UK Centre for Ecology & Hydrology

AMMONIA IN A TIME OF COVID-19

A submission of evidence to Defra/AQEG.

Contributors C. F Braban,* Y.S. Tang, U Dragosits, M.M Twigg, Sarah Leeson, Matthew Jones, Ivan Simmons and Duncan Harvey M.A. Sutton, E. Nemitz, S. Reis (*chri2@ceh.ac.uk)
In collaboration with Ricardo EE (Defra/EA UKEAP Contract) & the University of Manchester (NERC SPF OSCA project)
Note All 2020 data shown are provisional and have not been fully ratified

Summary

- Ammonia gas (NH_3) is a priority pollutant both as a precursor to particulate matter and for ecosystem impacts
- Three scenarios for UK emission reductions during COVID-19 in emission sectors, where activity is likely reduced ,have been assessed
- Total UK emissions of NH_3 are likely to have decreased slightly (~2%), which is within the uncertainty and meteorological variability of the UK atmosphere
- Urban background and urban on road and roadside emissions of NH_3 are likely to have decreased, by as much as 30% and 90% respectively compared with usual emissions before COVID-19
- Unratified data from three of the five UK automatic NH_3 analysers (Auchencorth Moss, Chilbolton Observatory, and Manchester OSCA Observatory) show typical springtime NH_3 concentrations across the UK.
- Data from the non-automatic National Ammonia Monitoring Network will enable analysis at UK level in the months ahead. This includes roadside data from London Cromwell Rd.
- Evidence gaps & future approaches are outlined. Future analysis of the Defra UKEAP rural networks proposed.
- The key measurement gap is urban roadside NH_3 (and PM ammonium) as there is only one long-term site in the UK measuring roadside NH_3 concentrations. It is suggested that a roadside network of samplers and/or analysers are urgently put in place (perhaps aligned with the UK Urban NO_2 Network; UUNN) to monitor NH_3 at roadsides during and post COVID-19 lock down where possible.

Background

Atmospheric ammonia (NH_3) gas is gaining increasing importance in the global pollution climate, with effects at local to international (transboundary) scales (see Tang et al. 2018 for a detailed overview UK NH_3 science). NH_3 is emitted in gaseous form and has a short atmospheric lifetime on the order of hours to a few days. It is primarily emitted at ground level in the rural environment; however, sources of NH_3 in an urban environment include, but are not limited to, emissions from humans and their activities: pets, vehicle exhausts, industrial processes including fertiliser manufacture, cigarette smoking, sewage, fertiliser, compost, soils, wild animals, landfill sites, combustion and household products. There are also concerns that the ammonia emission potential of the fleet when Selective Catalytic Reduction (SCR) retro-fits will increase transport based NH_3 emissions. There is already evidence of increasing use of three-way catalysts in cars (Borsari & de Assunção 2017) and SCR systems (Stelwagen & Ligterink 2015) reduces the emissions of nitrogen oxides (NO_x), but increases emissions of NH_3. (Reche et al. 2012). There are also tentative suggestions use of ammonia as a fuel for transport (e.g. McInley et al., 2020) could further affect future emissions.

Estimated emissions changes during COVID-19 lockdown.

Using the National Atmospheric Emissions Inventory (NAEI) 2017 emissions (see Data Sources below), three NH_3 emission reduction scenarios have been simply estimated. The approach taken was to assess which sectors might be expected to have reduced emissions due to decrease human activity during the COVID-19 shutdown. This was done at the UK, urban and urban-roadside scale (Table 1). Details of the sector changes are provided in the Appendix, but are primarily transport and industry related. The three scenarios looked at were 30, 50 and 90% reductions in NH_3 emissions in the sectors affected (low medium and high reductions).

From this exercise, UK-wide emission were found to be only slightly reduced even in the 90% reduction scenario for the affected source sectors, with an overall emission reduction of 2.6%. This is primarily due to the dominance of

agricultural emissions in the UK NH_3 budget (estimated at 88% of national emissions, UK Clean Air Strategy 2019). When the set of emission sectors were narrowed to urban emissions, covering urban transport, domestic emissions etc. the low to high reduction scenarios resulted in a decrease of 10-30%. Focussing still further on urban roadside the NH_3 emission reductions were in the range 30-90% (see Appendix for sectors). It was assumed that smoking which might normally have been expected to occur by roads for some of the time was taken as being completely non-roadside due to the movement restrictions). This assessment is only a high-level estimate and a detailed emissions assessment would be appropriate.

Table 1 Estimated reduction of A: UK total NH_3 emissions, B: UK urban NH_3, and C: "on-road" NH_3 emissions under a low, medium and high ammonia emission reduction scenarios

UK 2017 NH_3 all emissions	294.3 ktonnes	Low reduction (30%)	Medium reduction (50%)	High reduction (90%)
Amount in sectors likely to reduce in ktonnes (% total)	8.57 (2.9%)	6.65	4.09	0.82
Amount in UK urban sectors likely to be reduced (ktonnes)		2.26	1.39	0.28
Relative reduction of total UK NH_3		0.65%	1.52%	2.63%
UK 2017 NH_3 "urban" emission	6.5 ktonnes	Low reduction	Medium reduction	High reduction
Amount in UK urban sectors likely to be reduced (ktonnes)		5.86	5.40	4.49
Relative reduction of UK urban NH_3		10.4%	17.4%	31.2%
UK 2017 NH_3 "urban roadside" emission	2.0 ktonnes	Low reduction	Medium reduction	High reduction
Amount in UK urban road transport sectors reduced (ktonnes)		1.40	1.00	0.20
Relative reduction of UK urban ***on-road*** NH_3		30.0%	50.0%	90.0%

Possible impact on UK NH_3 concentrations

Data from the two rural air quality supersites (Figure 1A) show that rural NH_3 concentrations are typical of Spring levels observed in previous years (as shown for Auchencorth Moss in Figure 1B), which is consistent with the estimate above that the COVID-lockdown will have minimal impact on NH_3 emissions nationally. The 72 sites in the UK National Ammonia Monitoring Network provide monthly average NH_3 concentrations. These will be able to provide the national picture once samplers are analysed (estimated data availability Sept 2020, depending on laboratory re-opening).

There are three urban background sites measuring NH_3 within the NERC SPF Clean Air OSCA project, Honor Road Park, Birmingham and Manchester. The NH_3 data from the Manchester site is also shown in Figure 1A with Auchencorth Moss and Chilbolton data for March and April 2020. Indicatively the concentration variation falls between the agriculturally influenced Chilbolton site and the background site at Auchencorth Moss (the three sites lie very approximately on a north-south transect). Once the data have been ratified from all five UK automatic NH_3 sites, coupled with wind direction and windspeed data, an assessment may give insight into the relative importance of local urban NH_3 and transported rural air masses. This may enable the relative importance of the urban NH_3 emission reductions on background urban concentrations during the COVID-19 shutdown to be assessed.

The UK currently has a long-term urban NH_3 monitoring site at London Cromwell Road. The site is part of the UK Eutrophying and Acidifying Atmospheric Pollutant networks, within the National Ammonia Monitoring Network. Figure 1D shows the data from the past twenty years (1999-2019). The annual mean concentration is 3.08±0.64 $\mu g.m^{-3}$ with peak concentrations occurring in spring and summer. The London Cromwell Road monitoring station is located in the southwest corner of the front gardens of the Natural History Museum at a traffic light controlled crossroads. The nearest road, the A4 Cromwell Road, is approximately 4 m from the monitoring station. The traffic flow on Cromwell Road is normally approximately 53,000 vehicles per day (information taken from UK-Air site April 2020). The surrounding area is generally open but there are trees occur within 2 metres distance of the monitoring station. Data will not be available for the COVID-19 shutdown period until September 2020 (depending on the COVID-19 regulations). Data from this site, being a highly traffic-emission dominated NH_3 site, will be a good test of the emission reduction estimate. If the estimation is accurate, then the NH_3 concentration may be as low as ~0.3 $\mu g.m^{-3}$. However,

as above, it is noted, there are significant uncertainties associated with this estimate. Historical data from previous research campaigns are shown in Figure 1C. Concentrations at Cromwell Road fall between those at Marylebone Road and those at the urban background site at North Kensington. Data from the BT Tower show the much lower concentrations observed at altitude compared to ground-level measurements.

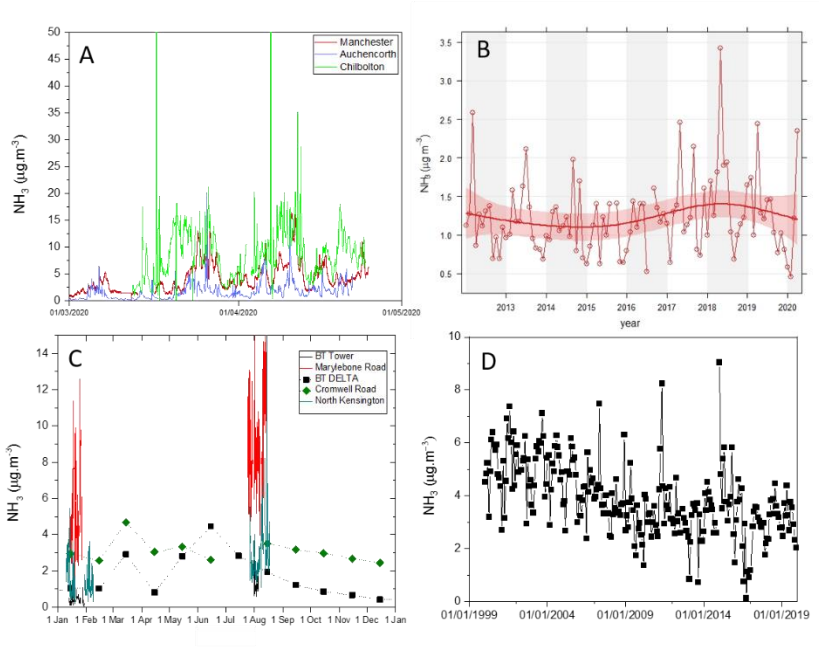

Figure 1 A: NH_3 concentrations over March and April 2020 for Chilbolton, Auchencorth Moss and Manchester OSCA Observatory (note all data provisional and unratified), B: Trend in ammonia concentration at Auchencorth Moss 2012-2020; C: 2012 NER Clearflo (BT Tower, Marylebone Road and N Kensington) and UKEAP NAMN London Cromwell Rd NH_3 data; D Defra/EA National Ammonia Monitoring Network site London Cromwell Road 1999-2019 monthly passive (ALPHA© sampler) data

During COVID-19, ammonia concentrations are likely to be reduced at the roadside, but in general, only small reductions in NH_3 concentrations would be observed at urban background sites given the relatively small magnitude of the transport sector NH_3 emissions. This is indicatively evidenced by the Manchester data (Figure 1A).

Implications of urban NH_3 concentration reductions

The impact of reducing urban on-road ammonia emissions (at the same time as reducing all other vehicular emissions) is largely unknown. NH_3 gas partitions into aerosol and water droplets in the form of ammonium, as well as being transported away through the atmosphere and dry deposition on surfaces. Ammonium is a major component of UK $PM_{2.5}$. A major reduction in roadside NH_3 is likely to have the largest impact locally due to the small magnitude of on-road NH_3 emissions compared to the total ammonia emission budget. However, although urban NH_3 emissions are small, they are spatially collocated with high NO_x emissions and are therefore, on a per mass basis, more efficient in acting as $PM_{2.5}$ precursors than emissions in the rural environment. The introduction of more SCR systems to remove NO_x emissions is predicted to increase the on-road NH_3 emissions. Therefore understanding this local atmospheric chemistry and the impacts of the changing chemical climate is a priority.

There is likely a direct interaction with PM within metres of the roadside as well as significant dispersion. Ammonium in particles have also been linked with processing of organic chemicals and therefore any significant reduction in ammonium may change the chemical properties of the PM (Montoya-Aguilera et al. 2018, Strangl et al., 2017; Huang et al. 2018). However it is noted that PM chemical processing of ammonium with respect to organic compounds is a less well studied area of atmospheric chemistry.

Key action for evidence

Given the absence of NH_3 and NH_4 measurement at roadside locations in the UK, unless a short term investment in installing monitoring locations, little evidence will be available to assess the changes of urban ammonia with the reduction of human activity and transport (and hence better quantify the on-road emissions when traffic returns to the roads).

There is an opportunity, if acted upon immediately to gain a baseline of urban NH_3 in the UK, prior to the hypothesised increase in emissions from transport.

> ***A**: The National Ammonia Monitoring Network and the UUNN networks could potentially co-locate to gather NO_2 and NH_3 in roadside locations for spatial NH_3 concentration data*
> ***B**: roadside automatic instruments deployed for high temporal resolution data.*
> ***C:** Simultaneous gaseous NH_3 and aerosol NH_4^+ measurements to understand ammonium nitrate formation*

Key questions to address and investigate once data are available

- Further assessment of the differences in emission of UK urban and rural NH_3 and its partitioning into PM
- Assessment of whether London Cromwell Road site could be upgraded to an automatic site given the data record from 1999 to present and its unique NH_3 measurement dataset
- ***Analyse of the Acid Gas and Aerosol Network gas phase (SO_2, HNO_3) and PM inorganic composition data*** to assess the UK national distributions and changes in atmospheric composition. (27 sites across UK).
- Use of the UKEAP supersite and rural network data to ***verifying modelled speciation of reduced and oxidised nitrogen*** and assess changes to nitrogen deposition from NH_3, PM and precipitation (UKEAP data).
- **Use of the 2020 evidence and current models to drive a step change in understanding the formation of ammonium nitrate** in urban areas and the role of transport compared to other emission sectors.
- It is uncertain whether the reduction in urban ammonia will have positive impacts for nature and human health. There is a modelling and literature knowledge gap which might usefully be undertaken to understand benefits (and hence inform future air quality scenario assessment within the Clean Air Strategy).
- Analysis of urban NH_3 reduction co-benefits for waste management, nature and human health

References

Borsari V and de Assunção, J.V. Ammonia emissions from a light-duty vehicle, Transportation Research Part D: Transport and Environment, 51, 53-61, doi.org/10.1016/j.trd.2016.12.008, 2017.

Huang, M. et al.. "Chemical analysis of particulate products of aged 1, 3, 5-trimethylbenzene secondary organic aerosol in the presence of ammonia." *Atmospheric Pollution Research* 9, no. 1 (2018): 146-155.

McKinlay, C.J.,et al. 2020. A Comparison of hydrogen and ammonia for future long distance shipping fuels, LNG/LPG and Alternative Fuel Ships, Royal Institute of Naval Architects, United Kingdom. 29 - 30 Jan 2020. 13 pp

Montoya-Aguilera, J., et al. "Reactive Uptake of ammonia by Biogenic and Anthropogenic Organic Aerosols." In *Multiphase Environmental Chemistry in the Atmosphere*, pp. 127-147. American Chemical Society, 2018.

NAEI 2017, https://naei.beis.gov.uk/data/data-selector-results?q=132473, downloaded 27/04/2020

Reche et al. 2012. Atmos. Environ. 57, 153-164

Stelwagen U. & Ligterink N.E. NH3 emission factors for road transport. TNO report 2015 R11005, 45pp. 2015.

Stangl, C. M., and M. V. Johnston. "Aqueous reaction of dicarbonyls with NH_3 as a potential source of organic nitrogen in airborne nanoparticles." *The Journal of Physical Chemistry A* 121, no. 19 (2017): 3720-3727.

Tang, Y. S. et al. 2018. "Drivers for Spatial, Temporal and Long-Term Trends in Atmospheric NH3and Ammonium in the UK." *Atmospheric Chemistry and Physics* 18 (2): 705–733. https://doi.org/10.5194/acp-18-705-2018.

Datasets***:***

Monitor for AeRosols and Reactive Gases (MARGA) at Auchencorth: Twigg, M. M. Leeson, S. R. Jones, M. R. Simmons, I. Harvey, D. Braban, C. F. UK Centre for Ecology & Hydrology (UKCECH), Edinburgh, UK, https://uk-air.defra.gov.uk/networks/network-info?view=ukeap

Monitor for AeRosols and Reactive Gases (MARGA) at Chilbolton: Sanocka, A., Dernie, J. Ritchie, S., Conolly, C., Ricardo, Harwell, UK. https://uk-air.defra.gov.uk/networks/network-info?view=ukeap

LGR ammonia analyser, NERC Integrated Research Observation System for Clean Air (OSCA), N. Marsden, H. Coe, Pers. Comm. April 2020

UK-Air 2017-2019, https://uk-air.defra.gov.uk/data/, National Ammonia Monitoring Network, London Cromwell Road Open Government Licence v3.0, downloaded 27/04/2020

NAEI 2017, https://naei.beis.gov.uk/data/data-selector-results?q=132473, downloaded 27/04/2020

Appendix

A Summary of NH_3 emission sectors which may be expected to reduced during the COVID-19 lockdown with a high, medium and low reduction scenario

NFR/CRF Group	Source	Activity	Activity	2017 emission (ktonne)	COVID reduction possible?	Why	Low reduction (30%) (ktonne)	Low reduction (50%) (ktonne)	High reduction (90%) (ktonne)
1A1a	Miscellaneous industrial/commercial combustion	MSW	MSW	0.01023504	Y	Non-essential Businesses closed	0.00716453	0.00511752	0.0010235
1A2f	Cement - non-decarbonising	Clinker production	Clinker production	0.38038336	Y	Building work stopped	0.26626835	0.19019168	0.03803834
1A2gvii	Industrial off-road mobile machinery	DERV	DERV	0.00261058	Y	Non-essential Businesses closed	0.00182741	0.00130529	0.00026106
1A2gvii	Industrial off-road mobile machinery	Gas oil	Gas oil	0.01221137	Y	Non-essential Businesses closed	0.00854796	0.00610569	0.00122114
1A2gvii	Industrial off-road mobile machinery	Petrol	Petrol	0.00083819	Y	Non-essential Businesses closed	0.00058674	0.0004191	8.3819E-05
1A2gviii	Other industrial combustion	Biomass	Biomass	2.24963059	Y	Non-essential Businesses closed	1.57474142	1.1248153	0.22496306
1A3bi	Road transport - cars - rural driving	Petrol	Petrol	1.48370697	Y	Reduced travel	1.03859488	0.74185348	0.1483707
1A3bi	Road transport - cars - rural driving	DERV	DERV	0.33069308	Y	Reduced travel	0.23148516	0.16534654	0.03306931
1A3bi	Road transport - cars - urban driving	Petrol	Petrol	0.2651019	Y	Reduced travel	0.18557133	0.13255095	0.02651019
1A3bi	Road transport - cars - urban driving	DERV	DERV	0.15904565	Y	Reduced travel	0.11133196	0.07952283	0.01590457
1A3bi	Road transport - cars - motorway driving	Petrol	Petrol	1.18518976	Y	Reduced travel	0.82963283	0.59259488	0.11851898
1A3bi	Road transport - cars - motorway driving	DERV	DERV	0.16382688	Y	Reduced travel	0.11467882	0.08191344	0.01638269
1A3bi	Road transport - cars - cold start	Petrol	Petrol	0.31381645	Y	Reduced travel	0.21967151	0.15690822	0.03138164
1A3bi	Road transport - cars - cold start	DERV	DERV	0.07665138	Y	Reduced travel	0.05365597	0.03832569	0.00766514
1A3bii	Road transport - LGVs - rural driving	Petrol	Petrol	0.02556061	Y	Reduced travel	0.01789243	0.01278031	0.00255606
1A3bii	Road transport - LGVs - rural driving	DERV	DERV	0.10847675	Y	Reduced travel	0.07593372	0.05423837	0.01084767
1A3bii	Road transport - LGVs - urban driving	Petrol	Petrol	0.00461532	Y	Reduced travel	0.00323072	0.00230766	0.00046153
1A3bii	Road transport - LGVs - urban driving	DERV	DERV	0.05170443	Y	Reduced travel	0.0361931	0.02585221	0.00517044
1A3bii	Road transport - LGVs - motorway driving	Petrol	Petrol	0.02207364	Y	Reduced travel	0.01545155	0.01103682	0.00220736
1A3bii	Road transport - LGVs - motorway driving	DERV	DERV	0.04708146	Y	Reduced travel	0.03295702	0.02354073	0.00470815
1A3bii	Road transport - LGVs - cold start	Petrol	Petrol	0.00359981	Y	Reduced travel	0.00251987	0.0017999	0.00035998
1A3bii	Road transport - LGVs - cold start	DERV	DERV	0.02522601	Y	Reduced travel	0.01765821	0.01261301	0.0025226
1A3biii	Road transport - buses and coaches - rural driving	DERV	DERV	0.00384734	Y	Reduced travel	0.00269314	0.00192367	0.00038473
1A3biii	Road transport - HGV articulated - rural driving	DERV	DERV	0.05176142	Y	Reduced travel	0.03623299	0.02588071	0.00517614
1A3biii	Road transport - HGV rigid - rural driving	DERV	DERV	0.05433467	Y	Reduced travel	0.03803427	0.02716733	0.00543347
1A3biii	Road transport - buses and coaches - urban driving	DERV	DERV	0.0070264	Y	Reduced travel	0.00491848	0.0035132	0.00070264
1A3biii	Road transport - HGV articulated - urban driving	DERV	DERV	0.00850976	Y	Reduced travel	0.00595683	0.00425488	0.00085098
1A3biii	Road transport - HGV rigid - urban driving	DERV	DERV	0.02238787	Y	Reduced travel	0.01567151	0.01119393	0.00223879
1A3biii	Road transport - buses and coaches - motorway driving	DERV	DERV	0.00105715	Y	Reduced travel	0.00074	0.00052857	0.00010571
1A3biii	Road transport - HGV articulated - motorway driving	DERV	DERV	0.07994018	Y	Reduced travel	0.05595812	0.03997009	0.00799402
1A3biii	Road transport - HGV rigid - motorway driving	DERV	DERV	0.03425915	Y	Reduced travel	0.02398141	0.01712958	0.00342592
1A3biv	Road transport - motorcycle (>50cc 2st) - rural driving	Petrol	Petrol	0	Y	Reduced travel	0	0	0
1A3biv	Road transport - motorcycle (>50cc 4st) - rural driving	Petrol	Petrol	0.00376958	Y	Reduced travel	0.00263871	0.00188479	0.00037696
1A3biv	Road transport - mopeds (<50cc 2st) - urban driving	Petrol	Petrol	0.0001393	Y	Reduced travel	9.7508E-05	6.9649E-05	1.393E-05
1A3biv	Road transport - motorcycle (>50cc 2st) - urban driving	Petrol	Petrol	0.0001071	Y	Reduced travel	7.4969E-05	5.3549E-05	1.071E-05
1A3biv	Road transport - motorcycle (>50cc 4st) - urban driving	Petrol	Petrol	0.00422388	Y	Reduced travel	0.00295672	0.00211194	0.00042239
1A3biv	Road transport - motorcycle (>50cc 4st) - motorway driving	Petrol	Petrol	0.00072605	Y	Reduced travel	0.00050823	0.00036302	7.2605E-05
1A3c	Railways - intercity	Gas oil	Gas oil	0.00205897	Y	Reduced travel	0.00144128	0.00102949	0.0002059
1A3c	Railways - regional	Gas oil	Gas oil	0.00233646	Y	Reduced travel	0.00163552	0.00116823	0.00023365
1A3c	Railways - freight	Gas oil	Gas oil	0.00168318	Y	Reduced travel	0.00117823	0.00084159	0.00016832

1A3c	Rail - coal	Coal	Coal	0.0021	Y	Reduced travel	0.00147	0.00105	0.00021
1A3dii	Shipping - coastal	Fuel oil	Fuel oil	0.00166216	Y	Reduced travel	0.00116351	0.00083108	0.00016622
1A3dii	Shipping - coastal	Gas oil	Gas oil	0.01207051	Y	Reduced travel	0.00844936	0.00603525	0.00120705
1A3dii	Sailing boats with auxiliary engines	DERV	DERV	1.69E-05	Y	Reduced travel	1.1833E-05	8.4524E-06	1.6905E-06
1A3dii	Sailing boats with auxiliary engines	Gas oil	Gas oil	0	Y	Reduced travel	0	0	0
1A3dii	Sailing boats with auxiliary engines	Petrol	Petrol	0	Y	Reduced travel	0	0	0
1A3dii	Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	DERV	DERV	0.00078679	Y	Reduced travel	0.00055075	0.00039339	7.8679E-05
1A3dii	Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	Gas oil	Gas oil	0.00031994	Y	Reduced travel	0.00022396	0.00015997	3.1994E-05
1A3dii	Motorboats / workboats (e.g. canal boats, dredgers, service boats, tourist boats, river boats)	Petrol	Petrol	0.00034049	Y	Reduced travel	0.00023835	0.00017025	3.4049E-05
1A3dii	Personal watercraft e.g. jet ski	DERV	DERV	0	Y	Reduced travel	0	0	0
1A3dii	Personal watercraft e.g. jet ski	Gas oil	Gas oil	0	Y	Reduced travel	0	0	0
1A3dii	Personal watercraft e.g. jet ski	Petrol	Petrol	0.00013644	Y	Reduced travel	9.551E-05	6.8221E-05	1.3644E-05
1A3dii	Inland goods-carrying vessels	DERV	DERV	0	Y	Reduced travel	0	0	0
1A3dii	Inland goods-carrying vessels	Gas oil	Gas oil	1.51E-05	Y	Reduced travel	1.0586E-05	7.5613E-06	1.5123E-06
1A3dii	Inland goods-carrying vessels	Petrol	Petrol	0	Y	Reduced travel	0	0	0
1A3dii	Shipping between UK and Gibraltar	Fuel oil	Fuel oil	0.00015182	Y	Reduced travel	0.00010628	7.5912E-05	1.5182E-05
1A3dii	Shipping between UK and OTs (excl. Gib and Bermuda)	Fuel oil	Fuel oil	4.67E-05	Y	Reduced travel	3.2676E-05	2.334E-05	4.6679E-06
1A3dii	Shipping between UK and Bermuda	Fuel oil	Fuel oil	4.53E-06	Y	Reduced travel	3.1703E-06	2.2645E-06	4.5289E-07
1A3dii	Shipping between UK and CDs	Fuel oil	Fuel oil	2.54E-06	Y	Reduced travel	1.7785E-06	1.2703E-06	2.5407E-07
1A3dii	Shipping between UK and CDs	Gas oil	Gas oil	6.48E-05	Y	Reduced travel	4.5386E-05	3.2418E-05	6.4837E-06
1A3eii	Aircraft - support vehicles	Gas oil	Gas oil	0.00141825	Y	Reduced travel	0.00099277	0.00070912	0.00014182
2H1	Paper production	Process emission	Process emission	0.005	Y	Reduced travel	0.0035	0.0025	0.0005
z_11C	Adult breath and sweat	Population	Population	0.95152789	Y	Reduced outdoor activity	0.66606952	0.47576394	0.09515279
	TOTALs			8.57345008			6.64967824	4.09231119	0.81846224
	Fraction of UK annual emission								

B Summary of NH_3 urban emission sectors which may be expected to reduced during the COVID-19 lockdown with a high, medium and low reduction scenario

NFR/CRF Group	Source	Activity	Units	2017 emission (ktonne)	COVID reduction possible?	Why	Low reduction (30%) (ktonne)	Low reduction (50%) (ktonne)	High reduction (90%) (ktonne)
1A2f	Cement - non-decarbonising	Clinker production	kilotonne	0.38038336	Y	Building work stopped	0.26627	0.19019	0.03804
1A3bi	Road transport - cars - urban driving	Petrol	kilotonne	0.265101903	Y	Reduced travel	0.18557	0.13255	0.02651
1A3bi	Road transport - cars - urban driving	DERV	kilotonne	0.159045654	Y	Reduced travel	0.11133	0.07952	0.01590
1A3bi	Road transport - cars - cold start	Petrol	kilotonne	0.313816449	Y	Reduced travel	0.21967	0.15691	0.03138
1A3bi	Road transport - cars - cold start	DERV	kilotonne	0.07665138	Y	Reduced travel	0.05366	0.03833	0.00767
1A3bii	Road transport - LGVs - urban driving	DERV	kilotonne	0.051704427	Y	Reduced travel	0.03619	0.02585	0.00517
1A3bii	Road transport - LGVs - cold start	Petrol	kilotonne	0.00359981	Y	Reduced travel	0.00252	0.00180	0.00036
1A3bii	Road transport - LGVs - cold start	DERV	kilotonne	0.025226013	Y	Reduced travel	0.01766	0.01261	0.00252
1A3biii	Road transport - buses and coaches - urban driving	DERV	kilotonne	0.007026405	Y	Reduced travel	0.00492	0.00351	0.00070
1A3biii	Road transport - HGV articulated - urban driving	DERV	kilotonne	0.008509759	Y	Reduced travel	0.00596	0.00425	0.00085
1A3biii	Road transport - HGV rigid - urban driving	DERV	kilotonne	0.022387869	Y	Reduced travel	0.01567	0.01119	0.00224
1A3biv	Road transport - mopeds (<50cc 2st) - urban driving	Petrol	kilotonne	0.000139297	Y	Reduced travel	0.00010	0.00007	0.00001
1A3biv	Road transport - motorcycle (>50cc 2st) - urban driving	Petrol	kilotonne	0.000107098	Y	Reduced travel	0.00007	0.00005	0.00001
1A3biv	Road transport - motorcycle (>50cc 4st) - urban driving	Petrol	kilotonne	0.004223885	Y	Reduced travel	0.00296	0.00211	0.00042
1A4bi	Domestic combustion	Anthracite	kilotonne	0.005265088	N	NO REDUCTION	0.00527	0.00527	0.00527
1A4bi	Domestic combustion	Coal	kilotonne	0.007833286	N	NO REDUCTION	0.00783	0.00783	0.00783
1A4bi	Domestic combustion	Coke	kilotonne	0	N	NO REDUCTION	0.00000	0.00000	0.00000
1A4bi	Domestic combustion	Wood	kilotonne	2.256142175	N	NO REDUCTION	2.25614	2.25614	2.25614
1A4bii	House and garden machinery	DERV	kilotonne	8.63E-05	N	NO REDUCTION	0.00009	0.00009	0.00009
1A4bii	House and garden machinery	Petrol	kilotonne	0.000440591	N	NO REDUCTION	0.00044	0.00044	0.00044
2D3a	Non-aerosol products - household products	Non-fuel domestic	kilotonne	1.208218406	N	NO REDUCTION	1.20822	1.20822	1.20822
2G	Cigarette smoking	Cigarettes	kilotonne	0.114809318	N	NO REDUCTION	0.11481	0.11481	0.11481
6A	House and garden machinery	Domestic fertilizer	kilotonne	0.277767857	N	NO REDUCTION	0.27777	0.27777	0.27777
6A	Infant emissions from nappies	Population 0to4yrs	kilotonne	0.038910743	N	NO REDUCTION	0.03891	0.03891	0.03891
6A	Parks, Gardens & Golf courses	Non-fuel combustion	kilotonne	0.358559535	N	NO REDUCTION	0.35856	0.35856	0.35856
z_11C	Adult breath and sweat	Population	kilotonne	0.951527889	Y	Reduced time outside	0.66607	0.47576	0.09515

C Summary of NH_3 urban on-road emission sectors which may be expected to reduced during the COVID-19 lockdown with a high, medium and low reduction scenario

NFR/CRF Group	Source	Activity	Units	2017 emission (ktonne)	COVID reduction possible?	Why	Low reduction (30%) (ktonne)	Low reduction (50%) (ktonne)	High reduction (90%) (ktonne)
1A3bi	Road transport - cars - urban driving	Petrol	kilotonne	0.265101903	Y	Reduced travel	0.18557	0.13255	0.02651
1A3bi	Road transport - cars - urban driving	DERV	kilotonne	0.159045654	Y	Reduced travel	0.11133	0.07952	0.01590
1A3bi	Road transport - cars - cold start	Petrol	kilotonne	0.313816449	Y	Reduced travel	0.21967	0.15691	0.03138
1A3bi	Road transport - cars - cold start	DERV	kilotonne	0.07665138	Y	Reduced travel	0.05366	0.03833	0.00767
1A3bii	Road transport - LGVs - urban driving	DERV	kilotonne	0.051704427	Y	Reduced travel	0.03619	0.02585	0.00517
1A3bii	Road transport - LGVs - cold start	Petrol	kilotonne	0.00359981	Y	Reduced travel	0.00252	0.00180	0.00036
1A3bii	Road transport - LGVs - cold start	DERV	kilotonne	0.025226013	Y	Reduced travel	0.01766	0.01261	0.00252
1A3biii	Road transport - buses and coaches - urban driving	DERV	kilotonne	0.007026405	Y	Reduced travel	0.00492	0.00351	0.00070
1A3biii	Road transport - HGV articulated - urban driving	DERV	kilotonne	0.008509759	Y	Reduced travel	0.00596	0.00425	0.00085
1A3biii	Road transport - HGV rigid - urban driving	DERV	kilotonne	0.022387869	Y	Reduced travel	0.01567	0.01119	0.00224
1A3biv	Road transport - mopeds (<50cc 2st) - urban driving	Petrol	kilotonne	0.000139297	Y	Reduced travel	0.00010	0.00007	0.00001
1A3biv	Road transport - motorcycle (>50cc 2st) - urban driving	Petrol	kilotonne	0.000107098	Y	Reduced travel	0.00007	0.00005	0.00001
1A3biv	Road transport - motorcycle (>50cc 4st) - urban driving	Petrol	kilotonne	0.004223885	Y	Reduced travel	0.00296	0.00211	0.00042
2G	Cigarette smoking	Cigarettes	kilotonne	0.114809318	N	NO REDUCTION (assume displaced)	0.11481	0.11481	0.11481
z_11C	Adult breath and sweat	Population	kilotonne	0.951527889	Y	Reduced time outside	0.66607	0.47576	0.09515