Ammonia emissions from UK non-agricultural sources in 2014: 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 2014 (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 Ricardo-AEA. 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 household-based composting were included for the first time in the 2013 report by Ricardo-AEA and have been moved to CEH's remit by mutual agreement for the 2014 report. The best estimate for the emission factor is 0.45 kg NH_3-N t^{-1} fresh-weight (range 0.23 – 0.68 kg NH_3-N t^{-1} fresh-weight), a small modification of the previous household composting emission factor.

4. The amount of NH_3 volatilized from fertiliser applied to parks and gardens increased to 2.24% (from 2.22%), following revision of grassland volatilisation estimates in the agricultural inventory for 2014. The new best estimate is 0.67 kg NH_3-N ha^{-1} (range 0.23 – 1.35 kg), and replaces the previous emission factor of 0.68 kg NH_3-N ha^{-1}.

5. The volatilization rates of NH_3 from fertiliser applied to golf courses decreased marginally from 3.02% to 2.99%, due to the revision of the emission factor for a UK average of all fertilisers applied to grassland (2.24%), rather than solely Ammonium Nitrate (1.8%) in the agricultural inventory. The emission factor increased to 0.713 kg NH_3-N ha^{-1} (range 0.41 – 1.16 kg), replacing the previous estimate of 0.705 kg NH_3-N ha^{-1}.

6. There was a marginal increase in the emission factor for smokers – both adults and young persons – from 15.8 g NH_3-N $smoker^{-1}$ to 16.6 g NH_3-N $smoker^{-1}$ and 3 g NH_3-N $smoker^{-1}$ to 4 g NH_3-N $smoker^{-1}$ respectively.

Emission source populations

7. The horse population estimate for the UK has been divided into three categories (previously two), for improved transparency, in the same way as for 2013; professional horses (i.e. horses on a higher protein diet), 'normal' horses located on agricultural holdings (and counted in the agricultural census) and 'normal' privately owned horses (not counted in the agricultural census). There has been a reduction of 35,835 in the total number of equines (i.e., including donkeys, mules, etc.), mainly due to a reduction of 43,000 'normal' privately owned horses (offset by slight increases in both professional horses and horses on agricultural holdings). The best estimate for 2014 is 11.89 kt NH_3-N for all horses, a decrease of 0.43 kt NH_3-N from 2013.

8. The latest estimates of waste being land-filled, based on landfill statistics for the four countries of the UK show a large decrease of 1,608 kt to 9,450 kt (approx. 15.6%). while the amount of sewage sludge going to landfill has also decreased substantially from 6 kt to 4.2 kt. Overall there has been a decrease in NH_3 emissions from this source, down from 1.54 kt NH_3-N in 2013 to 1.31 kt NH_3-N in 2014. This decrease is largely due to

reduced amounts of waste to landfill and, to a much lesser extent, the reduction as a percentage of organic matter to landfill.

9. The amount of sewage sludge applied to land (agriculture and land reclamation) was updated with the latest figures for 2014 used in the UK Greenhouse Gas Inventory, 1,332 kt total dry solids year^{-1} (an increase of 45 kt from 2013), resulting in a revised emission estimate of 3.2 kt NH_3-N yr^{-1}.

10. Anaerobic digestion (AD) plants in the UK are estimated to have inputs of approx. 6,852 kt in 2014 (increased from 5,235 kt in 2013), with approx. 50% of materials originating from non-farm sources (compared to around 62% in 2013). The quantity of non-farm inputs in 2014 has risen by 6% from 2013 but the proportion of the total inputs to AD plants of non-farm inputs has decreased by roughly 12% from 2013 (mainly due to a large increase in plant waste from farms). The emissions for 2014 were estimated at 1.1 kt NH_3-N yr^{-1} for fugitive and storage emissions at AD plants, and 2.9 kt NH_3-N yr^{-1} for landspreading of non-farm-based materials. These represent an increase from 0.9 kt NH_3-N yr^{-1} and 2.3 kt NH_3-N yr^{-1} respectively.

11. The amount of waste input to household-based composting in 2014 in the UK is approximately 209 kt (an increase from 188 kt in 2013). This resulted in an emissions estimate of 0.09 kt NH_3-N yr^{-1} for 2014 and is included in this report for the first time (though it was included in the 2013 inventory by Ricardo-AEA). Inputs to non-household composting facilities increased by approximately 9% to 2,548 kt dry matter, resulting in an increased emissions estimate of 5.2 kt NH_3-N yr^{-1} from 4.8 kt NH_3-N yr^{-1} in 2013.

12. New population figures for domestic pets (dogs decreased by 500,000 and cats decreased by 600,000 from 2013 to 2014) resulted in decreased emissions by 0.3 kt and 0.06 kt NH_3-N yr^{-1} for dogs and cats, respectively, between 2013 and 2014.

13. The area burnt through biomass burning ('muirburn') in the UK was updated in 2014 to 185 km^2, a decrease from 274 km^2 in 2013, due to new information becoming available on estimating burnt areas. This resulted in a decreased emissions estimate of 0.19 kt NH_3-N yr^{-1} for 2014 (from 0.29 kt NH_3-N yr^{-1} in 2013).

14. The source populations for other categories (e.g., human subcategories, wild geese, wild deer and wild seals) were also updated, however any changes were small in absolute terms and have not resulted in substantial changes in emissions. No new data were found for game birds, domestic chickens, other wild animals, parks and gardens, golf courses, sewage works, household appliances and seabirds.

UK Emission estimates for 2014

Overall emissions from SNAP codes 6, 9 and 11 amount to 42.6 kt NH_3-N year^{-1} for 2014, with an uncertainty range of 20.1 – 82.4 kt NH_3-N year^{-1}. This constitutes a small increase of 0.5 kt NH_3-N yr^{-1}, compared with the 2013 estimate (42.1 kt NH_3-N yr^{-1}). The main changes between 2013 and 2014 are the increases in emissions from anaerobic digestion by 0.9 kt NH_3-N yr^{-1} (both fugitive emissions and emissions from landspreading combined), the increase of emissions from non-household composting by 0.4 kt NH_3-N yr^{-1} (9%) and the decreases in emissions from horses (a reduction of 0.4 kt NH_3-N yr^{-1}) and pets (a reduction of 0.4 kt NH_3-N yr^{-1}). Other notable changes are decreased emissions from landfill (by 0.2 kt NH_3-N yr^{-1}), increased emissions from sewage spreading to farmland (by 0.1 kt NH_3-N yr^{-1}) and the newly introduced emissions from household-based composting of 0.1 kt NH_3-N yr^{-1}.The largest relative changes were for emissions from anaerobic digestion (both fugitive emissions and emissions from landspreading) which increased over 27% (up 0.9 kt NH_3-N yr^{-1}), while biomass burning emissions decreased by 33% (down 0.1 kt NH_3-N yr^{-1}), due to the new information regarding the area burnt.

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 15-20% 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-2011 to Sep-2016) for the inventory years 2010-2014 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 Ricardo-AEA on 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 2014 update. It should be noted that emissions from anaerobic digestion are not included in the official UK inventory total for 2014, as advised by Defra, and allocated to SNAP Code 00.

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 2014, 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 late October 2015.

3. RESULTS

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

3.1.1. New emission source strength data

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

3.1.2. New source data

Source numbers for hair products were updated using UK 2014 population numbers (see Section on Humans below for details), resulting in a very small, non-significant increase in emissions from SNAP Code 6 (solvents) for the year. The current best estimate remains 0.99 kt NH_3-N yr^{-1}.

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

3.2.1. New emission source strength data

Landfill

The detailed research undertaken to update the estimated N content of land-filled materials from municipal waste streams in the 2013 inventory, to replace the old value derived from Burton and Watson-Craik (1998), was repeated for the 2014 inventory. Various waste composition reports (Defra 2014; Resource Futures 2013; SEPA 2012; The University of Warwick 2005; WRAP Cymru 2010 & Zero Waste Scotland 2010) were used to analyse the tonnage of different materials going to landfill to produce a new N content estimate of 0.55% for 2013 (used again unchanged for 2014), a 10% increase from the figure of 0.5% used in inventory years prior to 2013.

Also, the input of 4.2 kt of sewage sludge to the landfill process in 2014 (reintroduced in 2013 following the availability of new data) meant more high-nitrogen materials were going to landfill in 2014 (the N content for sewage sludge remained at 3.6% as per previous years). The 2014 best estimate emission factor is 0.14 kg NH_3-N t^{-1} of landfilled materials.

Non-household Composting

The data from Horne *et al.* (2013), used in the 2012 inventory, regarding the composition of materials composted at facilities, were used to apportion the amount of tonnes sent to compost in 2014 based on Local Authority waste streams (see Section 3.2.2). The 2012 best estimate emission source strength of 2.04 kg NH_3-N t^{-1} dry matter composted (range 0.5 - 2.7 kg) has not changed.

Household Composting

Domestic composting has been included in this report for 2014 after being introduced in the 2013 inventory by Ricardo-AEA. Due to scant scientific information regarding emissions or emission factors from home-based composting techniques, it was decided to use the dry matter fraction and N-content of garden waste that goes to composting facilities (40% and 1.11% respectively). Furthermore, a scaling factor of 0.78 was applied to account for the lack of any regular turning of the composting materials, a reflection of the ratio between EFs of turned and non-turned materials cited in Cuhls *et al.* (2015). This resulted in a 2014 best estimate emission source strength of 0.45 kg NH_3-N t^{-1} of dry matter composted (range 0.23 – 0.68 kg).

Landspreading of sewage sludge and sewage works

The N content of sewage applied to land was adjusted to match that used in the UK Greenhouse Gas Inventory for emissions from spreading of sewage to agricultural land (Cardenas *et al*. 2015) during the previous inventory year (Tomlinson *et al.* 2014). As the N content of 3.6% has not been updated by Cardenas *et al*. (2015), the emission factor of 2.4 kg (range 0.9-4.5) NH_3-N t^{-1} (dry solids) is still the best estimate.

3.2.2. New source data

Landfill

Source numbers were updated with 2014 landfill statistics (municipal solid waste, MSW) for all parts of the UK (England: Defra (2015); Scotland: SEPA (2015); Northern Ireland: NIEA (2015); Wales: StatsWales (2015)). 4.2 kt of sewage sludge, at 3.6% N content, was included in the total amount of landfilled materials (via Sarah Gilhespy, Rothamsted, pers. comm.). UK landfill totals for 2014 amount to 9,454 kt MSW – a reduction of 1,614 kt MSW from the previous year. It should be noted that inventories prior to 2013 did not include Local Authority Collected Waste from commercial sources for Scotland and this has been included for the 2014 inventory (217 kt landfilled).. Overall, emissions from landfill have decreased as less waste went to landfill (and was diverted to other processes and treatments). The current best NH_3 emission estimate for 2014 is 1.31 kt NH_3-N year^{-1} (range 1.18 - 1.44 kt), compared with 1.54 kt NH_3-N year^{-1} in 2013.

Non-household Composting

The 2012 data on ratios of types of waste composted from Horne *et al.* (2013) were used to calculate the different compost streams for the 2014 inventory due to no further update being available at the time of writing. Overall, 6,398 kt of materials were estimated to be composted in 2014 - producing 2,548 kt of dry matter - amounting to emissions of 5.2 kt NH_3-N year^{-1} (range 1.2 – 7 kt), an increase from the 2013 estimate of 4.8 kt NH_3-N year^{-1}. This increase was solely due to the 9% increase in inputs to the composting processes. It should be noted that a number of unlicensed composting sites exists in the UK, from which it is not possible to estimate inputs and/or emissions – i.e. the current best estimate is likely an underestimate.

Household Composting

Inputs to household composting were calculated by using population statistics (ONS, 2012) and district level analysis for home composting in the UK (Parfitt, 2009). Inputs for the newly included household composting totalled 209 kt for 2014 (up from 188 kt in 2013, previous number given by Ricardo-AEA). The best NH_3 emission estimate for 2014 is 0.09 kt NH_3-N year^{-1} (range 0.05 – 0.14 kt).

Landspreading of sewage sludge

The amount of sewage sludge applied to land was adjusted to match that used in the UK Greenhouse Gas Inventory, for emissions from spreading of sewage to agricultural land (Cardenas *et al*. 2015), of 1,332 total dry solids year^{-1}, more than the 1,287 kt estimated for 2013 (Cardenas *et al.* 2014). This resulted in an emission estimate of 3.2 kt NH_3-N yr^{-1} (range 1.2 – 6 kt) for 2014, compared with 3.1 kt NH_3-N yr^{-1} for 2013.

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

3.3.1. New emission source strength data

Anaerobic digestion

Emission factors calculated for fugitive and storage emissions at AD plants in the 2013 inventory were modified to account for legislation that requires all AD plants to cover input and output storage areas (WRAP/EA 2009); this modification remained in place for the 2014 inventory. NB: Manure sources are assumed to be mostly included in the agricultural inventory already in terms of landspreading emissions, and were omitted here, to avoid potential double-counting, as for the previous years. In the 2012 inventory, an estimated 50% of AD sites were assumed to use covers for materials stored on site, both pre- and post-digestion, which reduce emissions by 80% (Smith *et al*. 2007). The amount of sites using the covering was estimated to be 100% for 2013 and this is carried forward to 2014. The average emission factor in 2011 of 0.8 kg NH_3-N t^{-1} (fresh weight, range 0.6-1.1 kg) derived for fugitive and storage emissions from measurements by Cumby *et al*. (2005) was therefore reduced by 40% to 0.49 kg NH_3-N t^{-1} fresh weight (range 0.35 – 0.64 kg) in 2012 and was further reduced to 0.16 kg NH_3-N t^{-1} fresh weight (range 0.12 – 0.21 kg) in 2013 (or an 80% reduction on the 2011 emission factor). This emission factor remains for the 2014 inventory.

The average emission factor of 0.56 kg NH_3-N t^{-1} fresh weight (range 0.4 – 0.7 kg) for landspreading of digestate was not revised in 2014 for digestates from non-manure materials. Recent results from UK NH_3 emission measurements of digestate spreading (WRAP/Defra 2013, DC-Agri project) show much higher volatilisation rates, by up to 40% higher for broadcasting and up to 75% higher for band spreading, compared with cattle slurry (Fig 2, DC-Agric Bulletin 5[1]). However, for the current submission, the relatively conservative estimates described above for the 2013 inventory were re-used unchanged, until further data from the project is made available.

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 information was found on emission source strength for biomass burning (muirburn), and the current best estimates and uncertainty range remain at 1.1 g (range 0.3-2.4) NH_3-N m^{-2}.

Domestic Chickens

The category of domestic chickens was introduced to the 2013 inventory to account for the growing popularity of 'backyard' poultry in the UK (The Ranger 2011). Each animal has been attributed an emission factor of 0.25 kg NH_3-N $chicken^{-1}$. This is a slightly modified estimate for non-agricultural layers as derived from the agricultural inventory for 2013 (Misselbrook *et al*. 2014), accounting for the birds spending more time outdoors than estimated for commercial flocks in larger free-range units. There is no update of the emission factor for the 2014 inventory.

Other animals

The category of 'pheasants' was revised for the inventory year 2012 to 'game birds', incorporating the large population of red-legged partridges in the UK (Bicknell et al., 2010; Defra, 2013), which are reared in the same way as pheasants. The emission source strength was

[1]Defra/WRAP DC-Agri Bulletin 5, http://www.wrap.org.uk/sites/files/wrap/DC-Agri%20-%20Bulletin%205%20-%20Nitrogen%20Use%20Efficiency.pdf

weighted to allow for the smaller mass (on average) of a partridge compared to a pheasant (BTO, 2013), creating an average emission factor for game birds of 0.017 kg NH_3-N bird^{-1} yr^{-1} (range 0.01 – 0.05 kg), a slight decrease from 0.02 kg NH_3-N bird^{-1} yr^{-1} for pheasants.

No new information was found on emission source strength for wild animals, wild geese or seabirds for 2014.

Other sources – cigarette smoking

The latest smoking statistics available for the UK are from the Opinions and Lifestyle Survey, Adult Smoking Habits in Great Britain 2013 (ONS 2014). The number of cigarettes smoked by adults increased slightly for men while women remained unchanged which resulted in slightly increased emissions per smoker of 16.6 g NH_3-N yr^{-1} (range 8.3 – 30.1 g) from 15.8 g NH_3-N yr^{-1}for 2013. The emission factor per cigarette smoked is unchanged from previous estimates, with no relevant new data found in the literature.

For smokers under 16 years old, new statistics (Fuller *et al.* 2015) show that the proportion of regular smokers remained at 3% and the proportion of occasional smokers dropped from 4% to 2%, while the number of cigarettes smoked by occasional smokers increased from 3.4 to 5 cigarettes per week (the number of cigarettes smoked by regular smokers stayed at 31.1 per week). Overall these changes result in a 28% increase in the average emission factor per young smoker (to 3.8 g NH_3-N yr^{-1}) due to there being fewer occasional smokers who smoke more cigarettes per week.

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 was updated in line with the emission factors for fertiliser application to agricultural grassland in the UK inventory for 2014 (Misselbrook *et al*., 2015). For parks and gardens, an average of all fertiliser types was used rather than just ammonium sulphate and di-ammonium phosphate, which slightly increased the emission factor from 2.22% to 2.24% in 2014. Similarly for golf courses, the average of all fertiliser types was used (instead of only ammonium nitrate), including the usage of some N-rich urea, and the best estimated emission factor for 2014 is 2.99%, a slight decrease from 3.02% in 2013. Finally, the average area of an 18-hole golf course, which increased slightly from 0.51 km^2 to 0.53 km^2 due to new information in 2013 (de Castella 2013), has been carried forward unchanged. Following these adjustments to the emission factors in the 2014 inventory, the new best estimate for parks and gardens is 0.68 kg NH_3-N ha^{-1} (range 0.23 – 1.35 kg), replacing the previous emission factor of 0.67 kg NH_3-N ha^{-1}. For golf courses, the best estimate emission factor is unchanged at 0.71 kg NH_3-N ha^{-1} (range 0.41 – 1.16 kg).

As a final note, detailed information regarding golf-course composition and fertiliser application practice was ascertained for the 2012 inventory (Bartlett and James, 2011; Kearns and Prior, 2013) and has remained for this years' inventory. In principle, golf courses do not receive a uniform rate of fertiliser application over the areas of green, tee, rough and fairway, and so these course composition studies allow more detailed estimates to be made.

3.3.2. New source data

Anaerobic digestion

The amounts of materials treated in UK AD plants are considerable, and this source has been growing rapidly. New NH_3 emission sources from anaerobic digestion were identified for the 2014 inventory, along with updates for existing sources (see list on p.19), and a comprehensive search for AD sites resulted in data found for a total of 265 plants operational during 2014 (see Reference List), a large increase from 149 in 2013. These plants were estimated to process 6,852 kt of materials (fresh weight) during 2014, an increase of approx. 31% on 2013. As per 2013, large volumes of materials (approx. 950 kt) were removed entirely from the non-farm based input stream after it was established they did not enter the AD process (vegetable washings in particular). It should also be noted that 1,205 kt of distillery wastes were not included in the emissions estimate for 2014 as they are likely to be processed in other ways; these distillery wastes have also been removed from the historic timeline for AD. For estimating fugitive and storage emissions, all processed materials were included in the calculations, whereas for estimating landspreading emissions for digestate, farm-based products (i.e., mainly manure/slurry) were excluded, to avoid double-counting with the agricultural inventory by Misselbrook *et al.* (2015).

By combining these data with the emission factors reported in Section 3.3.1, the estimate of UK NH_3 emissions from AD for 2014 was 1.13 kt NH_3-N yr^{-1} (range 0.8 – 1.46 kt) for fugitive and storage emissions at AD plants, and 2.94 kt NH_3-N yr^{-1} (range 2.08 – 3.8 kt) for landspreading of non-farm-based materials. The 31% increase in fugitive and storage emissions is due to the large increase of materials sent to AD processing plants, despite the removal of distillery wastes. Regarding emissions from landspreading of digestate, the slightly smaller 26 % increase (0.61 kt yr^{-1}) occurred due to an overall increase of non-manure based input materials to AD sites (at a smaller scale of growth compared to manure-based inputs).

This results in a total estimated emission of 4.07 kt NH_3-N (2.88 – 5.25 kt) from anaerobic digestion for 2014, compared with 3.19 kt NH_3-N in 2013, an increase of 0.88 kt NH_3-N.

Biomass burning (muirburn)

The area of biomass burnt annually in the UK through muirburn was updated for the 2014 inventory, based on a recent remote sensing study. Douglas *et al.* (2015) suggest that burning occurred across 8,551 1-km squares in the UK. Based on typical vegetation regeneration rates, they assume that burning in these squares took place within the last 25 years. The area detected as burnt is estimated to be 1,428 km^2 with, on average, 16.7 % of the area of each grid square burnt. The area burned varies from year to year, depending on weather conditions and burning frequency, and is estimated between 57 km^2 – 142 km^2 for an average burning frequency of 15 years (uncertainty range 10-20 years). Previous equivalent biomass burning estimates of between 205 – 411 km^2 yr^{-1} were based on data from the Moorland Working Group (2002) and Yallop *et al.* (2006). An average of these two estimates was used, giving an estimated 131 – 276 km^2 yr^{-1} (assuming a burning frequency of 10 – 20 years), giving an emission estimate of 0.19 kt NH_3-N (range 0.04 – 0.66 kt) for biomass burning.

It should be noted that these estimates are due to improved data rather than real changes over time, compared with any earlier estimates. It is recommended that this estimate is used as a constant for back-casting timelines, as there is insufficient evidence to show any change in the practice of muirburn and resulting NH_3 emissions.

Parks & gardens + golf courses

Emissions from parks, gardens and golf course were revised with the updated volatilisation rates described in Section 3.3.1 (above). There were no new data regarding the area or composition of parks and gardens or golf courses, and the current best estimates for parks (England: English Heritage (2013); Scotland: Historic Scotland (2013); Northern Ireland: DOENI (2013)) and golf courses (England: England Golf (2013); Wales: Welsh Golf Courses (2013); Northern Ireland: GUI (2013)) are carried over from 2013 to 2014. This resulted in a total emission of 0.19 kt NH_3-N yr^{-1} (range 0.06 – 0.39 kt) for parks and gardens and 0.09 kt NH_3-N yr^{-1} (range 0.05 – 0.15 kt) for golf courses. This resulted in a very small overall increase of approx. 0.4% from 2013 in the emissions from these sources combined.

Humans

The UK population figures were updated to the latest available data, the mid-2012 estimate of 64,596,800 (ONS 2015). This constitutes an increase of approx. 490,000 people or 0.8%, compared with 2013. The emission source populations were also updated for the number of infants in the two age groups considered for babies' nappy emissions (0-1 years, >1 – 3 years old), as well as for adult (over 16 years old) and young smokers (11-15 years old).

New data on adult cigarette smoking (ONS 2014) show that the proportion of male adults who smoke has increased from 21% to 22% while the proportion of female adults who smoke has decreased from 19% to 17% and the average number of cigarettes smoked per day has increased by one to 13 for men and remained at 11 for women. The increase in UK emissions from adult cigarette smoking (by ~3%) is due to the slight increase in the proportion of adult males who, in turn, smoke a slightly increased amount of cigarettes per week, combined with an overall increase in the UK population. Cigarette smoking emissions from young people decreased by 10% to 680 kg NH_3-N yr^{-1} for 2014, due to a reduction in population of 11 – 15 year olds, a reduction from 4% to 2% in occasional smokers in the age category and also a decrease in the number of cigarettes consumed by occasional smokers (Fuller *et al.*, 2015).

Emissions from other human sources (breath, sweat and babies' nappies) are estimated at 0.8 kt NH_3-N yr^{-1} for the UK in 2014, with a very small increase of ~6 t NH_3-N yr^{-1} from 2013, due to the overall increase in the UK population.

Pets

New survey data from the Pet Food Manufacturers Association (PFMA 2015) for 2014 show UK population estimates for cats has decreased by approx. 600,000 to 7.4 million while dogs have decreased by approx. 500,000 to 8.5 million from 2013 figures. With the same emission estimate per animal as used for previous inventory years, emissions for 2014 have dropped from 0.89 kt NH_3-N yr^{-1} to 0.82 kt NH_3-N yr^{-1} for cats (range 0.35 – 1.33 kt), and decreased from 5.75 kt NH_3-N yr^{-1} to 5.43 kt NH_3-N yr^{-1} for dogs (range 2.26 – 9.47 kt).

Seabirds

The population trends for 2000 to 2013 (JNCC 2014) used to update the 2013 inventory were carried forward for 2014 due to lack of new data. The population trends (as a % change) for each species were applied to previously existing population estimates and the emissions were scaled accordingly. The total population estimate for seabirds in the UK in 2014 is 6.05 million, a decrease from 6.67 million in 2012. Estimated emissions remain at 2.7 kt NH_3-N yr^{-1} (range 1.8 – 5.4 kt).

Horses

The UK population estimate for horses was updated for the 2014 inventory with new figures on all horses registered in the UK, with British Equestrian Trade Association's National Equestrian Survey 2015 (pers. comm.), updated from the 2013 population estimates. The current best population estimate is 987,780 equines (range 0.89 – 1.09 million), down from 1,023,615 in 2013. Numbers of horses kept by professionals (as a proxy for higher protein diets) are estimated at 87,980. Estimated emissions from horses for 2014 are 11.89 kt NH_3-N (range 6.3 – 22.41 kt), a decrease of 0.44 kt NH_3-N compared with 2013.

The non-professional horses were re-categorised as 'non-agricultural "normal" horses' (summarised from agricultural census/survey data from the UK Devolved Administrations) and 'agricultural "normal" horses', to differentiate between those on and not on agricultural holdings. The split is 596,424 equines on non-agricultural holdings (down from 639,177, perhaps due to economic downturn) and 303,376 equines kept by private owners elsewhere (an increase of 10,000 equines).

Wild animals

For the 2014 update, some new estimates of wild deer populations were made; previous population estimates for the 2010 inventory were updated using population growth estimations for five species of deer (Munro, 2002; POST Report 325, 2009). This resulted in a new total source estimate of 1,681,871 deer in the UK in 2014, an increase of 9% from the 2013 inventory. Overall the emissions estimate for 2014 was 1.55 kt NH_3-N (range 0.58 – 3.93 kt), an increase of 0.1 kt NH_3-N from 2013.

SCOS (2014) estimates grey seal population numbers of 111,600 (92,000-137,900) for 2014. This is a minor increase (0.3 %) on the previous population estimates from 2012, with an emission estimate of 49 t NH_3-N (0.3% increase).

The 2014 estimate of wild geese populations in the inventory was updated with the best estimates of various species types from different sources (Mitchell 2015; Musgrove *et al.* 2011; WWT 2015). Overall, approx. 173,000 geese are estimated to be resident in the UK all year round (no change from last year's estimate), with a further approx. 891,000 (previously 884,000) 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. Emissions from wild geese are estimated at 106 t NH_3-N (range 79 - 132 t) for 2014, compared with 105 t for 2013. While the total emissions from wild geese are relatively small, these are locally important sources in areas where geese congregate in large numbers, e.g., in western Scotland and on some Scottish islands (especially Islay).

In 2012, the pheasant category was broadened to 'game birds' to include the UK population of red-legged partridges. Population numbers in 2013 were 50.3 million for both species combined, of which 73% were pheasants (Bicknell et al., 2010; Defra, 2013). There is no updated information for populations in 2014, so the estimate of UK NH_3 emissions from game birds remains unchanged at 0.84 kt NH_3-N (0.23 – 2.79 kt).

Domestic Chickens

The new category of Domestic Chickens was introduced to the 2013 inventory to account for the growing popularity of 'backyard' poultry in the UK (The Ranger 2011). There is some difficulty estimating this unregulated source of poultry but secondary sources (PFMA 2014; The Ranger 2011), including the National Farmers Union chairman, estimate the population at 1 to 3 million. A best estimate of 2 million chickens was used for the 2013 inventory and remains unchanged in 2014. Estimated emissions remain as 0.49 kt NH_3-N yr^{-1} (range 0.25 – 0.74 kt) for 2014. It is currently not possible to develop a timeline for this new source.

3.4. 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 42.59 kt NH_3-N $year^{-1}$ for 2014, with a range of 20.09 – 82.43 kt NH_3-N $year^{-1}$.

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 2014 UK population.

SNAP code 9 (waste treatment and disposal)

Landfill emissions have decreased by 15% from the 2013 emission estimate (1.54 kt NH_3-N) to 1.31 kt NH_3-N in 2014, mainly due to the reduction of inputs to landfill and also a smaller amount of high-N content sewage sludge going into the landfill process.

Non-household composting emissions for 2014 are 9% higher than the 2013 estimate, at 5.2 kt NH_3-N, compared with 4.77 kt NH_3-N previously. This is due to an increase in the tonnage of materials sent to compost. Furthermore, household based composting is included in this report for the first time, constituting a total emissions estimate of 0.09 kt NH_3-N.

SNAP code 11.7.3 (forest and other vegetation fires)

Area burnt under muirburn schemes were updated for the 2014 inventory, resulting in a lower emissions estimate of 0.19 kt NH_3-N, compared with 0.29 kt NH_3-N previously.

SNAP code 11.7.2 (mammals)

The major change in NH_3 emissions from (domestic) mammals for 2014 was a decrease in emissions from dogs by 0.32 kt NH_3-N yr^{-1} to 5.43 kt NH_3-N yr^{-1}, due to new population estimates. Total emissions from equines reduced by 0.43 kt NH_3-N in 2014 to 11.89 NH_3-N, due to a reduction in population numbers. Non-professional horses were split into two categories as per Section 3.3.2., to provide full transparency of all horse categories.

SNAP code 11.7.3 (other animals)

The largest change in NH_3 emissions from other animals was wild deer, which increased from 1.45 kt NH_3-N yr^{-1} to 1.55 kt NH_3-N yr^{-1} , due to new population estimates, while emissions from all other wild animal groups have had only very small change or no changes at all (wild geese, seabirds, gamebirds, other major wild animals or wild seals).

Table 1: Ammonia emissions from UK non-agricultural sources for 2014

2014 (Ammonia as NH3-N)	**emission estimates source-1**				**number of sources**				**UK emissions 2014 (kt NH3-N yr-1)**		
source	**best estimat**	**low**	**high**	**units as NH3-N**	**best estimate**	**low**	**high**	**units**	**best estimat**	**low**	**high**
human breath	2.04	0.69	6.21	g person-1 yr-1	64,596,800	-	-	persons	0.13	0.04	0.40
human sweat	10.17	1.56	42.08	g person-1 yr-1	62,190,711	-	-	persons	0.63	0.10	2.62
infants emissions < 1yr	11.70	2.38	54.20	g infant-1 yr-1	778,365	-	-	children <1 yr	0.01	0.00	0.04
infants emissions 1-3 yrs	14.63	2.98	67.75	g infant-1 yr-1	1,627,724	-	-	children 1-3 yr	0.02	0.00	0.11
cigarette smoking (adults)	16.60	8.30	30.06	g smoker-1 yr-1	10,193,899	-	-	smokers	0.17	0.08	0.31
cigarette smoking (young people)	4.04	2.02	7.31	g smoker-1 yr-1	177,591	-	-	smokers	0.00	0.00	0.00
horses kept by professionals	27.26	12.37	53.48	kg animal-1 yr-1	87,980	79,182	96,778	animals	2.40	1.60	3.41
Non-agricultural 'normal' horses	10.55	2.32	45.68	kg animal-1 yr-1	596,424	536,782	656,066	animals	6.29	3.11	12.60
Agricultural 'normal' horses	10.55	2.32	45.68	kg animal-1 yr-1	303,376	273,038	333,714	animals	3.20	1.58	6.41
dogs	0.64	0.30	1.01	kg animal-1 yr-1	8,500,000	7,650,000	9,350,000	animals	5.43	2.26	9.47
cats	0.11	0.05	0.16	kg animal-1 yr-1	7,400,000	6,660,000	8,140,000	animals	0.82	0.35	1.33
domestic chickens	0.25			kg animal-1 yr-1	2,000,000	1,000,000	3,000,000	birds	0.49	0.25	0.74
wild deer (large)	1.45	0.73	2.90	kg animal-1 yr-1	656,836			animals	0.95	0.36	2.38
wild deer (small)	0.58	0.29	1.16	kg animal-1 yr-1	1,025,035			animals	0.59	0.22	1.55
other major wild animals (mammals inc. seals)	-	-	-	-	-	-	-	-	1.00	0.27	2.68
wild geese	-	-	-	kg bird-1 yr-1	1,063,660	-	-	birds	0.11	0.06	0.16
seabirds	-	-	-	-	6,054,450	-	-	birds	2.72	1.82	5.43
biomass burning (heather burning, "muirburn")	1.05	0.30	2.39	g m-2 yr-1	203,003,967	142,352,380	304,505,950	burnt area in m2	0.19	0.04	0.66
ecosystems	0.00	0.00	0.00	-	-	-	-	-	0.00	0.00	0.00
sewage works	-	-	-	-	-	-	-	-	1.20	0.70	4.90
sewage spreading	2.41	0.90	4.51	kg t-1 (dry solids) yr-1	1,332	1,332	1,332	kt total dry solids yr-1	3.21	1.20	6.01
landfill	0.14	0.12	0.15	kg t-1 landfilled	9,454,161	-	-	t landfilled (MSW + sludge)	1.31	1.18	1.44
appliances &household products	-	-	-	-	-	-	-	-	0.99	0.30	3.67
non-agricultural fertilizers (households)	-	-	-	-	-	-	-	-	0.23	0.08	0.48
composting	2.04	0.47	2.73	kg NH3-N t-1 dry matter	2,547,533			t of dry matter composted	5.20	1.19	6.96
household composting	0.45	0.23	0.68	kg NH3-N t-1 fresh weight	208,661			t of fresh matter compostec	0.09	0.05	0.14
game birds (pheasants and red-legged partridge)	0.02	0.01	0.05	kg bird-1 yr-1	50,287,533	45,258,780	55,316,286	birds	0.84	0.23	2.79
parks and gardens	0.68	0.23	1.35	kg ha-1 yr-1	285,997	278,383	285,997	hectares	0.19	0.06	0.39
golf courses	0.71	0.41	1.16	kg ha-1 yr-1	130,703			hectares	0.09	0.05	0.15
Anaerobic digestion (fugitive emissions + storage of digestate)	0.16	0.12	0.21	kg t-1 (fresh weight) yr-1	6,851,641	6,851,641	6,851,641	tonnes (fresh weight)	1.13	0.80	1.46
Anaerobic digestion (landspreading of non-agricultural materials only)	0.57	0.40	0.73	kg t-1 (fresh weight) yr-1	5,186,697	5,186,697	5,186,697	tonnes (fresh weight)	2.94	2.08	3.80
TOTAL	-	-	-	-	-	-	-	-	**42.59**	**20.09**	**82.43**

Note: The estimate of emissions from horses has been split into three categories for transparency and includes ALL horses, including horses counted in the agricultural census (and included with the agricultural emission sector in the inventory).

SNAP code 00 (other sources)

Anaerobic digestion

Emission sources from anaerobic digestion (AD), identified and included in the 2010 inventory estimates by Dragosits et al. (2012) for the first time, were re-calculated for 2014 with new data on AD sites becoming available. Land spreading emissions from digestate of non-manure origin were estimated at 2.9 kt NH_3-N yr^{-1} (range 2.1 – 3.8 kt), an increase of 0.6 kt due to increased non-farm based inputs. Fugitive and storage emissions at AD plants were estimated at 1.1 kt NH_3-N yr^{-1} (range 0.8 – 1.5 kt), a 31% increase from 2013, due to large increases in inputs to AD facilities. This results in a total estimated emission of 4.1 kt NH_3-N yr^{-1} (range 2.9 – 5.3 kt) from AD for 2014, compared with a total of 3.2 kt NH_3-N yr^{-1} in 2013.

Humans

Emissions from humans increased by very small amounts between 2013 and 2014, mainly due to the continuing increase in the UK population (by 480,000 persons or 0.7%), but also due to a small increase in the emissions from adult smokers.

Gardens, parks and golf courses

The best estimates for emissions from fertiliser application to parks and gardens are 0.2 kt NH_3-N yr^{-1}, and 0.1 kt NH_3-N yr^{-1} are estimated for golf courses. Overall, this constitutes a very small increase of 0.4% for these sources compared with 2013, due to updates to volatilisation rates for fertiliser application, using the best estimates from the agricultural inventory.

5. CONCLUSIONS

New UK estimates of non-agricultural NH_3 emissions were calculated and brought up to date to 2014 (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 42.6 kt NH_3-N $year^{-1}$ for 2014, with a range of 20.1 – 82.4 kt NH_3-N $year^{-1}$. This constitutes an increase of ~0.5 kt NH_3-N overall, compared with 2013 (42.1 kt NH_3-N). These changes are mainly due to increases in emissions from AD (by 0.9 kt NH_3-N) and non-household composting (by 0.4 kt NH_3-N), offset by decreases in emissions from horses (by 0.4 kt NH_3-N), dogs (by 0.3 kt NH_3-N) and landfill (by 0.2 kt NH_3-N) .

In summary, the main changes to the inventory are increases in NH_3 emissions from anaerobic digestion and composting processes and decreases in emissions from horses, dogs and landfill. Emissions from other sources not mentioned explicitly changed only by small amounts.

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