Ammonia emissions from UK non-agricultural sources in 2009: contribution to the National Atmospheric Emission Inventory

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EXECUTIVE SUMMARY

Estimation of total UK ammonia emissions from nature, waste disposal and other miscellaneous sources

1. Ammonia emission estimates were reviewed for natural sources, waste disposal and other miscellaneous sources regarding both source strength estimates ("emission factors") and source populations for the UK, and brought up to date to 2009 (or the latest available data).

2. The emission sources listed above were assigned to the classification system used by the UNECE Emission Inventory Guidebook, and adjusted to match the system used by AEAT. The relevant categories ("SNAP codes") in the guidebook are "use of solvents" (SNAP code 6), "waste disposal" (SNAP code 9) and other miscellaneous sources (SNAP code 11 or unclassified).

Emission source strength estimates

3. Emissions from composting were revised with new data from the scientific literature on the N content of materials composted and on volatilisation rates for different types of materials. The new average volatilisation rates for green compost are higher than previous estimates, at 13% (range 1-17%), whereas volatilisation rates from high N materials (e.g. kitchen and food wastes) were decreased slightly, to 38 % (range 17-46%).

Emission source populations

4. The overall horse population estimate for the UK was updated with the latest available data on equines (i.e., including donkeys, mules, etc.) from a survey by the British Equestrian Trade Association (BETA), to a new total of 1.2 million equines. This constitutes an increase of 225,000, compared with the previous best estimate.

5. The amount of materials composted has increased again between 2008 and 2009, from 4,475 kt to 5,100 kt. It is expected that this trend will continue for the foreseeable future. By combining the latest data with the revised emission estimates for composting, the UK total from this source has been calculated at 3.8 kt NH_3-N for 2009, an increase of 37%.

6. The latest estimates of waste being land-filled show a slight decrease again, resulting in reduced NH_3 emissions from this source, down from 2.3 kt NH_3-N for 2008 to 2.1 kt NH_3-N for 2009. This trend appears to be linked with increased recycling rates and reduced disposal to landfill in the UK.

7. The source populations and some source strength estimates for other categories (e.g., human subcategories, seals, wild deer, wild geese, cats, dogs, non-agricultural fertiliser use) were also updated, however any changes were very small and have not resulted in substantial changes in emissions. No new data were found for pheasants, seabirds, wild mammals (other than deer), and sewage.

UK Emission estimates for 2009

8. Overall emissions from SNAP codes 6, 9 and 11 amount to 40.8 kt NH_3-N $year^{-1}$ for 2009, with a range of 18.4-82.9 kt NH_3-N $year^{-1}$. This constitutes an increase of 3.1 kt NH_3-N yr^{-1}, compared with the estimate for the same sources for 2008 (37.7 kt NH_3-N yr^{-1}). The main changes to the inventory are increases in emissions from horses by 19% due to a new population estimate, and from composting (by 37%), due to increased amounts of materials being composted as well as revised emission factors and N content. The main decreases to note are from landfill (by -10%) due to less material being land-filled, and from wild deer (-9%), due to new data on deer populations. The

developments in composting and landfill are linked, with materials being diverted from landfill to composting plants for recycling.

CONTENTS

1. INTRODUCTION

Ammonia (NH_3) emissions are recognized as a major component in the assessment of transboundary air pollution fluxes for acidification and eutrophication. While most attention has been and is being given to agricultural sources, non-agricultural sources of ammonia represent around 20% of the total, but had received very little attention until the late 1990s in the UK, when Defra funded a review of the different sources by CEH (Sutton *et al*. 2000), and an assessment of the potential for reducing emissions from these sources, conducted by AEAT (Handley *et al*. 2001). Since 2003 (inventory year 2002), CEH has been providing annual updates on the following non-agricultural emission source categories for inclusion in the National Atmospheric Emission Inventory (NAEI):

- SNAP code 6 (solvent use): household cleaning materials, perming solutions, refrigeration etc
- SNAP code 9 (waste disposal): landfill, sewage works and sewage spreading, composting (excluding incineration)
- SNAP code 11 (other sources and sinks, including natural sources): non-agricultural horses, pets, wild mammals, seabirds, humans, biomass burning

The current contract (Oct-2008 to Sep-2011) for the inventory years 2007-2009 exploits the expertise of CEH in non-agricultural sources of NH_3, focusing on emissions from nature, waste disposal and other miscellaneous sources, which complements the expertise of AEAT regarding combustion, industry and transport sources.

2. METHODOLOGY AND WORK SCHEDULE

Emission sources are referenced to the "SNAP code" (Selective Nomenclature of sources for Air Pollution) system recommended by the UNECE Emission Inventory Guidebook (2006) for the 2009 update.

An extensive literature search is conducted annually for new scientific publications on the sources under investigation, to improve existing estimates of source strength, as well as to scan the literature for new sources. In addition, a wide-ranging search for new source activity statistics is carried out for the annual inventory update. Any new information found is used in the inventory calculations, which result in "best estimates" for each source type. Low and high estimates are also calculated to provide a range/indication of the uncertainty.

The current report focuses on updating non-agricultural ammonia emissions for the inventory year 2009, both regarding new scientific information and assembling of data on source activities and calculation of annual UK emissions. The annual reports contain a short description of methodology, highlighting changes in source strength and source populations and their consequences on NH_3 emissions. This report incorporates the latest information available by the end of October 2010.

3. RESULTS

3.1. New emission source strength data

3.1.1. SNAP CODE 6 (SOLVENT AND OTHER PRODUCT USE)

No new scientific literature was found that would merit changing the current approach.

3.1.2. SNAP CODE 9 (WASTE TREATMENT AND DISPOSAL, EXCLUDING INCINERATION)

Landfill

No new scientific literature was found that would merit changing the current approach.

Composting

New data on the amount and types of materials composted as well as composting processes in the UK were available from a survey of UK compost producers for 2008/09, by the Association for Organics Recycling (Stone *et al*. 2010). These data, together with results from a literature search (Komilis and Ham 2006, Stredwick 2001, Pagans *et al*. 2006, Lin 2008, Eklind *et al*. 2007, Jarvis *et al*. 2009, Cadena *et al.* 2009) were used to update the average N content of materials composted and emission factors for this source. The average N content of materials composted in the UK is similar from the previous year's estimate by Dragosits *et al.* (2010), at 1.2% N, or 1.1% for green waste and 2.8% for kitchen waste. The average % volatilisation rates were revised by incorporating the new data with the existing emission estimates. This resulted in new best estimate volatilisation rates of 13% (range 1-17%) for green waste and 38% (17-46%) for kitchen and other high N materials, and an average UK emission factor of 1.9 kg NH_3-N t^{-1} dry matter composted (range 0.35-2.44).

Landspreading of sewage sludge and sewage works

No new scientific literature was found that would merit changing the current approach.

3.1.3. SNAP CODES 11 AND 00 (OTHER SOURCES AND SINKS)

Only SNAP codes 11.3 (forest and other vegetation fires), and 11.7 (animals) are considered as relevant ammonia sources for the purpose of this report; semi-natural habitats such as woodlands, grasslands and wetlands are considered to be net sinks (Sutton *et al*. 2000).

Biomass burning

No new scientific literature was found that would merit changing the current approach.

Other animals

No new information was found on emission source strength for wild animals or seabirds.

Other sources – cigarette smoking

The latest smoking statistics available for the UK are from the General Lifestyle Survey 2008 (Robinson and Bugler 2010). The smoking habits of the average cigarette smoker are almost unchanged from the previous value for 2007 (Robinson and Lader 2009), for both male and female adult smokers.

For smokers under 16 years old, new statistics (NCSR 2010) show that the number of cigarettes per regular smoker has decreased slightly, from 39.3 per week to 38.1 per week. The number of cigarettes smoked by occasional smokers increased, from 3.9 to 4.5 cigarettes per week. Overall these small changes result in a decrease in the average emission factor per young smoker.

Other human sources

No new scientific literature was found that would merit changing the current approach.

Golf courses, parks and gardens

The average NH_3 volatilisation rate for fertiliser application to golf courses, parks and public gardens was updated from 2.6% to 2.7% (range 2.3-3.6%), in line with the emission factors

for fertiliser application to agricultural grassland from the UK inventory for 2008 (latest data available at the time of reporting the data to AEAT; Misselbrook *et al*., 2009).

3.2. New source data

Solvents/household products

Source numbers were updated for SNAP code 6 (solvent use) with an estimated slight increase in the number of households in the UK for 2009 to nearly 25.9 million (Barnard, 2010).

Landfill

Source numbers were updated with 2009 landfill statistics (municipal solid waste, MSW) for all parts of the UK (England: Defra (2010); Scotland: SEPA (2010); Northern Ireland: NIEA (2010); Wales: National Assembly for Wales (2010)). The latest available figures for land-filled sewage sludge are also included in the total amount of landfilled materials (22.5 kt dry solids in the UK (2005 data for Great Britain, 2004 for Northern Ireland, (Defra 2007)). UK totals for 2009 amount to 16,367 kt MSW (inc. landfilled sewage sludge). Overall, emissions from landfill have decreased again, mainly due to another decrease in the overall amount of waste going to landfill in the UK. The current best NH_3 emission estimate for 2009 is 2.1 kt NH_3-N $year^{-1}$ (range 1.0-4.1 kt), compared with 2.3 NH_3-N $year^{-1}$ kt in 2008.

Composting

The latest available data on amounts and types of waste composted in 2008/09 were taken from Stone *et al*. (2010) for the 2009 update of the inventory. Stone *et al.* (2010) estimate that 5,100 kt of organic materials were composted in 2008/9, which represents an increase of 14% compared with the previous year (Smith *et al*. 2009). Composting is still a growth area, and increases in emissions from this source are expected for some time to come.

For the derivation of emissions from composting facilities, a new % split of the mixed category "kitchen and garden wastes" was used, with high N food waste typically only making up 10% or less (Stone *et al*. 2010). Previously this split was not defined explicitely in the reports, and a 60/40 split between high N and low N materials had been assumed, in the absence of further information. This resulted in a relative decrease in the total amount of N from materials composted, compared with previous years' estimates.

Overall, emissions of 3.4 kt NH_3-N from composting are estimated for 2009, which represents an increase of 1 kt (37%) from the figures calculated for 2008 by Dragosits *et al*. (2010), due to an increase in the best estimate of the volatilisation rate for low N materials and overall amount of materials composted, despite a decrease in the relative proportion of high N materials composted.

Landspreading of sewage sludge

No new data were found in amounts of sewage sludge, the 2005 data in Defra (2008) still appear to be the best available.

Biomass burning

No new data were found that merit an update of the 2007 estimate.

Parks & gardens + golf courses

No new data were found that merit an update of the detailed approach developed for the 2008 inventory (Dragosits *et al*., 2010). Applying the updated volatilisation rate described in Section 3.1.(above) results in a total of 0.4 kt NH_3-N yr^{-1} (range 0.2-0.6 kt) for parks and gardens and 0.3 kt NH_3-N yr^{-1} (range 0.1-0.8 kt) for golf courses.

Humans

The UK population figures were updated to the latest available data, the mid-2009 estimate of 61,792,000 (ONS 2010). This constitutes an increase by approx. 409,000 people or 0.7%, compared with 2008. The emission source populations were also updated for the number of infants in the two age groups considered for babies' nappy emissions, as well as for adult and young smokers (11-15 years old).

New data on adult cigarette smoking (Robinson and Bugler 2010) show that the proportion of adults over 16 years old who smoke has not changed significantly since 2008. The very slight increase in emissions from adult cigarette smoking by 3%, is mainly due to an overall increase in the UK population. Cigarette smoking emissions from young people decreased by 3%, mainly due to a lower cigarette consumption per smoker and a small decrease in the number of young smokers (NCSR 2010).

Emissions from other human sources (breath, sweat and babies' nappies) are estimated at 0.76 kt NH_3-N yr^{-1} for the UK in 2009, with a very small increase of ~5 t NH_3-N yr^{-1} from 2008.

Pets

New survey data from the Pet Food Manufacturers Association (PFMA) for 2009 show unchanged UK population estimates compared with 2008, with populations of 8.0 million dogs and 8.0 million cats. With the same emission estimate per animal as used in 2008, emissions remain unchanged for 2009, at 0.9 kt NH_3-N yr^{-1} for cats (range 0.4-1.4 kt NH_3-N yr^{-1}), and 5.1 kt NH_3-N yr^{-1} for dogs (range 2.1-8.9 kt NH_3-N yr^{-1}).

Seabirds

No new survey data were found, the estimate of 3 kt NH_3-N $year^{-1}$ for 2007 (Dragosits *et al*. 2009) was carried forward for the current inventory year.

Horses

The UK population estimate for horses was updated with surveys carried out by the British Equestrian Trade Association (BETA) and detailed discussions on these data with BETA (pers. comm). The new best population estimate is 1.2 million equines (range 1.1-1.3 millions), which constitutes an increase of 225,000 equines (+ 23%), compared with previous data from the National Equine Database (NED) of 975,000. The latest available data from the NED give a total of 1.43 million horse passports registered, however a substantial number are thought to be deceased, where as some would be double-registered, and others (e.g., feral horses) are expected to be unregistered. With the new population estimates, 2009 ammonia emissions from horses are estimated at 15.2 kt NH_3-N (range 8.8-26.8 kt), an increase of 19%.

As for previous years, it should be noted that this estimate includes emissions from all UK horses, a) those counted in the agricultural census and therefore included the agricultural emission inventory calculated by Rothamstead Research, North Wyke (Misselbrook *et al*. 2010), and b) all other horses, i.e., the "non-agricultural" part of the UK horse emissions.

Wild animals

For the 2009 update, several new estimates of wild animal populations were included:

For grey seals, SCOS (2010) gives a new best estimate of 183,000 (85,600-359,300) animals. These figures replace the previous year's best estimate of 160,100 animals (84,500-304,500), however SCOS (2010) state that these new figures are due to the use of a different modelling approach rather than an indication of an increase in population. These new figures result in an increase in emissions from 70 t to 91t NH_3-N $year^{-1}$.

The new estimate of wild geese populations in the inventory is based on a combination of best estimates from different sources (Mitchell *et al*. 2010, Mitchell 2010, Calbrade *et al*. 2010, Fox *et al*. 2009, Holt *et al*. 2009, Hall 2008 and Rowell *et al*. 2004). Overall, approx. 104,000

geese are estimated to be resident in the UK all year round (previous population of 81,500 from a number of sources, see Dragosits *et al*. 2010), with a further approx. 625,000 (previously 546,000) migratory geese over-wintering in the UK. These winter visitors stay in the UK between September/October/November and March/April, depending on species. An average residence time of six months has been estimated for the purpose of the NH_3 inventory. In total, emissions from wild geese are estimated at 86 t NH_3-N (range 49-135 t) for 2009, compared with 61 t for 2008. This is perhaps on the conservative side due to a lack of data on emission source strength (Dragosits *et al*. 2007). While the total emission from wild geese is relatively small, it they are locally important sources in areas where they congregate in large numbers, e.g. in western Scotland and some Scottish islands (especially Islay).

Data from a report by Munro (2002) on the "Deer Industry in Great Britain" was incorporated in the inventory calculation of deer species populations in the UK, which is based on a number of sources (Hansard 2007, Hunt 2003, Yalden 1998). This led to new, slightly lower, population estimates for red, roe and fallow deer and a slight increase in the number sika deer. Overall this results in a slight decrease in NH_3 emissions from wild deer, from 1.5 to 1.3 kt NH_3-N.

No new data were found for other wild mammals or pheasants.

3.3. New UK emissions

UK NH_3 emission totals for non-agricultural sources were recalculated with the updated source strength and source population data, as described above. Emission source strength and source population data as well as UK emission totals from SNAP codes 6, 9 and 11 are summarised in Table 1 below. Overall, emissions from SNAP codes 6, 9 and 11 (including unclassified sources under SNAP Code 00) amount to 40.8 kt NH_3-N $year^{-1}$ for 2009, with a range of 18.4-82.9 kt NH_3-N $year^{-1}$.

Table 1: Ammonia emissions from UK non-agricultural sources for 2009

2009 (Ammonia as NH_3-N)	emission estimates source^{-1}				number of sources				UK emissions 2009(kt NH_3-N yr^{-1})		
source	best estimate	low	high	units (NH3 as NH_3-N)	best estimate	low	high	units	best estimate	low	high
human breath	2.0	0.7	6.2	g person^{-1} yr^{-1}	61,792,000	-	-	persons	0.126	0.043	0.384
human sweat	10.2	1.6	42.1	g person^{-1} yr^{-1}	61,792,000	-	-	persons	0.60	0.09	2.50
infants emissions < 1yr	11.7	2.4	54.2	g infant^{-1} yr^{-1}	784,200	-	-	children <1 yr	0.009	0.002	0.043
infants emissions 1-3 yrs	14.6	3.0	67.8	g infant^{-1} yr^{-1}	1,543,800	-	-	children 1-3 yr	0.023	0.005	0.105
cigarette smoking (adults)	18.5	9.3	33.5	g smoker^{-1} yr^{-1}	10,795,630	-	-	smokers	0.200	0.100	0.362
cigarette smoking (young people)	4.5	2.2	8.1	g smoker^{-1} yr^{-1}	403,018	-	-	smokers	0.002	0.001	0.003
competition/race horses *	27.3	12.4	53.5	g animal^{-1} yr^{-1}	151,700	-	-	animals	4.1	3.1	6.7
other horses *	10.5	2.3	45.7	g animal^{-1} yr^{-1}	823,300	-	-	animals	11.1	5.7	20.1
dogs	0.64	0.30	1.01	g animal^{-1} yr^{-1}	8,000,000	7,200,000	8,800,000	animals	5.1	2.1	8.9
cats	0.11	0.05	0.16	g animal^{-1} yr^{-1}	8,000,000	7,200,000	8,800,000	animals	0.9	0.4	1.4
wild deer (large)	1.45	0.73	2.90	g animal^{-1} yr^{-1}	645,925			animals	0.937	0.3	2.6
wild deer (small)	0.58	0.29	1.16	g animal^{-1} yr^{-1}	664,000			animals	0.385	0.1	1.2
other major wild animals (mammals inc. seals)	-	-	-	-	-	-	-	-	1.00	0.25	2.85
wild geese					729,201	546,901	911,501	birds	0.07	0.04	0.11
seabirds	-	-	-	-	6,667,910	-	-	birds	2.96	1.98	5.91
biomass burning (heather burning, "muirburn")	2.10	0.95	3.89	g m^{-2} yr^{-1}	200,000,000	120,000,000	360,000,000	burnt area in m^2	0.42	0.11	1.40
ecosystems	0	0	0	-	0	0	0	-	0	0	0
sewage works	-	-	-	-	-	-	-	-	1.2	0.7	4.9
sewage spreading	-	-	-	-	1147	-	-	kt total dry solids yr^{-1}	3.3	0.8	7.1
landfill	0.13	-	-	kg t^{-1} landfilled	16,367,253	-	-	t landfilled (MSW + sludge)	2.1	1.0	4.1
appliances &household products	-	-	-	-	-	-	-	-	0.99	0.3	3.7
non-agricultural fertilizers (households)	-	-	-	-	-	-	-	-	0.23	0.1	0.5
composting					5,100,000			t of waste composted	3.83	0.70	4.97
pheasants	0.02	0.006	0.06	g bird^{-1} yr^{-1}	25,000,000	22,500,000	27,500,000	birds	0.50	0.14	1.65
parks and gardens	1.91	1.27	2.54	kg ha^{-1} yr^{-1}	214,871	181,217	255,025	hectares	0.41	0.23	0.65
golf courses	2.39	0.81	6.34	kg ha^{-1} yr^{-1}	116,126			hectares	0.28	0.09	0.74
TOTAL	-	-	-	-	-	-	-	-	**40.75**	**18.42**	**82.89**

*Note: The estimate of emissions from horses includes all horses in the UK, i.e. horses counted in the agricultural census are included in this estimate.

4. SUMMARY OF CHANGES AND CONSEQUENCES

SNAP code 6 (solvent and other product use)

Only minor changes were made to emissions from household products, by including new data on the number of households in the UK. Some of the estimates for individual sources changed very slightly, but this did not significantly affect the overall emissions from this category compared with 2008.

SNAP code 9 (waste treatment and disposal)

Landfill emissions have decreased again from the 2008 emission estimate (2.3 kt NH_3-N) to 2.1 kt NH_3-N in 2009, mainly due to a decrease in the proportion of municipal solid waste being land-filled.

Composting emissions are estimated to have increased, from 2.8 kt NH_3-N in 2008 to 3.8 kt NH_3-N in 2009. This is due to new data from the scientific literature becoming available on N content of composted materials and emission source strength, and is in line with the continuing growth in composting of organic materials. This trend is likely to continue, due to increased pressure to divert compost-able materials from landfill.

SNAP code 11.3 (forest and other vegetation fires)

No new data were found for muirburn (burning of heather moorland), and the 2007 value of 0.42 kt NH_3-N yr^{-1} (range 0.11-1.40 kt) was carried forward unchanged.

SNAP code 11.7.2 (mammals)

The major change in NH_3 emissions from (domestic) mammals is an increase in emissions from horses by 2.4 kt NH_3-N yr^{-1} to 15.2 NH_3-N yr^{-1} for 2009, due to new population estimates becoming available. The best estimate for emissions from cats and dogs remains unchanged between 2008 and 2009, with population estimates remaining stable.

SNAP code 11.7.3 (other animals)

The largest change in emissions from wild animals in 2009 is due to new population estimates for wild deer being included in the calculations, resulting in emissions decreasing to 1.4 kt NH_3-N yr^{-1} (-9%). Small changes in population data for have resulted in very minor increases in emissions from seals and similarly small increases in emissions from wild geese.

SNAP code 00 (other sources)

Humans

Emissions from humans increased by very small amounts between 2008 and 2009, mainly due to the continuing increase in the UK population (by 409,000 persons or 0.7%).

Gardens, parks and golf courses

The best emission estimates for from parks and gardens are 0.4 kt NH_3-N, and 0.3 kt NH_3-N from golf courses, with a very slight increase due to updated volatilisation estimates for emissions from fertiliser application to grassland.

5. CONCLUSIONS

New UK estimates of non-agricultural NH_3 emissions were calculated and brought up to date to 2008 (or the latest available data), for a range of sources (solvent use, waste disposal, nature and other miscellaneous sources), using the latest updates available for source strength estimates ("emission factors") as well as source activity statistics/source populations.

Overall, emissions from SNAP codes 6, 9, 11 and other miscellaneous sources amount to 40.8 kt NH_3-N $year^{-1}$ for 2009, with a range of 18.4-82.9 kt NH_3-N $year^{-1}$. This constitutes an increase of ~3.1 kt NH_3-N compared with the estimate for the same sources for 2008 (37.7 kt NH_3-N). The main changes to the inventory are increases in NH_3 emissions from composting, cats and dogs, and decreases in emissions from landfill. Emissions from other sources not mentioned explicitely changed only by small amounts.

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