\mathrm{animal^{-1}\,d^{-1}}$		
Pigs							
Dry sows	8.0	Slatted	17.0	Slurry:		Slurry (based on %DM):	
		Straw bedded	19.7	Circular stores	4.3	< 4%	15%
Farrowers	8.0	Slatted	29.5	Lagoons	2.4	4–8%	37%
		Straw bedded	34.1			> 8%	59%
Boars	8.0	Straw bedded	17.0	Solid manure	4.8		
Fatteners < 20 kg lw	0.9	Slatted	27.8			Solid manure	76%
		Straw bedded	45.6				
20–110 kg lw	N/A[c]	Slatted	79.2				
		Straw bedded	45.6				
> 110 kg lw	N/A	Slatted	79.2				
		Straw bedded	45.6				
Poultry							
Layers	0.5	Perchery	146.4	All as solid manure heaps:		All poultry[d]	45%
		Cages	132.0	Litter/manure	4.8		
Broilers	N/A	Litter	148.8				
Pullets	0.3	Manure	148.8				
		Litter	148.8				
Other Hens	0.5	Manure	148.8				
		Litter	148.8				
Other poultry	0.7	Litter	148.8				
Sheep							
Lowland-sheep	2.0	Sheep barn	3.0 g N $\mathrm{animal^{-1}\,d^{-1}}$	Solid manure:	2.5	Solid manure:	76%
-lambs	1.0						
Upland-sheep	0.6						
-lambs	0.3						
Deer							
Deer	2.0	Deer barn	3.0 g N $\mathrm{animal^{-1}\,d^{-1}}$	Solid manure:	2.0	Solid manure:	76%

[a] lu is equivalent to 500 kg liveweight.

[b] TAN content = total ammoniacal nitrogen content.

[c] N/A = not applicable.

[d] For poultry waste, TAN also includes uric acid nitrogen.

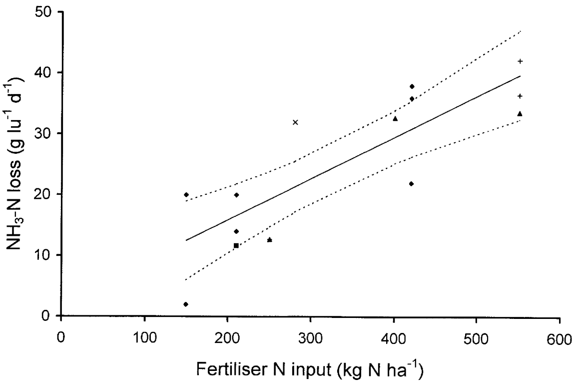

Fig. 2. Ammonia emission from grazing cattle related to annual inorganic N input to pasture being grazed. Fitted line ($y = 2.27 + 0.0683x$) together with 95% confidence intervals. Data from Jarvis et al. (1989) (◆), Bussink (1992) (+), Bussink (1994) (▲), Ledgard (1996) (■) and IGER unpublished (×).

from 1 year old steers continuously grazing a ryegrass sward receiving 280 kg inorganic N as fertiliser, with emissions from week-long monitoring periods throughout two grazing seasons ranging from 0.8 to 124 g NH_3-N lu^{-1} d^{-1} in 1992 and 14 to 74 g NH_3-N lu^{-1} d^{-1} in 1993.

For the UK, N fertiliser inputs onto grazed pasture for dairy cattle and all other cattle average 192 and 67 kg N ha^{-1}, respectively (Burnhill et al., 1998). Emission factors for the different sub-classes of cattle were based on these N inputs and standard liveweights of 550 kg for a milking dairy cow, 400 kg for an in-calf heifer, 140 kg for a calf up to 1 year old and 340 kg for all other sub-classes. Data from the ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (ADAS, unpublished) were used to estimate the number of days spent grazing by each sub-class of cattle. For dairy cattle 190 days are spent grazing, 183 for beef cattle and 200 for calves < 1 year old.

2.1.2. *Housing emissions*

Dairy cattle housing was considered to be either in cubicles or on litter-based systems, beef cattle on slurry or litter-based systems whilst calves were assumed to be all housed on litter. The proportion of cattle housed under each system, as well as mean housing periods, were derived from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (ADAS, unpublished). The emission factors for dairy cattle in cubicle housing and beef cattle on straw were obtained from recent experimental work (Demmers, 1997; Demmers et al., 1997. There is some evidence from recent work (Phillips et al., 1998) that emissions from dairy cattle housing during the summer, accounted for in the inventory by increasing the housing period by 24 d (3 h per day during the summer months) to account for time spent by milking dairy cattle being milked each day, have been underestimated. The emission factor for beef cattle housed in slurry-based systems was assumed to be the same as that for dairy cattle housed in cubicles and that for dairy cattle on litter to be the same as for beef cattle on litter. The emission factor for calves was estimated from recent measurements by Groot Koerkamp et al. (1998). Emissions from concrete collecting yards used by dairy cattle prior to milking were estimated as 8.31 g $animal^{-1}$ d^{-1} from recent measurements by Misselbrook et al. (1998).

2.1.3. *Waste management: storage emissions*

Emissions from storage were primarily based on estimates of the total surface area of each type of waste in storage each year. Storage of waste from dairy cows and beef cattle was sub-divided into the type of waste (i.e. slurry, farm yard manure (FYM), dirty water) and the type of storage facility used (e.g. for slurry: circular stores, lagoons and weeping walls; for FYM: concrete pads and field heaps). Estimates of the total surface area for each of these divisions were obtained from Nicholson and Brewer (1997) and Baines et al. (1997). Emission factors, expressed as g NH_3-N m^{-2} d^{-1}, were based on Danish data for slurry stores (Sommer et al., 1993) (Table 1). It was assumed that circular stores and lagoons which are stirred frequently (data from ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (ADAS, unpublished)) would not develop a crust whereas those stirred infrequently or not at all would develop a crust and have a lower emission factor. The emission factor for weeping wall stores was assumed to be the same as that for crusted stores. Emission factors for stored FYM were based on work conducted by IGER (unpublished data). No data on NH_3 emissions from stored dirty water were available, therefore an emission factor of 10% of that used for slurry storage was used, since the ammoniacal-N content of dirty water was approximately 10% of that of slurry.

The proportion of the year for which NH_3 loss occurs from stores will vary with the type of waste and store, together with management practice. It was assumed that slurry storage systems and dirty water tanks will always contain some waste, and so will emit NH_3 throughout the year. Solid manure is normally stored for 1 month to 2 years, so a weighted average of 6 months was used.

2.1.4. *Waste management: land application emissions*

The quantity of waste applied to land as slurry and FYM was calculated from quantities of waste excreted by the different classes of livestock (Smith, 1996). The quantity of FYM produced was estimated by increasing the excretal output by 1.3 to allow for the addition of straw. The quantity of dirty water applied to land was obtained from estimates of the volumes of water stored by farmers (Nicholson and Brewer, 1997). The proportions of waste applied to grassland and arable land, the timing of applications, the proportion applied by shallow injection and the proportion applied to arable land which was subsequently incorporated within 1 day or 1 week were derived from the ADAS Surveys of Animal Manure Practices in the Dairy and Beef Industries (ADAS, unpublished). It was assumed that all dirty water is applied to grassland.

Ammonia emissions from slurry applied to the land surface are known to be linearly related to the dry matter content of the slurry (Smith and Chambers, 1995). This relationship was used to calculate emission factors for a range of dry matter contents, viz. $< 4\%$, between 4 and 8%, and $> 8\%$, for slurry applied to land between August and April. Emission factors were expressed as NH_3 lost as a percentage of the total ammoniacal nitrogen (TAN) applied and ranged from 15 to 59% (Table 1). For slurry applied to land during the period May to July a constant emission factor of 60% was used, irrespective of slurry dry matter content. The TAN contents used for dairy cows and all other cattle were 2.25 and 1.75 kg TAN m^{-3} slurry, respectively (MAFF, 1995). An emission factor of 76% of the applied TAN for FYM applications to grassland and arable land was based on results from field experiments (Chambers et al., 1997; IGER unpublished data). An emission factor of 15% of the applied N, as used for slurry with a low dry matter content, was used for dirty water applications to grassland. Emission from slurry applied by shallow injection was assumed to be 80% less than for surface applied slurry. Reduction in emission following incorporation of slurry into arable land were 30 and 10% for incorporation after 1 day and 1 week respectively, compared to slurry which was left on the surface. Respective reductions applied to incorporation of FYM were 55 and 25%.

2.2. *Emission factors for pigs*

Pigs were divided into three main classes, breeding sows, boars and fatteners, with further division of sows to dry sows and farrowers. Fatteners were separated into three sub-classes on a weight basis, viz. < 20 kg liveweight (lw), 20–110 kg lw, and > 110 kg lw.

2.2.1. *Outdoor pig emissions*

The number of pigs kept outdoors in 1996 was estimated to be 25% sows, 25% boars and 10% of fatteners < 20 kg (Sheppard, 1998). From measurements of emissions from outdoor sows (unpublished data) an emission factor of 8 g NH_3–N animal^{-1} d^{-1} was derived. The same emission factor was used for boars kept outdoors and the emission factor for fatteners < 20 kg was based on the ratio of excretal outputs for sows and < 20 kg fatteners.

2.2.2. *Housing emissions*

Each pig class was split into appropriate housing categories, based on data from the MLC Pig Yearbook (1995) and Sheppard (1998). Emission factors, expressed as g NH_3–N lu^{-1} d^{-1}, were estimated from several recent studies (Groot Koerkamp et al., 1998; Demmers et al., 1997; Peirson, 1995; Phillips, unpublished) and pigs were assumed to be indoors for 365 days per year.

2.2.3. *Waste management: storage emissions*

Emission factors for stored pig waste were estimated in a similar way to that described for cattle using data on stored surface areas (Nicholson and Brewer, 1997), Danish emission data for circular slurry stores (Sommer et al., 1993) and recent UK data for slurry lagoons (Phillips et al., 1997). Phillips et al. (1997) give a mean emission factor of 18 g NH_3–N m^{-2} d^{-1} for stored pig FYM. Recent measurements (Williams, unpublished) give an emission factor for stored pig FYM of 4.8 g NH_3–N m^{-2} d^{-1}. Slurry and dirty water emissions were assumed to occur throughout the year and those from solid manure for 6 months.

2.2.4. *Waste management: land spreading emissions*

The amount and type of stored waste applied to grassland and arable land, and the associated emission factors, were estimated in a similar way to that for cattle. The proportions of waste applied to grassland and arable land, the timing of applications, the proportion applied by shallow injection and the proportion applied to arable land which was subsequently incorporated within 1 day or 1 week were derived from the ADAS Survey of Animal Manure Practices in the Pig Industry (ADAS, unpublished). Emissions factors for land application of slurry and FYM were the same as those used for cattle, as they were derived from experiments involving both cattle and pig manure. Reductions in emission for applications by shallow injection and for slurry or FYM incorporated within 1 day or 1 week were also as for cattle manure.

2.3. *Emission factors for poultry*

2.3.1. *Outdoor poultry emissions*

Poultry were divided into laying hens, broilers, pullets, other hens and other poultry (including turkeys, ducks, geese, ostriches and Guinea fowl). Numbers of free-range were estimated at 6% of layers and 10% of pullets, other hens and other poultry (S. Tucker, pers. comm.). However, it has been estimated that only 12% of the excreta is dropped outside by free-range poultry (A. Fuller, pers. comm.), the remainder being dropped in the house and therefore subject to the housing, storage and landspreading emission factors of housed poultry. The emission factor for excreta dropped outside by free-range poultry was estimated as 35% of excretal ammoniacal and uric acid N (AUN) output.

2.3.2. Housed emissions

The number of housed layers were sub-divided into perchery (32%) and cages (68%) according to data from the ADAS Survey of Animal Manure Practices in the Poultry Industry (ADAS, unpublished). Pullets and other hens were split on a 50 : 50 basis into manure and litter based housing, and all the other poultry types kept indoors were assumed to be on litter (Mercer, 1993). Emission factors were expressed as g NH_3–N lu^{-1} d^{-1} and were estimated from several recent studies (Groot Koerkamp et al., 1998; Demmers, 1997; Peirson, 1995). Building occupancy was assumed to be 100% as measurements reflected periods when occupancy was less than this.

2.3.3. Waste management: storage emissions

All poultry waste was considered to be stored as solid manure in field heaps after removal from the buildings. The surface area of broiler litter field heaps is more than twice that from layer manure field heaps (Nicholson and Brewer, 1997). The emission factor for manure was assumed to be the same as for pig FYM. The storage period for the field heaps was derived as 120 days from the ADAS Survey of Animal Manure Practices in the Poultry Industry (ADAS, unpublished).

2.3.4. Waste management: land spreading emissions

The quantity of manure spread onto land was estimated from poultry excretal output (Smith, 1996). Approximately 335 kt, representing 16%, of UK broiler and turkey litter is presently combusted annually for electricity generation, thus removing this fraction as a source of NH_3 emission.

Ammonia emissions from poultry manure spread onto land can persist for many weeks because of the slow conversion of uric acid to urea. An emission factor of 45% of AUN content of the poultry manure was estimated from the results of field experiments (Chambers et al., 1997). The average AUN content varies according to poultry type and was obtained from Nicholson et al. (1996).

2.4. Emission factors for sheep

The number of sheep was divided into adult sheep and lambs, with a split of approximately 50 : 50 between upland and lowland areas. The small population of farmed goats was included with sheep because liveweights are similar.

2.4.1. Outdoor sheep emissions

Emission factors for sheep grazing were estimated from measurements made by Jarvis et al. (1991) and some more recent measurements made at IGER (unpublished data). For upland sheep, emission factor was based on measurements made from sheep grazing grass/clover and grass swards receiving no inorganic N. Sheep were considered to graze outdoors year-round in upland areas, but to spend 30 days per year indoors during lambing in lowland areas.

2.4.2. Housing and waste management emissions

No information exists for indoor sheep and so the emission factor for ewes during lambing was obtained from the ratio of excretal outputs of sheep and beef cattle, multiplied by the emission factor for beef cattle housed on straw (converted to per animal per day). The small quantity of FYM produced by indoor ewes was assumed to be stored as field heaps and the same emission factor as for cattle FYM was used. Prior to land spreading, sheep FYM contains approximately 0.6 kg TAN t^{-1} and it was assumed that, as for cattle FYM, 76% of this was lost as NH_3.

2.5. Emission factors for deer

Although the contribution from deer to the total NH_3 emission is very small, it has been included in the calculation for completeness. Deer numbers were divided into stags, hinds and calves, with stags being outdoors all year round and hinds and calves being outdoors for 75% of the year (MAFF, 1994). Emission factors for grazing, housing, storage and landspreading were estimated using emission factors for sheep because of the similar body weights, output and N content of excreta.

2.6. Emission factors for inorganic N fertiliser applications to land

Nitrogen fertiliser applications to agricultural land were divided into grassland and arable land. The fertiliser types included urea, ammonium nitrate and other, with the quantity applied being estimated from the Survey of Fertiliser Practice (Burnhill et al., 1998) and the Statistical Review of Northern Ireland Agriculture (DANI, 1997). Emission factors used in this inventory for urea, ammonium nitrate and other were 23.0, 1.6 and 1.6% of the applied N, respectively, for grassland applications, and 11.5, 0.8 and 0.8% of the applied N, respectively, for arable land applications. The estimation of these values are fully discussed by van der Weerden and Jarvis (1997), in which an emission of 32.7 kt NH_3–N per year from N fertiliser applied to agricultural land in the UK was calculated. This value includes emissions from fertiliser applied to grazed grassland, whereas the inventory separates emissions from this source from other fertiliser applications because losses from applications to grazed pasture are included in direct losses from grazing for each livestock type. So losses from fertiliser applications in the inventory include only those from grassland used for silage and hay production and from arable crops. The inventory has been calculated in this manner to eliminate any risk of double-counting.

3. Updating the NH_3 emission inventory for 1997

Since the publication of the NH_3 emission inventory for UK agriculture of Pain et al. (1998), additional data have become available from more recent studies which has led to a revision of some emission factors. The emission factors presented in this paper incorporate these newly available data, so some differ from those used by Pain et al. (1998) in their estimate of NH_3 emission from UK agriculture in 1993. Using the revised emission factors together with census and statistical data for 1997 (HMSO, 1997; Burnhill et al., 1997; DANI, 1997) gives an increased estimate of NH_3 emission from UK agriculture (for 1997) of 229 kt NH_3–N (Table 2) compared with 197 kt NH_3–N for the earlier version (Pain et al., 1998).

4. Comparison with other studies

Details of emission factors used in compiling previous inventory estimates are not always given. Lee and Dollard (1994) compared emission factors for livestock classes derived from some of the earlier inventories, which show great variation, but give no detail as to emission factors from each stage of the production cycle (housing, storage, etc.). Much of the data used for these inventories has also been used for estimates made for countries within Western Europe by the European Centre for Ecotoxicology and Toxicology of Chemicals (ECETOC, 1994) and, more recently, within the EMEP/CORINAIR Atmospheric Emission Inventory Guidebook (McInnes, 1996) which gives default emission factor values for use by European countries in calculating national emission inventories. ECETOC tends to use largely Dutch or German data where national data are missing, adjusted to account for differences in excretion rates in some cases. EMEP/CORINAIR uses largely

Table 2
Inventory for ammonia emission from UK agriculture, 1997

	Source	Amount of NH_3–N lost (kt NH_3–N per year)	Percentage of total
Cattle			
	Housing	42.0	18.6
	Storage	15.7	7.0
	Land spreading	45.1	20.0
	Grazing	15.2	6.7
	Total	118.0	52.3
Sheep			
	Housing/storage	1.1	0.5
	Land spreading	0.8	0.4
	Upland grazing	2.7	1.2
	Lowland grazing	9.5	4.2
	Total	14.2	6.3
Pigs			
	Housing	16.2	7.2
	Storage	2.8	1.2
	Land spreading	7.0	3.1
	Outdoors	0.9	0.4
	Total	27.0	12.0
Poultry			
	Housing	27.5	12.2
	Storage	0.3	0.1
	Land spreading	14.1	6.3
	Outdoors	1.0	0.4
	Total	43.0	19.1
Deer	Total	0.04	< 0.1
Conserved grassland	Total	11.1	4.9
Tillage crops	Total	12.3	5.5
Grand Total		**225.6**	**100**

Table 3
Estimates of N excretion (kg N animal^{-1} yr^{-1}) and emission of NH_3–N (as % total N excretion) for different livestock types from ECETOC (1994), EMEP/CORINAIR (McInnes, 1996), FAL/IUL/FAT (1998)[a] and this paper

Livestock type	ECETOC UK values		EMEP/CORINAIR default values		FAL/IUL/FAT Switzerland	This paper	
	N Excretion	NH_3–N Emission	N Excretion	NH_3–N Emission	NH_3–N Emission	N Excretion	NH_3–N Emission
Dairy cow	122	27	100	24	32	104	21
Other cattle			50	24	37	51	11
Sow	33	30	36	38		33	13
Finishing pig	13	30	14	38	46	11	36
Laying hen	0.8	43	0.8	39	54	0.8	46
Broiler	0.3	22	0.6	37	48	0.8	24
Sheep	23	7	20	6	14	12	5

[a] No details of N excretion given by FAL/IUL/FAT (1998).

Dutch and UK data, with default values being agreed by a panel of experts representing 17 European countries. Emission factors for calculating ammonia emission from animal husbandry in Switzerland have also been recently published (FAL/IUL/FAT, 1998). Emission factors for each livestock type from these studies are compared with those derived from the emission factors presented in this paper in Table 3, with values expressed as a proportion of N excretion. Values given for Switzerland (FAL/IUL/FAT, 1998) are greater for all livestock types, but this may relate to differences in N excretion estimates, which are not given. Emission factors presented in this paper are lower for other cattle and sows than those given by ECETOC or EMEP/CORINAIR.

Emission factors for each of the production stages are given for each livestock type by ECETOC and EMEP/CORINAIR, although not to the level of detail given in this paper (with only one emission factor being given for each stage and no distinction between, e.g. housing type, manure type at land spreading, etc.). For cattle grazing, both ECETOC and EMEP/CORINAIR give the emission factor as 8% of the total N excreted by cattle during grazing, giving an emission factor of c. 30 g N animal^{-1} d^{-1} for dairy cattle, much greater than the value derived from the relationship between emission and inorganic N input to the pasture. The ECETOC emission factor for cattle ($>$ 2 years) housing of c. 50 g N lu^{-1} d^{-1} is much greater than that presented here for dairy or other cattle, whereas the value given by EMEP/CORINAIR for dairy cattle is similar to that presented here for cattle in cubicles and that for other cattle similar to that presented here for cattle housed on litter. Housing emission factors presented here for sows are lower than those quoted elsewhere, and those given here for poultry housing are lower than those given by ECETOC, but otherwise, housing emission factors are broadly similar. Emissions from manure storage are included within the housing emission factor for ECETOC values. EMEP/CORINAIR storage emission factors are given as a proportion of total N in the manure stored (6% for cattle and pigs, 4% for laying hens and 3% for broilers), rather than an emission factor for manure surface area, with no distinction between manure type or storage method. For manure spreading, ECETOC and EMEP/CORINAIR give emission factors as proportion of total N applied and do not distinguish between slurry and solid manure. ECETOC give 28.5% of total N for cattle manure, 5.35% for pig manure (very low in comparison with others), 37.6% for laying hens and 7.2% for broilers. EMEP/CORINAIR give 20% of total N for manure from all livestock types. Emission factors for fertiliser applications are given as 15 and 2% for urea and ammonium nitrate respectively.

Groot Koerkamp et al. (1998) conducted a series of measurements comparing NH_3 emissions from livestock buildings in Northern Europe from which emissions from much of the UK animal housing tended to be lower than those from the Netherlands, Denmark and Germany. It is not surprising therefore that default values, often based on research in the Netherlands or Germany, are greater than emission factors based on actual measurements in the UK. The inventory of Pain et al. (1998), updated in this paper, is derived from many more recent UK-specific data than were previously available, providing more robust estimates of emission factors to give a more accurate estimate of the total emission of NH_3 from UK agriculture. Also, emission factors specific to particular production systems are presented which, when combined with survey information, further improve the accuracy of the estimate as well as allowing for simpler updating of the inventory in the light of new surveys and scenario testing to assess the effect of changes in practice.

Acknowledgements

This work was funded by the MAFF mainly through Open Contract 9117. We thank John Webb (ADAS) for his valued contribution during the inventory compilation. IGER and SRI are supported by the Biotechnological and Biological Sciences Research Council.

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