Atmospheric ammonia, acid gas and aerosol monitoring in Northern Ireland

Year 1: March 2019 – February 2020

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1 Summary

ALPHA® and DELTA® network

- A new network of **25 ammonia** (NH_3) monitoring sites implementing the UKCEH ALPHA® method (**ALPHA® network**) and **4 reactive gases and aerosols** monitoring sites implementing the UKCEH DELTA® method (**DELTA® network**) was established in spring 2019 across Northern Ireland.
- The ALPHA® sites were selected to provide representative coverage of i) the range of modelled concentrations from FRAME (using the most recent 5 km NH_3 emissions data for 2016), (ii) each of seven major dominant emission source classifications: cattle (beef and dairy), pigs & poultry, sheep, mixed, non-agricultural, fertiliser and background (very low emission density, < 1 kg N ha^{-1} yr^{-1}), and (iii) spatial coverage across Northern Ireland.
- The aims of the measurements are to (i) explore spatial and temporal patterns in NH_3 concentrations, (ii) compare results with the FRAME atmospheric transport model and for verification of UK NAEI emissions inventory and FRAME model, (iii) monitor and assess relationship between NH_3 and interacting gases (HNO_3, SO_2) and inorganic particulate phase composition.
- Measurement data over the same period from existing UK long-term national network sites (Coleraine, Hillsborough, Lough Navar), and from the Ballynahone Bog project in Northern Ireland are also included in the report, to complement the network data.
- All measurements are made through monthly time-integrated sampling, which is cost-efficient for providing annual means while permitting detection of seasonal trends in the data.
- The first measurements in the ALPHA® and DELTA® networks started in early March 2019. The first full year of ratified monthly ALPHA® and DELTA® data for the period March 2019 – February 2020 are presented in this report.

Calibration of ALPHA® NH_3 data

- An annual field calibrated ALPHA® uptake rate is derived for each calendar year from the regression of passive ALPHA® versus active DELTA® measurements at nine inter-comparison sites in the UK National Ammonia Monitoring Network. The calibration is usually carried out in April each year, based on a full year of data from the preceding year. The updated uptake rate is then applied retrospectively to ALPHA® data for the year of calibration. Calibrated uptake rates derived from the UK national network are applied to the Northern Ireland ALPHA® network data. These were **0.0031665 m^3 h^{-1}** and **0.0031277 m^3 h^{-1},** for **2019** and **2020**, respectively**.**
- At AFBI25 Hillsborough, ALPHA® and DELTA® measurement are co-located with parallel measurements.

- At AFBI26 Ballynahone, DELTA® measurements are co-located with existing ALPHA® measurements (site UWT3) made as part of the Ballynahone Bog Ammonia project.
- The two inter-comparison sites in Northern Ireland allow a check on the use of the uptake rates derived from UK sites (none located in Northern Ireland) for ALPHA® measurements made in Northern Ireland.

Site review and changes

- Four sites were reviewed in September 2019 to check that they conform to the site selection criteria and to decide whether these sites may need to be relocated to more representative locations. The reviewed sites were AFBI06 Drumclamph parish church, AFBI12 Ratarnet Rd, AFBI20 Caddy Rd and AFBI23 Creggan.
- At AFBI06 Drumclamph, NH_3 concentrations were substantially higher than modelled values (mean 13.7 µg NH_3 m^{-3} (Mar - Aug19) *cf.* FRAME 3.3 µg NH_3 m^{-3}). On investigation, large buildings located approx. 200 m west of the site were discovered to be animal housing. The monitoring site therefore did not conform to siting criteria. Measurement at this site stopped at the end of August 2019 and it was relocated to a new location, AFBI29 Drumclamph 2.

First year of ammonia data from both ALPHA® and DELTA® networks

- Overall, the first year of data is already showing informative differences in concentrations between months and differences in the magnitude of concentrations between sites from different types of source areas.
- Site annual mean concentrations (Mar19 – Feb20) of gaseous NH_3 are in the range 0.5 (AFBI03 Beaghs Burn) – 7.5 µg m^{-3} (AFBI25 Hillsborough) (AFBI06 Drumclamph data are excluded from annual analysis). The high spatial heterogeneity in concentrations across NI demonstrates that a large number of sites is necessary to fully capture the variability.
- A comparison of year 1 annual mean NH_3 concentrations (Mar19 – Feb20) with the modelled surface concentrations from the FRAME model (for emission year 2016) show broad agreement between the two, regarding both magnitude and spatial variability.
- Differences between measured and modelled concentrations reflects the large local variability in NH_3 concentrations and the comparison of a point measurement with a model grid square average (e.g. due to nearness of monitoring point to sources at a local scale), or to uncertainties in the emissions estimates for different source sectors within the grid square.
- Seasonal pattern observed at the different sites show that NH_3 concentrations are related to emission source categories present locally (e.g. sites grouped according to dominant emission source sectors for the grid square) and by changes in environmental conditions, with smallest concentrations in the winter months.

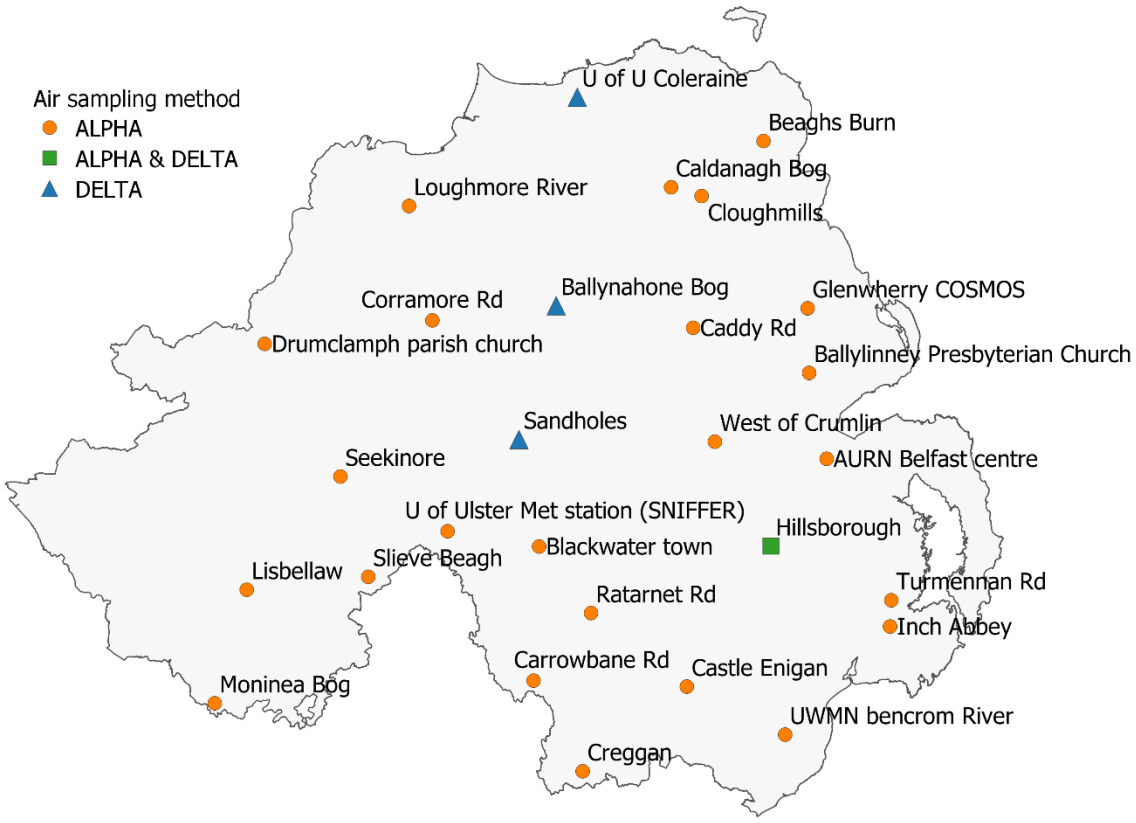
First year of reactive gas and aerosol data from DELTA® network

- The new DELTA® network provides monthly measurement data of gaseous NH_3, HNO_3, SO_2 and particulate NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, plus base cations Na^+, Ca^{2+} and Mg^{2+}.
- Annual mean NH_3 concentrations at the 4 DELTA® sites ranged from 1.9 – 6.8 µg NH_3 m^{-3}. This is larger than SO_2 (range = 0.30 – 0.57 µg SO_2 m^{-3}) and HNO_3 (mean 0.01 – 0.09 µg HNO_3 m^{-3}) measured at the same time.
- Concentrations of the basic particulate NH_4^+ are highly correlated with the sum of the acidic particulates NO_3^- and SO_4^{2-} (slope = 0.97, R^2 = 0.92), demonstrating the close coupling between NH_4^+ and NO_3^-/SO_4^{2-}.
- Annual mean particulate NH_4^+ concentrations (28 – 54 nmol m^{-3}) are in molar excess over SO_4^{2-} (4.4 - 9.5 nmol m^{-3}) and NO_3^- (19 – 42 nmol m^{-3}). This suggests that ammonium aerosols in Northern Ireland are more nitrate- than sulfate-rich, similar to those observed in the wider UK and across Europe.
- Scatter plots of the concentrations of particulate Cl^- and Na^+ show a significant correlation (R^2 = 0.91) and a near 1:1 relationship (slope = 0.97) between Cl^- and Na^+, consistent with a marine origin (sea salt) for these ions in the UK.

2 NI ALPHA® and DELTA® network

A new network of **25 ammonia** (NH_3) monitoring sites implementing the UKCEH ALPHA® method (ALPHA® network) and **4 reactive gases (NH_3, HNO_3, SO_2) and inorganic aerosols** monitoring sites implementing the UKCEH DELTA® method (DELTA® network) have been established across Northern Ireland (Figure 1) by UKCEH and AFBI. Monitoring started in early March 2019, and is currently planned to continue to the end of February 2022 to provide 3 full years of data.

Figure 1: **Map of new ALPHA® and DELTA® network (total = 28 sites) established across Northern Ireland in March 2019. There are 25 ALPHA® sites monitoring NH_3 (ALPHA network) and 4 DELTA® sites monitoring NH_3, interacting gases and aerosols (DELTA® network). At one site (Hillsborough), both methods are operated in parallel.**



At one site (AFBI25 Hillsborough), both the ALPHA® and DELTA® methods are co-located, with measurements made in parallel (Table 1). The ongoing inter-comparison allows a check on the use of the annually calibrated uptake rates (see Sect. 2.7.5) derived from UK sites (none located in Northern Ireland) for the ALPHA® measurements made in Northern Ireland.
A Picarro Cavity Ring-Down Spectroscopy (CRDS) NH_3 gas analyser (Picarro model Q2103; https://www.picarro.com) with high time-resolution, continuous measurement of NH_3 and an Automatic Weather Station (Campbell Scientific; www.campbellsci.eu) was also installed at the same time at AFBI25 Hillsborough. These instruments are operated alongside the new network measurements at Hillsborough.

Table 1: New air monitoring networks in Northern Ireland.

Site Type	Air pollutants measured	Number of sites
ALPHA®	Gas: NH_3	25
DELTA®	Gases: NH_3, HNO_3, SO_2, HCl Aerosols: NH_4^+, NO_3^-, SO_4^{2}, Cl^-, Na^+, Ca^{2+}, Mg^{2+})	4
Intercomparison site with both ALPHA® and DELTA®	See above (AFBI25 Hillsborough)	1
Total number of sites		**28**

2.1 Objectives

In the present study, the ALPHA® and DELTA® measurements from 28 sites in NI, combined with NH_3 concentration data from UK national air quality monitoring networks, other projects and studies, are used to provide a comprehensive assessment of the concentrations of gaseous NH_3 in Northern Ireland, to:

- investigate spatial and temporal patterns in ammonia (NH_3) concentrations,
- compare results with the FRAME atmospheric transport model and improve model estimates,
- provide independent verification of the NH_3 emissions inventory,
- monitor and assess the relationship between NH_3 and interacting acid gases (HNO_3, SO_2) and composition information on ammonium aerosols (ammonium nitrate NH_4NO_3, ammonium sulphate $(NH_4)_2SO_4$).

2.2 Site selections

A preliminary list of 40 potential sites across NI was identified, from which a final selection of 25 ALPHA® and 4 DELTA® sites was made (Table 2). Site selection was based on satisfying the following criteria:

- Representative spatial coverage of NI.
- Representative coverage for the range of NH_3 concentrations expected, based on FRAME modelled NH_3 concentrations at 5 × 5 km grid resolution.
- Representative coverage for each of seven major dominant emission source classifications: cattle (beef and dairy), pigs & poultry, sheep, mixed, non-agricultural, fertiliser and background (very low emission density, < 1 kg N ha^{-1} yr^{-1}), based on a dominant emission sources map at 5 km resolution.

The following additional information was also used to inform site selection:

Sites with historical measurements (see Table 2), e.g. NI NH_3 monitoring sites from the 2003 – 2004 SNIFFER study (Tang et al. 2004).

- Co-location with other monitoring networks in NI with air quality and ecosystem monitoring activities, e.g. Upland Waters Monitoring Network (UWMN), Environmental Change Network (ECN), COSMOS (soil moisture monitoring network operated by UKCEH, with an Automatic Weather Station at each site), Automatic Urban and Rural Monitoring Networks (AURN) and NIEA's Ballynahone Bog NH_3 project.
- Proximity to designated nature conservation sites (SACs, ASSIs) of key interest, e.g. Moninea and Ballynahone (see availability of mains power for the DELTA sites; the Ballynahone DELTA® site was set up using wind/solar power).
- Availability and access to a willing and helpful local contact.

Monitoring site set-up criteria

1. Open aspect, with good air flow around.
2. 100 m clearing all round preferable.
3. Not located under trees.
4. Avoiding hollows or dips in the land, where air concentrations will be different.
5. Avoiding proximity to buildings (at least 50 m away).
6. Avoiding proximity to local NH_3 sources, e.g. farmyards and manure heaps (need to be 0.5 km away from sources to avoid bias in NH_3 concentrations).
7. Sampling height at 1.5 m above ground.
8. If vegetation is likely to grow tall around the monitoring site, then effort should be made to cut the vegetation back and keep it short (all cut vegetation should be removed afterwards, as rotting vegetation will release NH_3).

Table 2: New Northern Ireland ALPHA® and DELTA® network details. At the time of site selection, 2016 emissions data for NH_3 was the most recently available data used in the FRAME model and for mapping dominant emission source sectors in this table.

ID	Name	Method	Lat	Long	Co-location with other sites	FRAME modelled NH_3	Dominant NH_3 emission source sector
AFBI01	U of Ulster met station	ALPHA®	-6.95	54.44	[1]Ex-SNIFFER NH_3 site	3.31	Pigs & Poultry
AFBI02	Castle Enigan	ALPHA®	-6.27	54.22		2.75	Mixed Cattle
AFBI03	Beaghs Burn	ALPHA®	-6.15	55.10	[2]UWMN; [3]UKEAP Precip-net	0.85	Mixed Agriculture
AFBI04	Slieve Beagh	ALPHA®	-7.16	54.36		1.13	Mixed Cattle
AFBI05	Moninea Bog	ALPHA®	-7.55	54.14		1.44	Mixed Cattle
[9]AFBI06	Drumclamph	ALPHA®	-7.49	54.72		3.27	Dairy
AFBI07	Seekinore	ALPHA®	-7.26	54.52		3.47	Mixed Cattle
AFBI08	Lisbellaw	ALPHA®	-7.49	54.32		2.49	Dairy
AFBI09	Glenwherry COSMOS	ALPHA®	-6.00	54.83	[4]COSMOS	1.70	Beef
AFBI10	UWMN Bencrom River	ALPHA®	-5.99	54.15	[2]UWMN	0.91	None
AFBI11	Blackwatertown	ALPHA®	-6.70	54.43		3.58	Mixed Cattle
AFBI12	Ratarnet Rd	ALPHA®	-6.54	54.33		3.97	Dairy
AFBI13	Inch Abbey	ALPHA®	-5.72	54.33		1.72	Mixed Cattle
AFBI14	AURN Belfast centre	ALPHA®	-5.92	54.59	[5]AURN	2.36	Non agric sources
AFBI15	Ballylinney Church	ALPHA®	-5.99	54.73		2.95	Mixed Cattle
AFBI16	West of Crumlin	ALPHA®	-6.23	54.61		3.87	Mixed Agriculture
AFBI17	Loughmore River	ALPHA®	-7.12	54.95		1.12	Mixed Cattle
AFBI18	Caldanagh Bog	ALPHA®	-6.40	55.01	[1]Ex-SNIFFER NH_3 site	2.64	Mixed Cattle
AFBI19	Cloughmills	ALPHA®	-6.31	55.00		3.89	Mixed Agriculture
AFBI20	Caddy Rd	ALPHA®	-6.31	54.79		3.51	Mixed Cattle
AFBI21	Turmennan Rd	ALPHA®	-5.73	54.37		3.55	Mixed Agriculture
AFBI22	Carrowbane Rd	ALPHA®	-6.69	54.21		5.03	Non agric sources
AFBI23	Creggan	ALPHA®	-6.54	54.07		2.10	Beef
AFBI24	Corramore Rd	ALPHA®	-7.03	54.78		0.91	Mixed Agriculture
AFBI25	Hillsborough	ALPHA® DELTA®	-6.06	54.45	[6]UKEAP NAMN/ AGANet/ PrecipNet/ NO_2Nnet [7]ECN [4]COSMOS	2.54	Mixed Cattle
AFBI26	Ballynahone	DELTA®	-6.70	54.81	[8]Ballynahone study	2.58	Mixed Cattle
AFBI27	UoU Coleraine	DELTA®	-6.68	55.15		1.92	Dairy
AFBI28	Sandholes	DELTA®	-6.77	54.59		4.33	Dairy
[10]AFBI29	Drumclamph 2	ALPHA®	-7.51	54.70		2.74	Dairy

[1]2003 – 2004 SNIFFER study (Tang et al. 2014)

[2]UWMN (Upland Waters Monitoring Network; http://www.ecn.ac.uk/what-we-do/about/research-partners/uk-uwmn)

[3]Precip-net (Precipitation network: https://uk-air.defra.gov.uk/networks/network-info?view=precipnet)

[4]**COSMOS (Cosmic-ray soil moisture monitoring network; https://cosmos.ceh.ac.uk/)**

[5]**AURN (Automatic Urban and Rural Network; https://uk-air.defra.gov.uk/networks/network-info?view=aurn)**

[6]**UKEAP (UK Eutrophying & Acidifying Air Pollutants Network; https://uk-air.defra.gov.uk/networks/network-info?view=ukeap)**

[7]**ECN (UK Environmental Change Network; http://www.ecn.ac.uk/)**

[8]**Ballynhaone study with Ulster Wildlife Trust (Stephens & Tang 2019)**

[9]*AFBI06 Drumclamph ALPHA® site closed at the end of August 2019 and relocated to AFBI29 Drumclamph 2*

[19]*AFBI29 Replacement site for AFBI06 Drumclamph.*

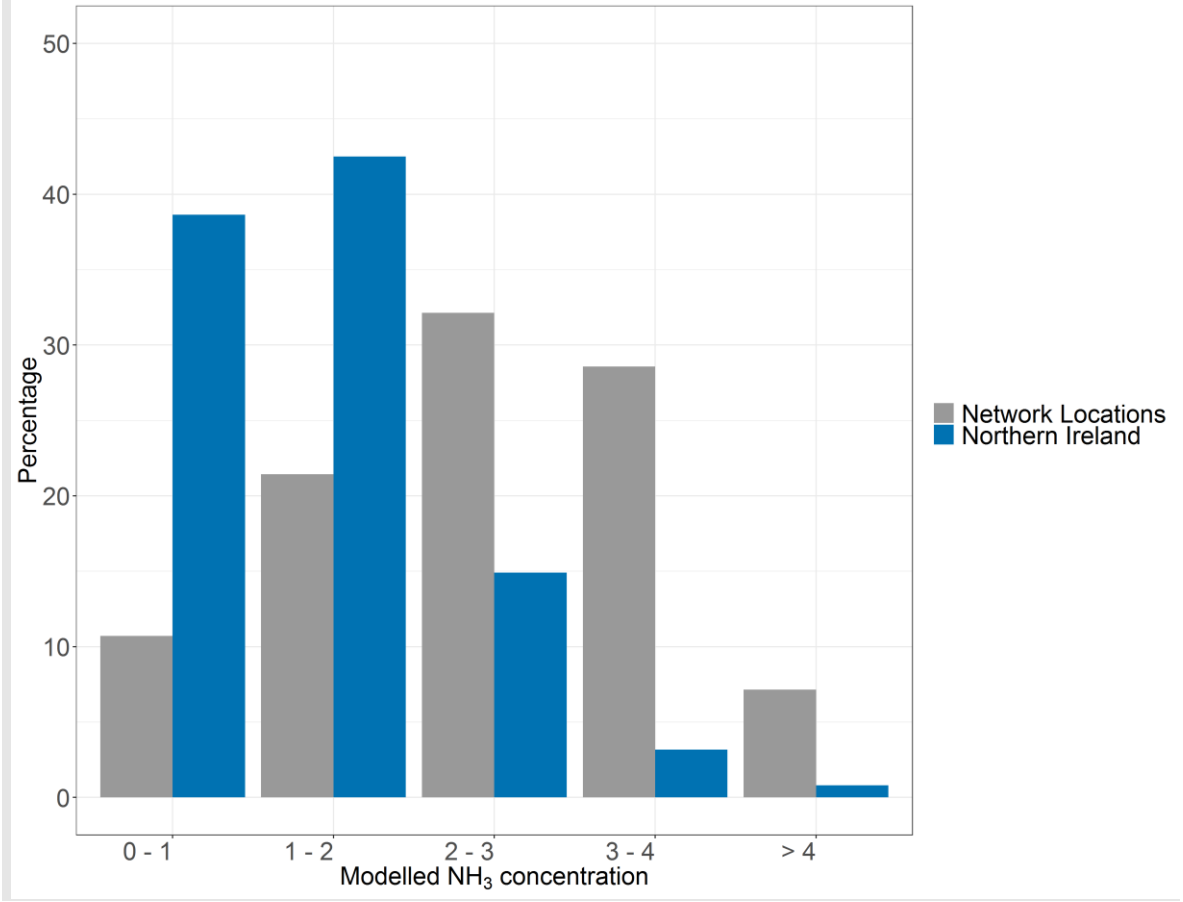
2.3 Representative coverage across range of modelled NH_3 concentrations

At the time of selecting sites for the new network, modelled NH_3 concentrations for each site in the ALPHA® and DELTA® network are provided by the Fine Resolution Atmospheric Multi-pollutant Exchange (FRAME) model (Singles et al., 1998; Fournier et al., 2002; Dore et al., 2015) for the emission year 2015/16 (baseline model run summer 2019 under the project; using mixed emission input data, with 2016 data for agriculture, latest available year at the time, referred to as 2016 data in this report). A comparison of modelled NH_3 concentrations from the 28 sites with FRAME modelled concentrations for the whole of NI (

Figure 2) shows that the network has a good coverage across the range of modelled concentrations.

Since NH_3 concentrations are generally more variable in high concentration areas (grid squares with concentrations > 2 µg NH_3 m^{-3}), a proportionately larger number of monitoring sites, compared with the percentage distribution of FRAME modelled concentrations were located in these areas than in low concentration areas where NH_3 concentrations are more homogeneous. Similarly, the monitoring sites were strategically selected to cover areas of high concentrations and variability on the basis of the FRAME model. This approach is expected to provide additional evidence to test the performance of the FRAME model (Dore et al., 2015).

Figure 2: ***Percentage distribution of modelled concentrations of NH_3 for the FRAME 5 km grid squares (using 2016 emissions data) containing ALPHA® and DELTA® sites (28 sites in total, in grey) and for all model grid squares (in blue) in Northern Ireland.***



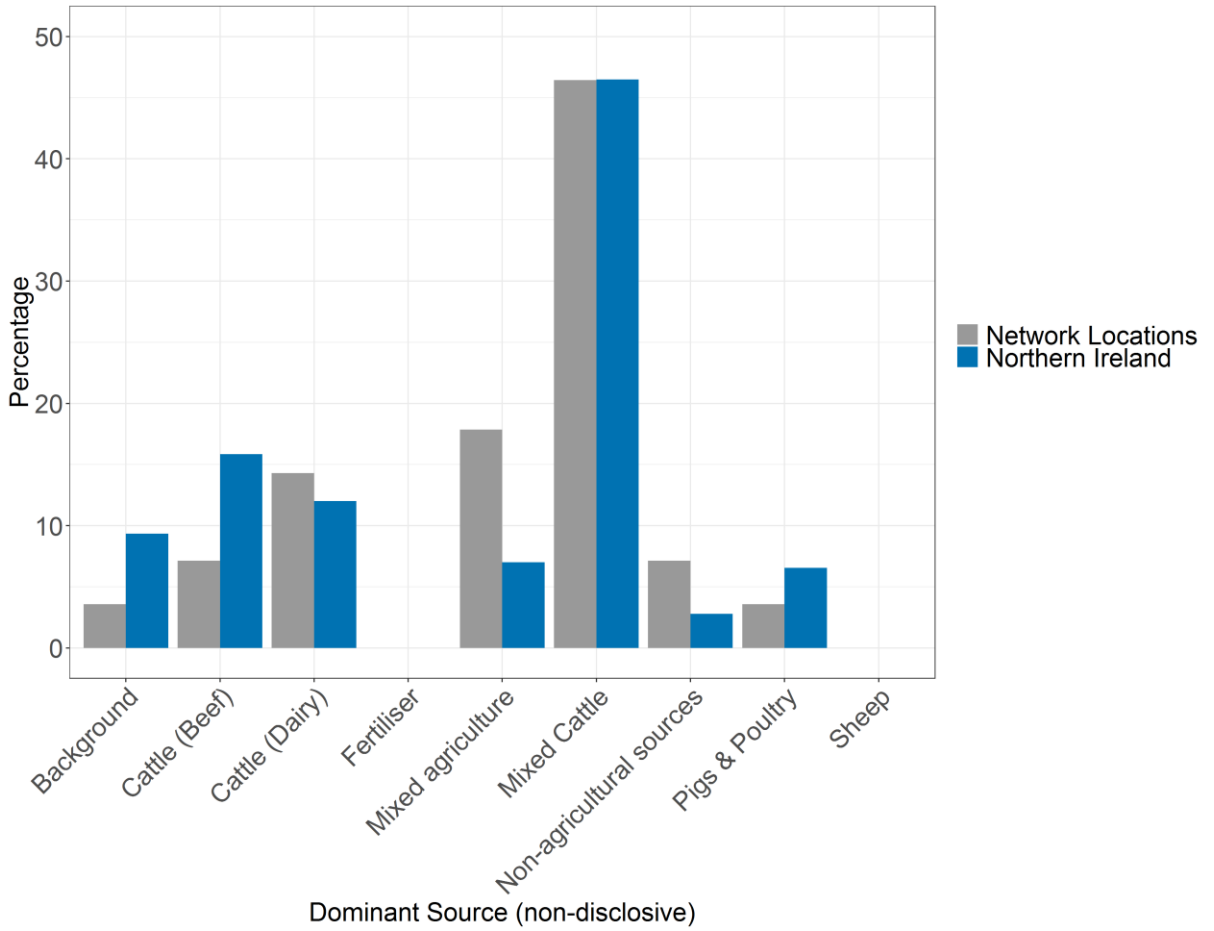
2.4 Representative coverage of dominant emission source sectors

Each site in the ALPHA® and DELTA® network is classed into one of seven NH_3 emission source categories, based on the dominant emission sources map for the 2016 emission year. The classification of each 5 km by 5 km grid square in the UK by emission source sectors uses the AENEID approach of Dragosits et al. (1998) and Hellsten et al. (2008), where grid squares with >45% from a given category are referred to as dominated by that source. The seven categories are:

- Cattle (beef and dairy)
- Pigs & Poultry (combined for data disclosivity reasons)
- Sheep
- Fertilizer application to crops and grassland
- Non-agricultural sources
- Mixed (where no single source dominates)
- Background (very low NH_3 emissions of <1 kg N ha^{-1} y^{-1}.).

The selection of monitoring sites was stratified to take account of different source sectors across Northern Ireland, for a representative network.

Figure 3: ***Percentage distribution of the modelled dominant NH_3 emission source category for the AENEID 5 km grid squares containing an ALPHA and DELTA site (2016), compared with the model classification for all grid squares in Northern Ireland.***

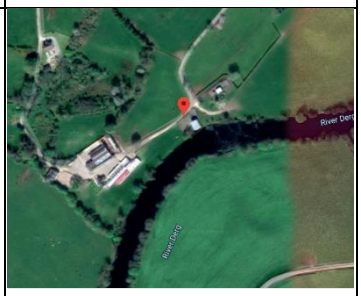
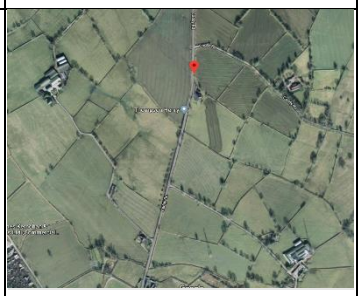


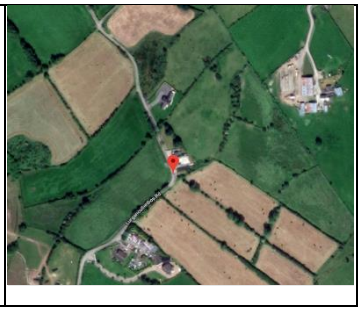
2.5 Site review and site change

An initial review of available data in August 2019 highlighted the fact that NH_3 concentrations at 4 ALPHA® sites were much higher than expected on the basis of FRAME model predictions. The sites were subsequently reviewed to check if they conform to the site selection criteria:

1) Identification of potential NH_3 emission sources (e.g. spotting buildings that look like animal housing) from google maps within 500 m radius of the monitoring locations;
2) Investigation / verification of emission sources by AFBI personnel.

Table 3: Review of 4 ALPHA® ammonia monitoring sites.

Site	Google map	Verification	Review comments	Google earth maps
AFBI06 Drumclamph parish church Ratio Measured/ FRAME = 4.1	Potential farm building <100m SW of site coordinates.	Animal housing = 200m to West. 2 anaerobic digesters in vicinity. The ALPHA® equipment is situated approx. between them. The distance between the digesters is approx. 1km.	Site is affected by close proximity to large emission sources. Site relocated at the beginning of September.	
AFBI12 Ratarnet Rd Ratio Measured/ FRAME = 2.5	Several large farms in W/S/SW of site, approx. 700-800m away.	Approx. 800m to closest farm/livestock buildings (landowner's farm)	Continue at present site.	
AFBI20 Caddy Rd Ratio Measured/ FRAME = 2.3	Dairy farm 200m to the W, dairy farms seem to be the only sources in the vicinity	Residential house 70m away. The equipment is located 5m from the Caddy Road. There are 2 dairy farms 1km apart nearby. Dairy farm 200m to the W, dairy farms seem to be the only sources in the vicinity	Continue at present site.	

AFBI23 Creggan Ratio Measured/ FRAME = 2.4	Possible farm 100m NE of coordinates – very difficult to tell from map	Small farms are scattered in the wider vicinity but no livestock buildings in the immediate vicinity.	Continue at present site.	

A summary of the review is provided in Table 3. At AFBI06 Drumclamph, NH_3 concentration was substantially higher than modelled values (mean 13.7 µg NH_3 m^{-3} (*n* = 6) *cf.* FRAME 3.3 µg NH_3 m^{-3}). On investigation, large buildings located *approx*. 200 m to the west of the site were found to be animal housing. Measurement at this site was stopped at the end of August and it was relocated to a new location, further away from sources. The replacement site was given a new site ID and site name – AFBI29 Drumclamph 2.

2.6 Other air quality measurements in NI

2.6.1 UKEAP project

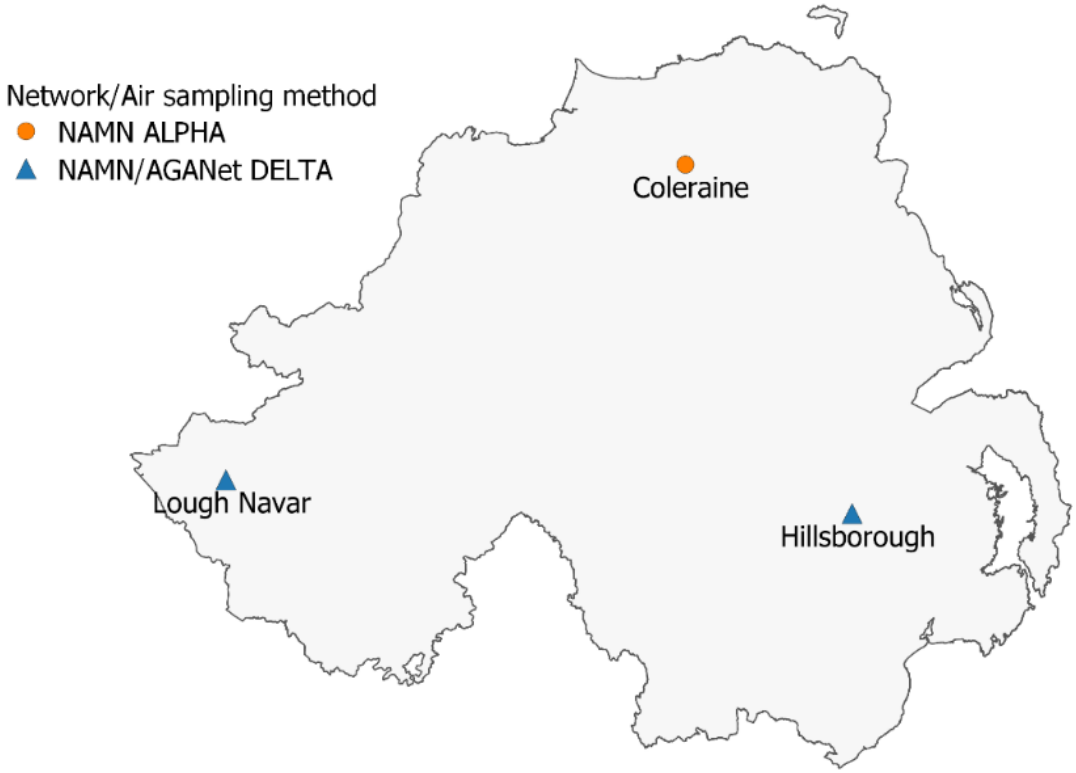
There are three active long-term national monitoring network sites in NI under the UKEAP (UK Eutrophying and Acidifying Atmospheric Pollutants) network (https://uk-air.defra.gov.uk/networks/network-info?view=ukeap) (Table 4,

Figure 4). NH_3 is monitored at all three sites as part of the UK National Ammonia Monitoring Network (NAMN; https://uk-air.defra.gov.uk/networks/network-info?view=nh3). Additional measurements of acid gases and aerosols are made at two of the NAMN DELTA sites as part of the UK Acid Gas and Aerosol network, Hillsborough and Lough Navar (AGANet; https://uk-air.defra.gov.uk/networks/network-info?view=aganet).

Table 4: ALPHA and DELTA measurements made under existing national monitoring networks in Northern Ireland.

Network / site name	Method/Air pollutants measured	UK-AIR ID	Number of sites
UKEAP NAMN: Coleraine	ALPHA® Gas: NH_3	UKA00401	1 ALPHA
UKEAP NAMN / AGANet: Hillsborough	DELTA® Gases: NH_3, HNO_3, SO_2 Aerosols: NH_4^+, NO_3^-, SO_4^{2}, Cl^-, Na^+, Ca^{2+}, Mg^{2+})	UKA00293	2 DELTA
UKEAP NAMN / AGANet: Lough Navar		UKA00166	
Total number of sites			**3**

Figure 4: **Three active long-term national network monitoring sites located in Northern Ireland under the UKEAP (UK Eutrophying and Acidifying Atmospheric Pollutants) project: Coleraine (NAMN ALPHA: NH_3) and Hillsborough / Lough Navar (NAMN-AGANet DELTA: NH_3, acid gases & aerosols) (https://uk-air.defra.gov.uk/networks/network-info?view=ukeap).**

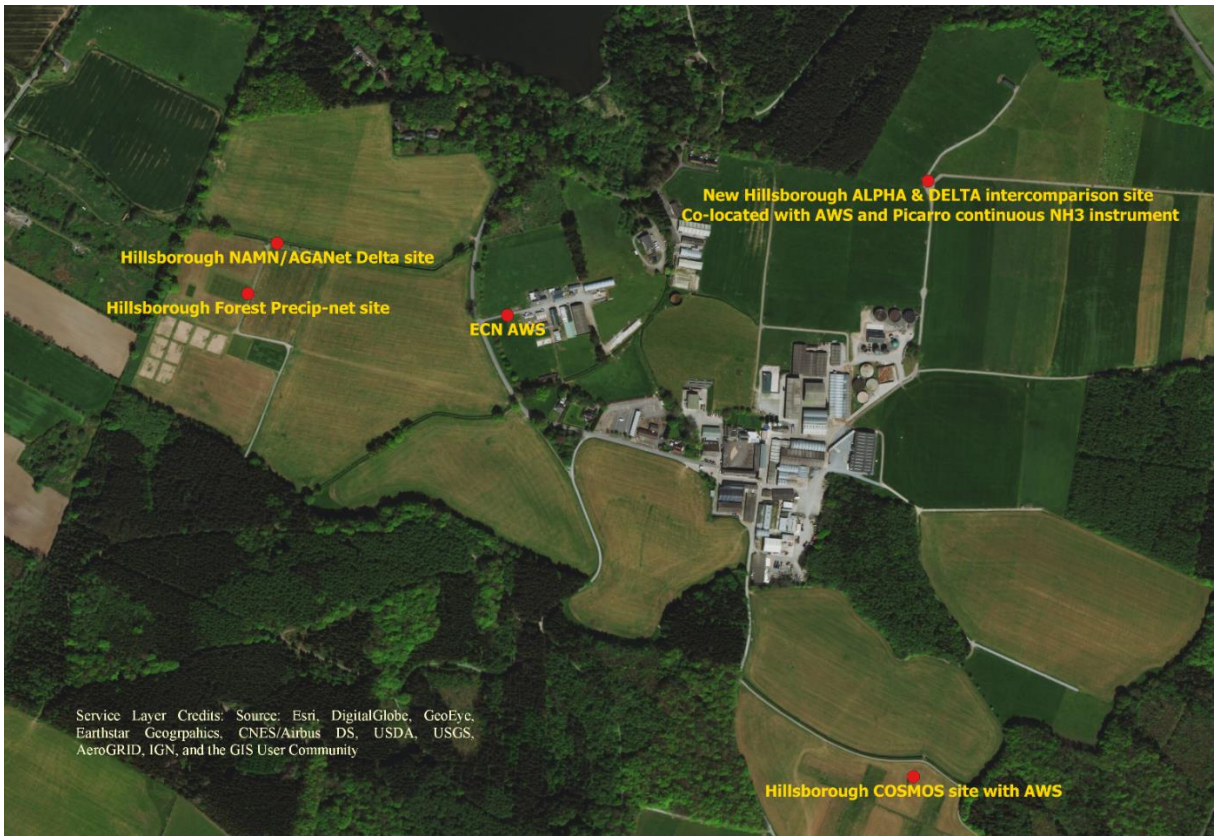


The new Hillsborough site AFBI25 on the AFBI Hillsborough farm is co-located (within 1 km) with a number of other air quality and ecosystem monitoring activities, as detailed below (see also

Figure 5).

- UKEAP NAMN/AGANet Hillsborough DELTA® site. The additional data should provide an indication of local variability in NH_3 and other gas/aerosol concentrations in the 5 × 5 km grid squares containing the sites.
- UKEAP Precip-net and NO_2-net Hillsborough Forest site that will provide 2-weekly wet deposition data and 4-weekly NO_2 data.
- Hillsborough ECN site and AWS for ecological and met data.
- Hillsborough COSMOS site for soil moisture and additional met data.

Figure 5: **Co-location of air quality and ecosystem monitoring activities at AFBI25 Hillsborough ALPHA® + DELTA® intercomparison site.**



2.6.2 Ballynahone NH_3 study

Continuous monthly NH_3 measurements with ALPHA® samplers have been made at 8 sites across Ballynahone Bog since November 2014 (

Figure 6), commissioned by Ulster Wildlife (UW) (Stephens & Tang 2019). The new AFBI26 Ballynahone DELTA® site (Figure 7) is located next to the existing ALPHA® measurements at Site 3 (UWT3) along a SW-NE transect. Monthly sample changes for the ALPHA® and DELTA® are carried out at the same time by the local site contact. This provides a second ALPHA-DELTA intercomparison site for the new network.

Figure 6. Ammonia monitoring at Ballynahone Bog. Brown rectangles show the site of new poultry houses (to the left of UWT 1). Red markers indicate placement of atmospheric ALPHA® ammonia measurement sites.

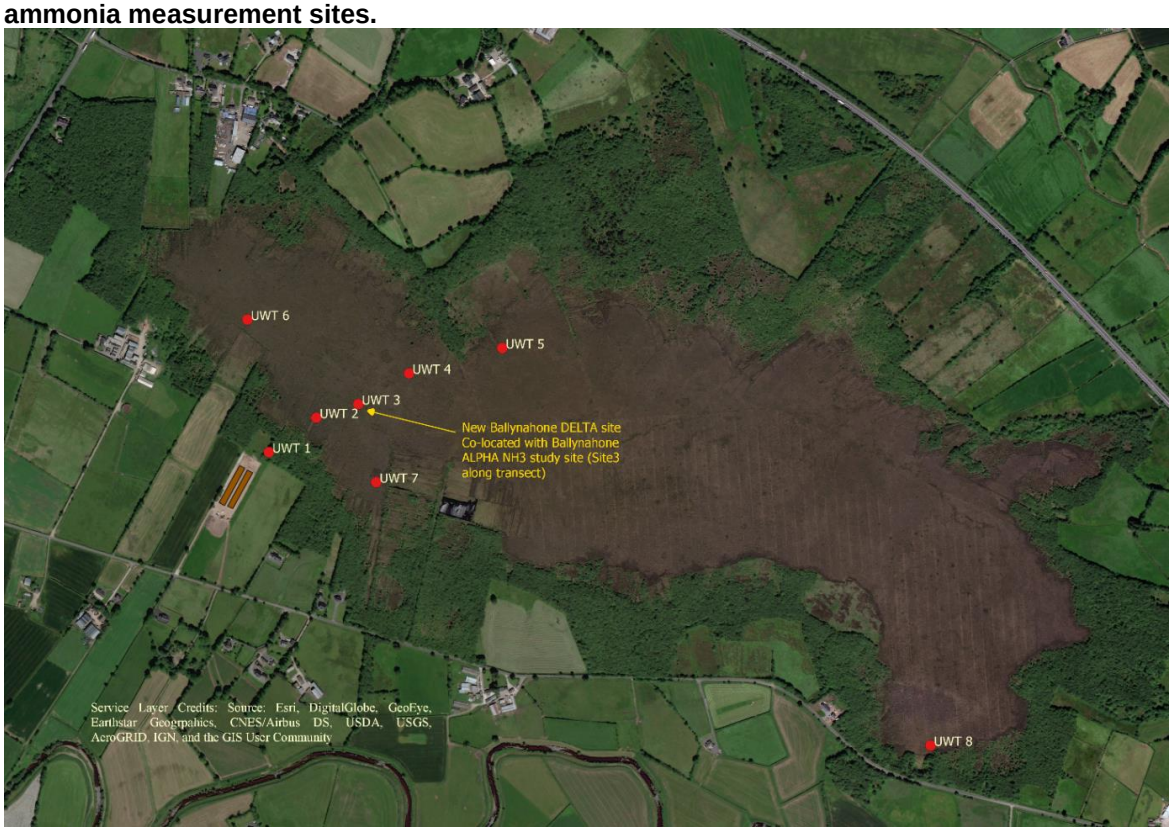
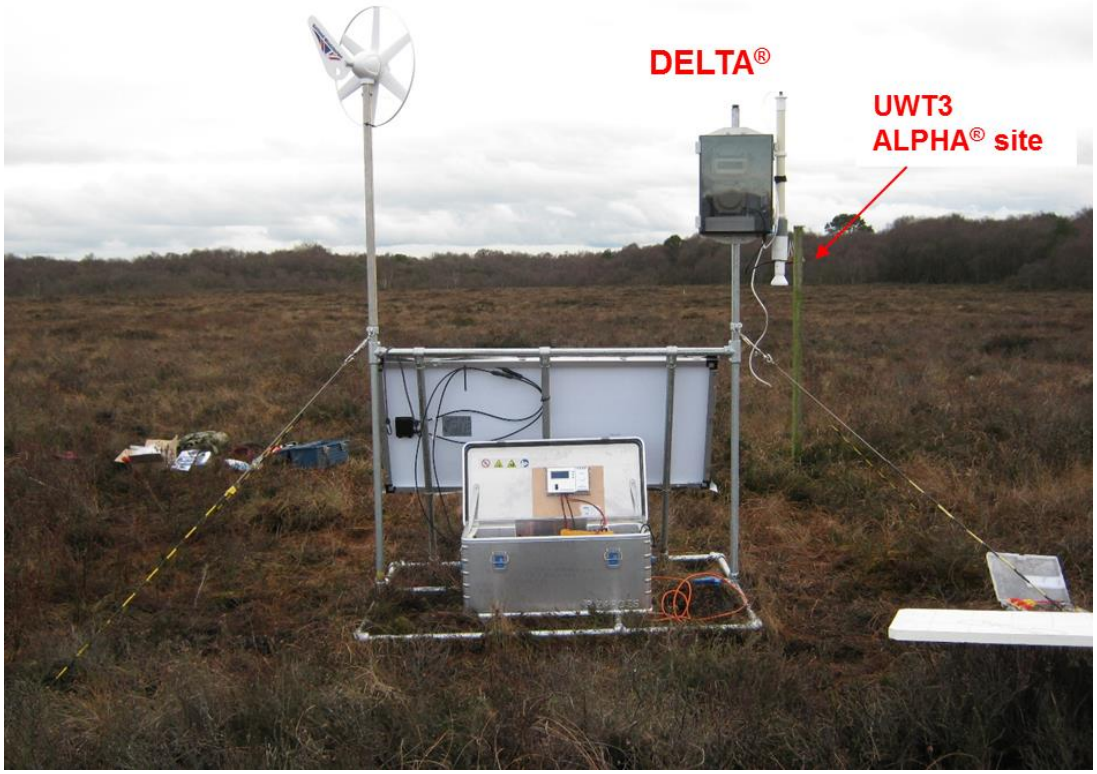


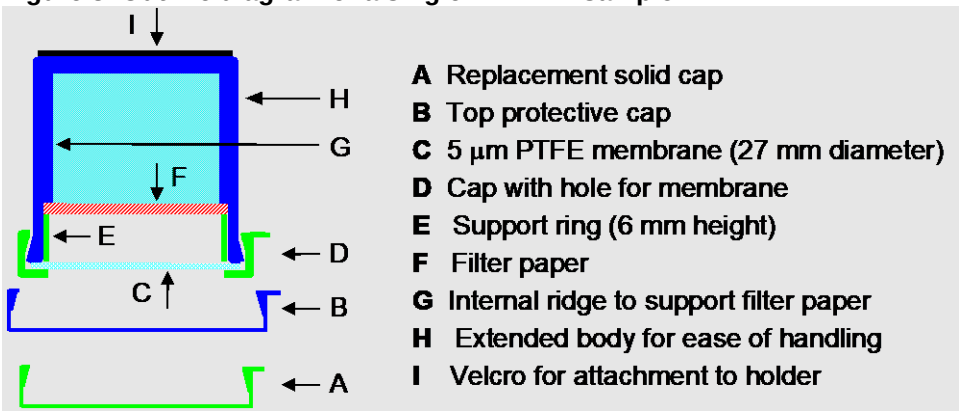
Figure 7. A picture of the wind-solar powered DELTA® air monitoring site at Ballynahone Bog during installation. This is co-located with an existing ALPHA® NH_3 monitoring site (UWT3) along the ecosystem transect on the bog.



2.7 ALPHA® methodology

Atmospheric NH_3 concentrations are monitored using the UKCEH ALPHA® (**A**dapted **L**ow-cost **P**assive **H**igh **A**bsorption) samplers, as shown in Figure 8 (Martin et al. 2019, Tang et al. 2001). Monitoring is carried out with a monthly frequency, which provides sufficient resolution to examine the main seasonal trends and cost-efficient for measuring the annual mean concentrations at each site.

Figure 8. Outline diagram of a single ALPHA® sampler.



2.7.1 Preparation of samplers

ALPHA® samplers are prepared in accordance with standard UKCEH protocols (Tang et al. 2019), using filter circles impregnated with 6 mg of citric acid. Triplicate samplers are prepared for each monitoring site and placed inside a sealed container, together with replacement solid caps that are used to replace the membrane + membrane caps at the end of sampling.

2.7.2 Exposure of samplers

ALPHA® samplers are attached by the use of Velcro to an aerodynamically shaped support (upturned plant saucer) on a post at about 1.5 m height above ground or vegetation (Figure 9). The sampling height of 1.5 m above ground is standard, providing a representative NH_3 concentration in the atmosphere. Plastic bird spikes are mounted on the top of the support to deter birds from perching. Triplicate samples are used at each site to provide an estimate of measurement precision for the air concentration of NH_3 and for QA/QC purposes.

Monitoring is on a monthly frequency from early March 2019, using continuous time-integrated sampling over each period. The ALPHA® samplers are prepared and analysed at the UKAS accredited laboratory of UKCEH Lancaster, following standard protocols developed by UKCEH (Tang et al., 2003).

ALPHA® monitoring sites were set up by an experienced member of staff from AFBI, in correspondence with staff at UKCEH and after training with UKCEH personnel. After the initial set up, sites were visited on a monthly basis by a local site operator appointed by AFBI that are trained to carry out the required monthly changeover of samples. A recording card is used by the site operator to record dates and times of the samples changes at each site, together with capturing relevant local information on the back of the form (e.g. agricultural activities taking place in the vicinity e.g. manure spreading, during the month or at the time of visit).

Figure 9: Sample post and ALPHA shelter at AFBI05 Moninea Bog ALPHA site.

2.7.3 Chemical analysis

Exposed samples are stored refrigerated at 4 °C until analysis. Citric acid coated filters from the exposed ALPHA® samplers are extracted into deionised water and analysed for ammonium on the SEAL Flow Injection Colorimetry system at the UKAS accredited laboratory of UKCEH Lancaster (Tang et al. 2018a).

2.7.4 Calculation of air concentrations

The air concentration (χ_a) of NH_3 gas (µg NH_3 m^{-3}) is determined according to Eq. 1:

$$c_a = \frac{Q}{V} \quad (1)$$

The amount of NH_3 collected (*Q, µg*) on an ALPHA® sampler due to air sampling is given by Eq. 2:

$$Q = (Ce - Cb) * v * (\frac{17}{18}) \quad (2)$$

- *C_e is the liquid concentration of an exposed sample (µg NH_4^+ ml^{-1}),*
- *c_b is the liquid concentration of a blank sample (µg NH_4^+ ml^{-1}) and*
- *v is the liquid volume of the extraction solution (ml).*
- *multiplied by $\frac{17}{18}$ to convert from NH_4^+ (measured in liquid extract) to NH_3*

V is the estimated volume of air sampled by ALPHA® sampler over the exposure period (*V*, m^3), which may be determined by Eq. 3:

$$V = UR_{NH_3} * t \quad (3)$$

- *UR_{NH3} is the field calibrated uptake rate of ALPHA® sampler for UKCEH Lancaster laboratory (derived from annual calibrations in the UK National Ammonia Monitoring Network; see Sect. 2.7.5)*

  2019 UR_{NH3} = 0.0031665 m^3 h^{-1}

  2020 UR_{NH3} = 0.0031277 m_3 h^{-1}

- *t is sampling duration (hours).*

2.7.5 QA/QC and calibration

The accuracy of the SEAL system for analysis of ammonium in aqueous solution is assured by participation in the AQUACHECK (water chemistry) laboratory proficiency testing schemes. Replicate (three) ALPHA® samplers are also used for each measurement and should, when performing well, agree to within 15 % (% Coefficient of Variation, % CV). Large discrepancies are most likely due to contamination of samples, or other factors that affect the performance of the samplers. The average reproducibility of replicate samples in the field, so far, are generally better than 10 % (CV) and the detection limit (3 σ of blanks) was 0.03 μg m^3 for a monthly exposure period. Transport blanks sent to sites on a periodic basis also achieved suitably low values (<3* monthly blank value), which indicate minimum contamination occurred during transport and storage.

At 9 UKEAP NAMN/AGANet sites in the UK, parallel measurements between the ALPHA® samplers and the reference active denuder sampling method (DELTA®) (CEN 2019, Tang et al. 2018a) are made to provide ongoing validation and calibration of ALPHA® sampler data. Calibration of measured concentrations using the ALPHA® sampler is necessary, because the gas permeable membrane placed at the inlet imposes an additional resistance against gas diffusion that is not taken into account in deriving the theoretical gas sampling rate. Field calibration of the samplers against the active reference method (DELTA®) provides a calibrated ammonia sampling uptake rate for the ALPHA® measurements each year (calendar year). The calibration is usually carried out in April each year, based on a full year of data from the preceding year. The updated uptake rate is then applied retrospectively to ALPHA® data for the year of calibration. Annually calibrated uptake rates derived from the UK national network are applied to the Northern Ireland ALPHA® network data. These were 0.0031665 m^3 h^{-1} and 0.0031277 m^3 h^{-1}, for 2019 and 2020, respectively (see Sect. 2.7.4)**.** The 2020 uptake rate is currently applied provisionally to 2021 ALPHA® data, until the 2021 uptake rate becomes available in April 2022.

2.8 DELTA® methodology

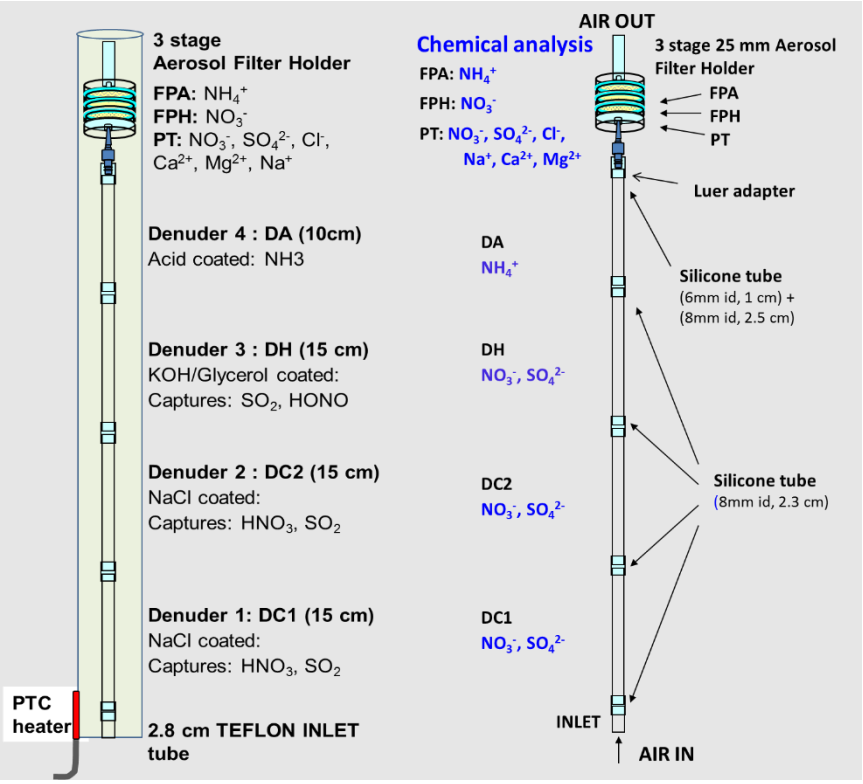
The DELTA® (DEnuder for Long-Term Atmospheric) sampling system was developed for long-term sampling of ammonia in the UK NAMN (Sutton et al*.* 2001a) and then later extended to sample acid gases and inorganic composition in the UK AGANet (Tang et al. 2018b) and the NitroEurope DELTA® network across Europe (Tang et al. 2009). This diffusion denuder method permits the selective removal of reactive gases on chemically impregnated denuders, with subsequent collection of aerosols on downstream aerosol filters (Ferm 1979, Sutton et al. 2001). The method is simple to deploy, using a small air pump to provide the desired air sampling rate of 0.2 – 0.4 L min^{-1}, and a high sensitivity dry gas meter to record sampled volume.

The DELTA® methodology is deployed at 4 DELTA® sites in the new NI network to measure gaseous NH_3, HNO_3, SO_2 and aerosol NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, plus base cations Na^+, Ca^{2+} and Mg^{2+}. At the AFBI26 Ballynahone site, which has no access to power, a wind-solar powered DELTA system was purpose-built and installed.

2.8.1 Preparation of DELTA® sample trains

The DELTA® sample train for measuring the full suite of reactive gases and inorganic aerosols is shown in Figure 10. It consists of a 2.8 cm Teflon inlet (to develop laminar flow), 2 x NaCl coated denuders, 1 x K_2CO_3/glycerol coated denuder, 1 x citric acid coated denuder and a 3-stage aerosol filter pack.

Figure 10: DELTA® sample train for speciated collection of reactive gases (HNO_3, SO_2, NH_3) and particles (NO_3^-, SO_4^{2-}, Cl^-, NH_4^+, Na^+, Ca^{2+}, Mg^{2+}). (Left) sample train in situ inside an external detachable sample holder, with a PTC heater at the base to maintain temperature inside the holder at about 3 degrees above ambient. (Right) details on chemical species that are analysed in the aqueous extracts from each component of the sample train.



2.8.2 Chemical analysis

Returned samples are stored in a cold room at 4 ºC until analysis (see Table 5). HNO_3 is collected by the first set of NaCl coated denuders (DC1 + DC2), while SO_2 is collected on both the NaCl and the K_2CO_3 / glycerol (DH) coated denuders. The citric acid coated denuder (DA) removes NH_3. A 3-stage filter pack at the end of the sampling train collects aerosol components. The first filter is a 2µm pore size PTFE membrane (PT) to collect aerosol NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+} and Mg^{2+}, followed by a second cellulose filter impregnated with K_2CO_3 / glycerol and a third cellulose filter coated with citric acid to collect evolved NO_3^- and NH4+ (from volatilisation of NH_4NO_3 off stage 1 PT membrane), respectively.

Base coated denuders (DC1, DC2, DH) and aerosol filters (PT, FPH) are extracted into 5 mL of deionised H_2O for analysis. Anions (NO_3^-, SO_4^{2-} and Cl^-) in the denuder and filter extracts are analysed by Ion Chromatography (IC). Base cations Na^+, Mg^{2+} and Ca^{2+} from the filter extracts are analysed by Inductively Coupled Plasma-Optical

Emission Spectroscopy (ICP-OES). Citric acid coated denuder (DA) and aerosol filter (FPA) are extracted into 3mL and 4mL deionised H_20, with analysis of NH_4^+ performed on a SEAL-AA3 flow injection colorimetric system.

Table 5: Summary table of gas and aerosol species captured by the DELTA sample train and details on method of analysis on the ions in the aqueous extracts from the different component parts.

Sample train component	DC1 + DC2	DH	DA	PT	FPH	FPA
Species collected	Gases: HNO_3 SO_2	Gases: SO_2 HONO	Gases: NH_3	Particulates: NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, Na^+, Ca^{2+}, Mg^{2+}	Particulates: NO_3^- Cl^-	Particulates: NH_4^+
Chemical species in aqueous extract /analytical method	NO_3^-, SO_4^{2-} Method = IC	SO_4^{2-} NO_3^- Method IC	NH_4^+ Method = SEAL-AA3	NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, Method = IC Na^+, Ca^{2+}, Mg^{2+} Method = ICP-OES	NO_3^- Cl^- Method = IC	NH_4^+ Method = SEAL-AA3

2.8.3 Calculation of gas concentrations

The amount of a gas collected (Q) on a denuder during air sampling is given by:

$$Q = (c_e - c_b)*v \quad (1)$$

Where c_e is the liquid concentration of an exposed sample, c_b is the liquid concentration of a blank sample and v is the liquid volume of the extraction solution. The air concentration (χ_a) of a trace gas is then determined as:

$$\chi_a = Q/V \quad (2)$$

where V is the volume of air sampled, which is found directly from the gas meter readings, and is typically 15 m^3 per month.

The use of two NaCl denuders in series permits the determination of capture efficiency, by comparing the amounts of trace gas in both. An infinite series correction factor, based on the capture efficiency, is applied for HNO_3 gas not captured (Sutton et al., 2001, Tang et al., 2018b). The corrected air concentration of HNO_3 ($\chi_{a\ (corrected)}$) is then determined as:

$$(\chi_{a\ (corrected)}) = \chi_{a\ (Denuder\ 1)} * [1/(1-(\chi_{a\ (Denuder\ 2)} / \chi_{a\ (Denuder\ 1)})] \quad (3)$$

At a typical capture efficiency of 90 % in the first denuder, the correction represents 1 % of the corrected air concentration of the gas. At 80 %, 75 % and 70 % capture, the correction amounts to 6 %, 11 % and 17 % of the total, respectively. Below 60 % capture efficiency, the correction amounts to greater than 50 % and is not be applied. The air concentration of the trace gas is then determined as:

$$\chi_a = \chi_{a\ (Denuder\ 1)} + \chi_{a\ (Denuder\ 2)} \quad (4)$$

2.8.4 Calculation of aerosol concentrations

The air concentration (χ_a) of inorganic chemical species from filter pack sampling is determined according to equations 1 and 2 described in Sect. 0. Since NH_4NO_3 and NH_4Cl are semi-volatile, the total concentrations of the NO_3^- and Cl^- ions are derived from the sum of species collected on the PT and FPH filters. For NH_4^+, this is is the sum of NH_4^+ collected on the PT and FPA filters (see below).

Ions	**Aerosol concentrations**
NO_3-	= sum PT (NO_3^-) + FPH (NO_3^-)
SO_4^{2-}	= PT (SO_4^{2-})
Cl^-	= sum PT (Cl^-) + FPH (Cl^-)
NH_4^+	= sum PT (NH_4^+) + FPA (NH_4^+)
Na^+, Ca^{2+}, Mg^{2+}	= PT (Na^+, Ca^{2+}, Mg^{2+})

2.8.5 Quality Assurance and Quality Control (QA/QC)

This section describes the main Quality Assurance (QA) and Quality Control (QC) approaches used in the measurements. QA of the network is maintained through careful adherence to Standard Operating Procedures (SOPs) and good laboratory and site operator practice. A number of QC criteria are applied to screen the collected data. Data passing and failing the QC thresholds can then be compared to identify any biases. Two levels of data filtration are provided:

1. Standard data filtration

DELTA system: The air pumps used are relatively stable, with flow rates set between 0.2 – 0.4 l min^{-1}. Data fail the QC standard where the flow rates for a sampling period are 20 % below the set rate. Flow rates that are lower than expected indicate that an extended power cut has occurred or that there is a leak in the system. Any low flow rate for a month is investigated promptly with the site operator.

ALPHA samplers: replicate samples (3) are used at every site to provide estimates of precision of the method, and to identify contamination artefacts. Where the % coefficient of variation (% CV = [standard deviation / mean]*100) of the replicate samplers is greater than 15 % for ALPHA samplers, the sample run is classed as failing the QC test. Large discrepancies greater than the set quality standard are most likely due to contamination of samples, or incorrectly prepared samples.

2. Ion balance checks

Close agreement is expected between NH_4^+ and the sum of NO_3^- and $2\times SO_4^{2-}$, as NH_3 is neutralised by HNO_3 and H_2SO_4 to form NH_4NO_3 and $(NH_4)_2SO_4$, respectively, and for Na^+ and Cl^-, as these are marine (sea salt) in origin (Tang et al. 2018b).

3. Manual screening of outliers

In addition to the above tests, the full dataset is investigated for anomalies and outliers. This is designed to identify any instances where there was clearly a sampling malfunction. This includes such events as vandalized samples, water ingress and invasion by invertebrates.

4. Expert review and data ratification

Data are reviewed in a 4-stage process, in accordance to SOPs for data processing, review, ratification and approval for release.

3 Data summary

3.1 Spatial variability in NH_3 concentrations

Monthly monitored NH_3 concentrations for the 12 month period from March 2019 to February 2020 from all sites in the new ALPHA® and DELTA® network are summarised in

Table 6 (Mar-Aug19) and Table 7 (Sep19- Feb20). Also included are other sites in Northern Ireland, i.e. the three long-established NAMN sites (S44, S45, S79) and one of the ALPHA® samplers established in 2014 for Ulster Wildlife (UWT3).

Table 6. Monthly NH_3 concentrations (Mar-Aug 2019) measured at 28 sites in the new AFBI ALPHA® and DELTA® networks, complemented with data from UKEAP NAMN/AGANet (3 sites) and Ballynahone NH_3 study site (UWT3) located in NI.

ID	Name	Method	Mar-19	Apr-19	May-19	Jun-19	Jul-19	Aug-19	Mean (6 months)	*n*
AFBI01	U of Ulster met station (SNIFFER)	ALPHA	3.07	6.47	ND[1]	3.75	4.59	3.54	**4.28**	**5**
AFBI02	Castle Enigan	ALPHA	2.53	2.41	6.24	1.71	7.87	1.57	**3.72**	**6**
AFBI03	Beaghs Burn	ALPHA	0.46	1.46	0.62	0.51	0.63	0.48	**0.69**	**6**
AFBI04	Slieve Beagh	ALPHA	0.33	2.16	1.56	1.16	1.32	0.76	**1.21**	**6**
AFBI05	Moninea Bog	ALPHA	0.79	3.52	2.68	2.00	3.16	2.52	**2.44**	**6**
AFBI06	Drumclamph church	ALPHA	14.14	10.25	21.2	11.3	21.2	9.01	**13.2**	**5**
AFBI07	Seekinore	ALPHA	2.50	4.63	6.29	3.00	3.67	2.57	**3.78**	**6**
AFBI08	Lisbellaw	ALPHA	2.23	4.77	5.92	3.31	12.2	2.43	**5.14**	**6**
AFBI09	Glenwherry COSMOS	ALPHA	2.69	2.16	1.41	ND[2]	2.77	1.78	**2.16**	**5**
AFBI10	UWMN Bencrom River	ALPHA	0.90	1.32	1.27	0.89	1.38	[a]0.84	**1.10**	**6**
AFBI11	Blackwater town	ALPHA	4.30	5.95	5.38	ND[2]	ND[2]	3.96	**4.90**	**4**
AFBI12	Ratarnet Rd	ALPHA	9.74	8.42	8.68	6.74	5.15	3.21	**6.99**	**6**
AFBI13	Inch Abbey	ALPHA	1.68	1.56	1.48	2.62	1.86	1.13	**1.72**	**6**
AFBI14	AURN Belfast centre	ALPHA	3.07	3.48	3.12	ND[2]	3.75	ND[1]	**3.35**	**4**
AFBI15	Ballylinney Presbyterian Church	ALPHA	4.03	3.43	4.68	2.44	8.21	2.38	**4.19**	**6**
AFBI16	West of Crumlin	ALPHA	3.55	3.64	3.39	2.14	3.19	2.17	**3.01**	**6**
AFBI17	Loughmore River	ALPHA	1.02	2.16	1.58	1.17	1.57	1.40	**1.48**	**6**
AFBI18	Caldanagh Bog	ALPHA	3.69	3.08	2.84	2.19	ND[1]	2.28	**2.82**	**5**
AFBI19	Cloughmills	ALPHA	10.20	4.14	3.80	2.90	3.82	2.33	**4.53**	**6**
AFBI20	Caddy Rd	ALPHA	5.12	5.67	11.6	4.78	12.5	3.97	**7.26**	**6**
AFBI21	Turmennan Rd	ALPHA	2.30	2.13	2.18	1.63	2.71	3.25	**2.37**	**6**
AFBI22	Carrowbane Rd	ALPHA	4.54	6.51	4.99	5.06	5.40	3.39	**4.98**	**6**
AFBI23	Creggan	ALPHA	4.68	2.38	6.74	2.27	3.24	1.59	**3.48**	**6**
AFBI24	Corramore Rd	ALPHA	0.86	1.53	1.57	1.08	1.62	0.94	**1.27**	**6**
*AFBI29	Drumclamph 2	ALPHA	-	-	-	-	-	-		**0**
AFBI25	Hillsborough	ALPHA	5.25	6.62	8.00	12.4	12.8	11.2	**9.38**	**6**
AFBI25	Hillsborough	DELTA	ND[3]	4.52	ND[1]	ND[1]	13.5	ND[1]	**9.00**	**2**
AFBI26	Ballynahone Bog	DELTA	3.23	4.08	3.08	ND[1]	4.05	3.68	**3.62**	**5**
UWT3	Ballynahone: co-located with AFBI26	ALPHA	ND[1]	3.83	3.48	4.53	4.17	4.90	**4.18**	**5**
AFBI27	U of U Coleraine Met Station	DELTA	2.14	3.14	ND[1]	1.20	ND[1]	1.18	**1.91**	**4**
AFBI28	Sandholes	DELTA	2.89	8.10	ND[1]	ND[1]	2.31	5.68	**4.75**	**4**
S44	NAMN/AGANet-Hillsborough	DELTA	ND[3]	4.37	3.10	1.93	ND[1]	3.23	**3.16**	**4**
S45	NAMN/AGANet-Lough Navar	DELTA	0.19	1.05	0.84	0.61	0.91	ND[1]	**0.72**	**5**
S79	NAMN-Coleraine	ALPHA	1.98	6.51	1.73	4.68	4.25	2.73	**3.65**	**6**

ND[1]: No Data – damaged, contaminated, or equipment malfunction (leak)

ND[2]: No Data – missing

ND[3]: No Data – power off

[a] *exposed for > 1 month*

Table 7. Monthly NH_3 concentrations (Sep2019 – Feb2020) measured at 28 sites in the new AFBI ALPHA® and DELTA® networks, complemented with measurement at UKEAP NAMN/AGANet (3 sites) and Ballynahone NH_3 study site (UWT3) located in Northern Ireland.

ID	Name	Method	Sep-19	Oct-19	Nov-19	Dec-19	Jan-20	Feb-20	Mean (12 months)	*n*
AFBI01	U of Ulster met station (SNIFFER)	ALPHA	2.92	8.15	3.15	2.29	2.25	1.62	**3.80**	**11**
AFBI02	Castle Enigan	ALPHA	1.89	1.70	1.51	1.27	1.56	1.35	**2.63**	**12**
AFBI03	Beaghs Burn	ALPHA	0.43	0.32	-	0.29	0.46	0.30	**0.54**	**11**
AFBI04	Slieve Beagh	ALPHA	0.57	0.70	0.62	0.46	0.37	0.37	**0.86**	**12**
AFBI05	Moninea Bog	ALPHA	1.57	1.06	0.88	0.98	1.21	0.92	**1.77**	**12**
AFBI06	Drumclamph church	ALPHA	Site relocated to AFBI29 Drumclamph 2							
AFBI07	Seekinore	ALPHA	2.73	2.06	2.80	1.25	1.20	1.11	**2.82**	**12**
AFBI08	Lisbellaw	ALPHA	3.11	3.99	2.01	2.07	1.62	1.66	**3.77**	**12**
AFBI09	Glenwherry COSMOS	ALPHA	1.63	1.49	0.42	1.14	1.74	1.06	**1.66**	**11**
AFBI10	UWMN Bencrom River	ALPHA	[a]0.84	0.46	0.16	0.26	0.56	0.45	**0.78**	**12**
AFBI11	Blackwater town	ALPHA	5.10	4.04	3.88	2.52	2.66	ND[2]	**4.20**	**9**
AFBI12	Ratarnet Rd	ALPHA	ND[1]	ND[1]	3.14	1.81	2.64	2.01	**5.15**	**10**
AFBI13	Inch Abbey	ALPHA	1.62	1.12	0.60	0.89	1.69	0.85	**1.43**	**12**
AFBI14	AURN Belfast centre	ALPHA	3.24	2.88	2.12	2.08	2.58	1.64	**2.80**	**10**
AFBI15	Ballylinney Presbyterian Church	ALPHA	5.65	2.22	1.13	1.74	3.03	1.76	**3.39**	**12**
AFBI16	West of Crumlin	ALPHA	2.48	6.22	1.04	1.88	2.02	1.27	**2.75**	**12**
AFBI17	Loughmore River	ALPHA	0.68	0.61	0.33	0.53	0.60	0.44	**1.01**	**12**
AFBI18	Caldanagh Bog	ALPHA	3.08	2.29	1.38	1.66	2.34	1.49	**2.39**	**11**
AFBI19	Cloughmills	ALPHA	2.52	2.42	1.64	2.28	2.90	1.96	**3.41**	**12**
AFBI20	Caddy Rd	ALPHA	4.39	2.93	ND[1]	2.58	2.97	1.79	**5.30**	**11**
AFBI21	Turmennan Rd	ALPHA	2.89	1.23	0.80	1.07	1.75	1.04	**1.92**	**12**
AFBI22	Carrowbane Rd	ALPHA	4.90	3.14	3.68	1.59	2.12	1.98	**3.94**	**12**
AFBI23	Creggan	ALPHA	2.04	3.03	1.78	ND[2]	2.49	1.50	**2.89**	**11**
AFBI24	Corramore Rd	ALPHA	0.78	0.52	0.20	0.35	0.51	0.44	**0.87**	**12**
AFBI29-A	Drumclamph 2	ALPHA	4.91	8.17	3.61	2.08	1.96	2.22	**3.82**	**6**
AFBI25	Hillsborough	ALPHA	8.64	6.13	4.12	4.63	5.94	4.12	**7.49**	**12**
AFBI25	Hillsborough	DELTA	8.23	6.83	3.57	4.28	4.11	ND[2]	**6.43**	**7**
AFBI26	Ballynahone Bog	DELTA	ND[1]	4.10	ND[1]	ND[1]	2.96	1.19	**3.29**	**8**
UWT3	Ballynahone: co-located with AFBI26	ALPHA	ND[2]	3.79	1.61	4.00	2.88	1.39	**3.46**	**10**
AFBI27	U of U Coleraine Met Station	DELTA	1.13	4.57	1.00	1.12	1.15	1.13	**1.78**	**10**
AFBI28	Sandholes	DELTA	ND[1]	4.91	4.06	2.90	2.81	2.27	**3.99**	**9**
S44	NAMN/AGANet-Hillsborough	DELTA	ND[1]	2.85	1.84	ND[1]	1.42	ND[1]	**2.68**	**8**
S45	NAMN/AGANet-Lough Navar	DELTA	0.33	0.40	0.29	ND[1]	ND[1]	0.25	**0.54**	**9**
S79	NAMN-Coleraine	ALPHA	3.48	2.61	2.94	3.01	2.67	1.18	**3.15**	**12**

ND[1]: No Data – damaged, contaminated, or equipment malfunction (leak)

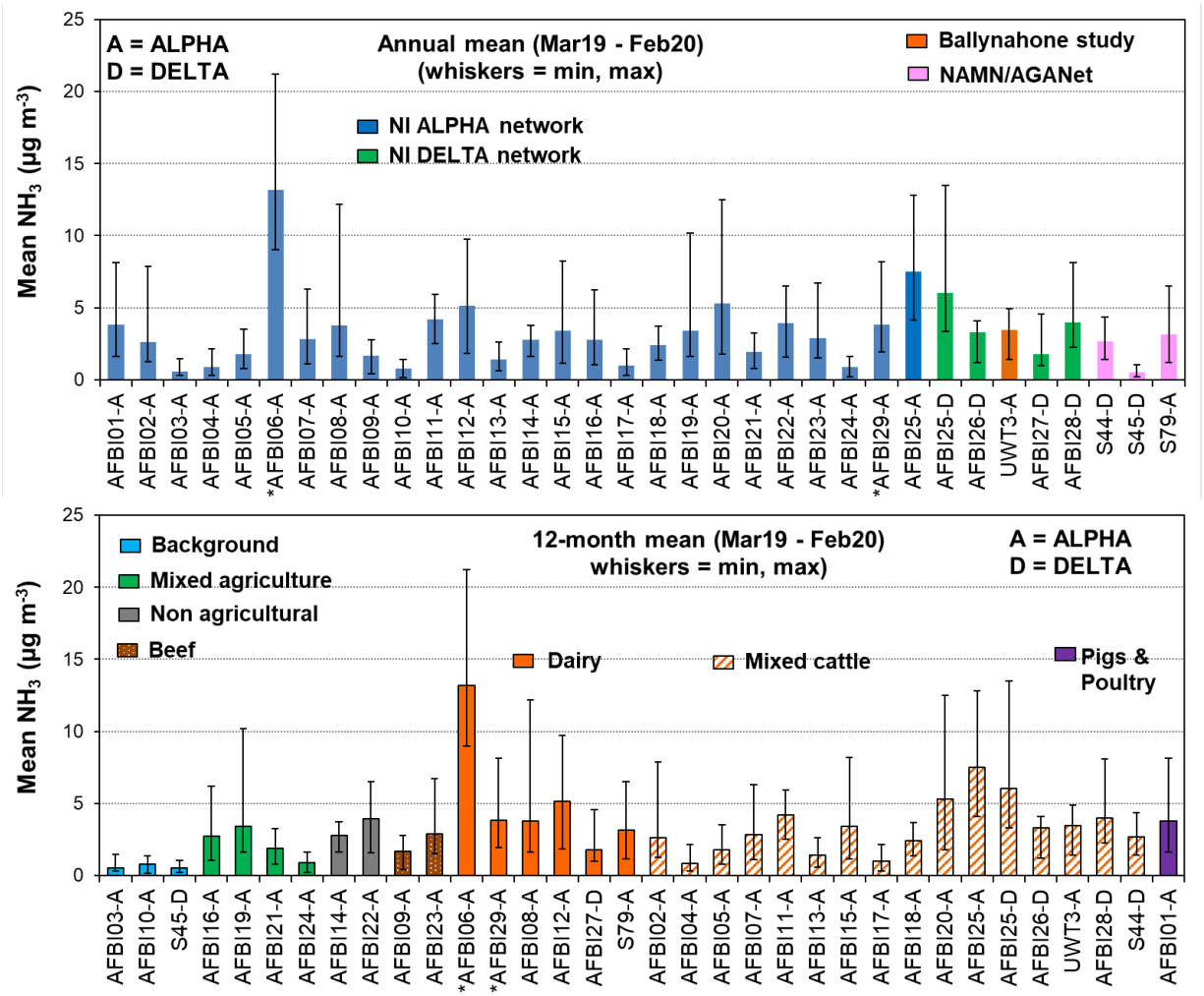
ND[2]: No Data – missing

ND[3]: No Data – power off

[a] *exposed for > 1 month*

Full details of exposure information and air concentration measurements for all sites are provided in the appendix. Data for the UKEAP NAMN/AGANet DELTA sites Hillsborough (S44) and Lough Navar (S45) and for the UKEAP NAMN ALPHA site Coleraine (S79) were accessed from the Department for Environment, Food & Rural Affairs (Defra) UK-AIR database (https://uk-air.defra.gov.uk/; 2019 and 2020 ratified data). Data for the Ballynahone UWT3 sites come from the Ballynahone Bog monitoring study that UKCEH is undertaking on behalf of the Ulster Wildlife and NIEA since October 2014 (Stephens and Tang 2019; Stephens et al., 2021a,b; Tang et al., 2021).

Figure 11: Mean monitored NH_3 concentrations, shown with the minimum and maximum values for each site at the new AFBI ALPHA® and DELTA® network sites across Northern Ireland. Data from Ballynahone UWT3 ALPHA® site (co-located with AFBI26 DELTA®; Stephens & Tang 2019) and from three UK national network sites (S44, S45 and S79) are also included for comparison. Top graph shows the site data in chronological order. Bottom graph shows the site data grouped according to their dominant NH_3 emission source classifications. *AFBI06 Drumclamph (Mar-Aug19 only), relocated to *AFBI29 Drumclamph 2 (Sep19-Feb20)



Monitored NH_3 concentrations across Northern Ireland are highly spatially variable and range from annual mean concentrations of 0.54 (AFBI03 Beaghs Burn) to 7.5 µg NH_3 m^{-3} (AFBI25 Hillsborough ALPHA® data) across the 28 sites for the full twelve month period from March 2019 to February 2020 (AFBI06 Drumclamph excluded) (Figure 11). If Site AFBI25 Hillsborough is also excluded (as it was deliberately placed close to a

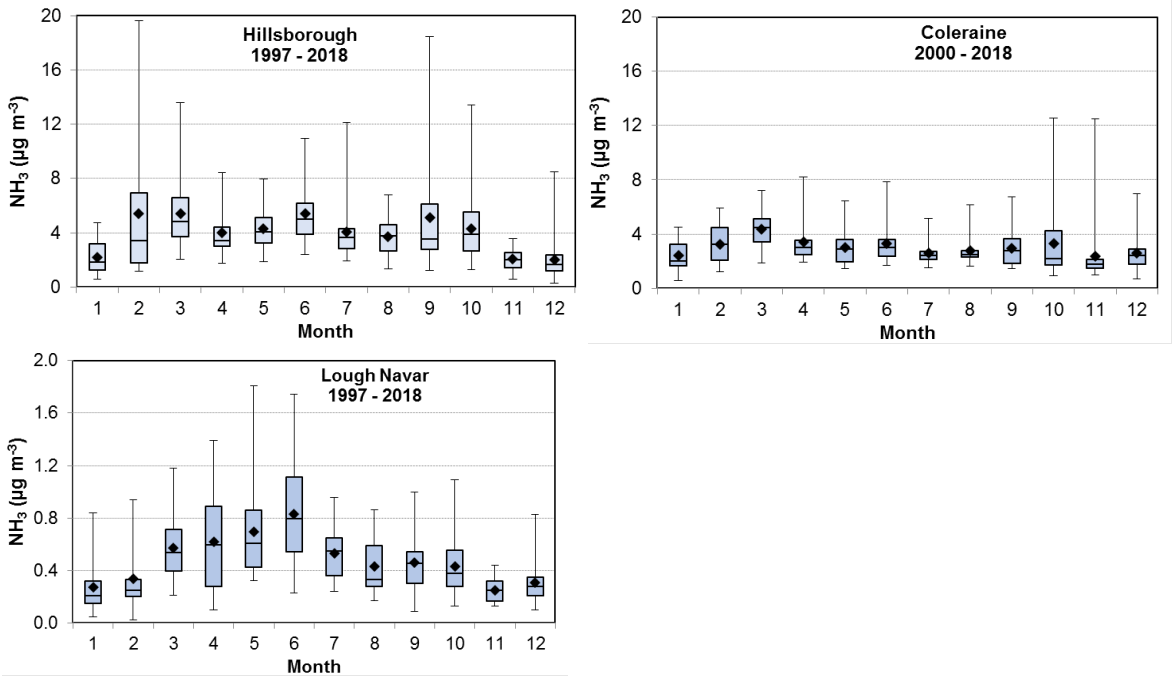
large farm source), then the mean annual concentrations range from 0.54 to 5.3 µg NH_3 m^{-3} (AFBI20 Caddy Road).
Differences in magnitude of concentrations are also related to emission source type (Figure 11). In addition, substantial variability is apparent at some sites between months, as indicated by the minimum and maximum values that are also plotted with the mean data. For example, the mean concentration at AFBI20 Caddy Rd is 5.3 µg NH_3 m^{-3}, but the range of monthly concentrations for the 12 month period was highly variable (1.8 to 12.5 µg NH_3 m^{-3}). Further analysis and discussions on seasonal variability in NH_3 concentrations are presented in the next section (Sect. 3.2).

3.2 Seasonal variability in NH_3 concentrations

3.2.1 National network sites in NI

Atmospheric NH_3 gas is known to be seasonally variable (Tang et al. 2018). To illustrate the seasonal variability in atmospheric NH_3 concentrations, long-term data from three UK national network sites in Northern Ireland (S79 Coleraine, S44 Hillsborough and S45 Lough Navar) were analysed and are presented here as examples.

Figure 12: Box plots showing changes in monthly mean NH_3 concentrations averaged over all years at three existing national network sites in Northern Ireland (S44 Hillsborough, S79 Coleraine and S45 Lough Navar; dominant emissions source category = Mixed cattle, Dairy and Beef, respectively). The diamonds show the monthly mean NH_3 concentration, with the grey box indicating the median and interquartile range, while the error bars show the range (minimum and maximum) of measured monthly concentrations.



Lough Navar is a background site located in the west of NI. Although the modelled dominant emissions source for the 5 km grid square containing the site is beef, local knowledge and the low annual mean monitored NH_3 concentrations (0.56 µg NH_3 m^{-3} in 2018) suggest that this is actually a background site. The distinct seasonal cycle for this site is also characteristic of a background site, with clear summer maxima and winter minima (Figure 12). In the summer months, peak concentrations are due to increased land surface volatilization of NH_3 in warm, dry conditions from low density grazing livestock and wild animals such as deer, as well as a potential role of the NH_3 compensation point of plants (Tang et al. 2018). Low temperatures and wetter conditions in the winter months produce the winter minima. Seasonal cycles at background sites, away from large emission sources, are therefore largely driven by changes in temperature and rainfall.

By contrast, Coleraine and Hillsborough are both in agricultural landscapes, reflected by the much higher annual mean monitored NH_3 concentrations of 4.4 and 3.1 µg NH_3 m^{-3} in 2018, respectively. The modelled dominant emission sources for the two sites are dairy and mixed cattle. Compared with Lough Navar, a more complex seasonal pattern is observed at Coleraine and Hillsborough. At these sites, the largest NH_3 concentrations occur in spring and autumn, corresponding to periods when manure/slurry are usually applied to land (Figure 12). NH_3 concentrations are also high in the summer months from increased grazing emissions promoted by warm, dry conditions, adding to the complex seasonal pattern. The key drivers for seasonal variability in NH_3 concentrations in cattle dominated areas are therefore a combination of agricultural practices (manure applications, grazing etc.) and weather that will affect emissions and atmospheric transport and deposition of NH_3.

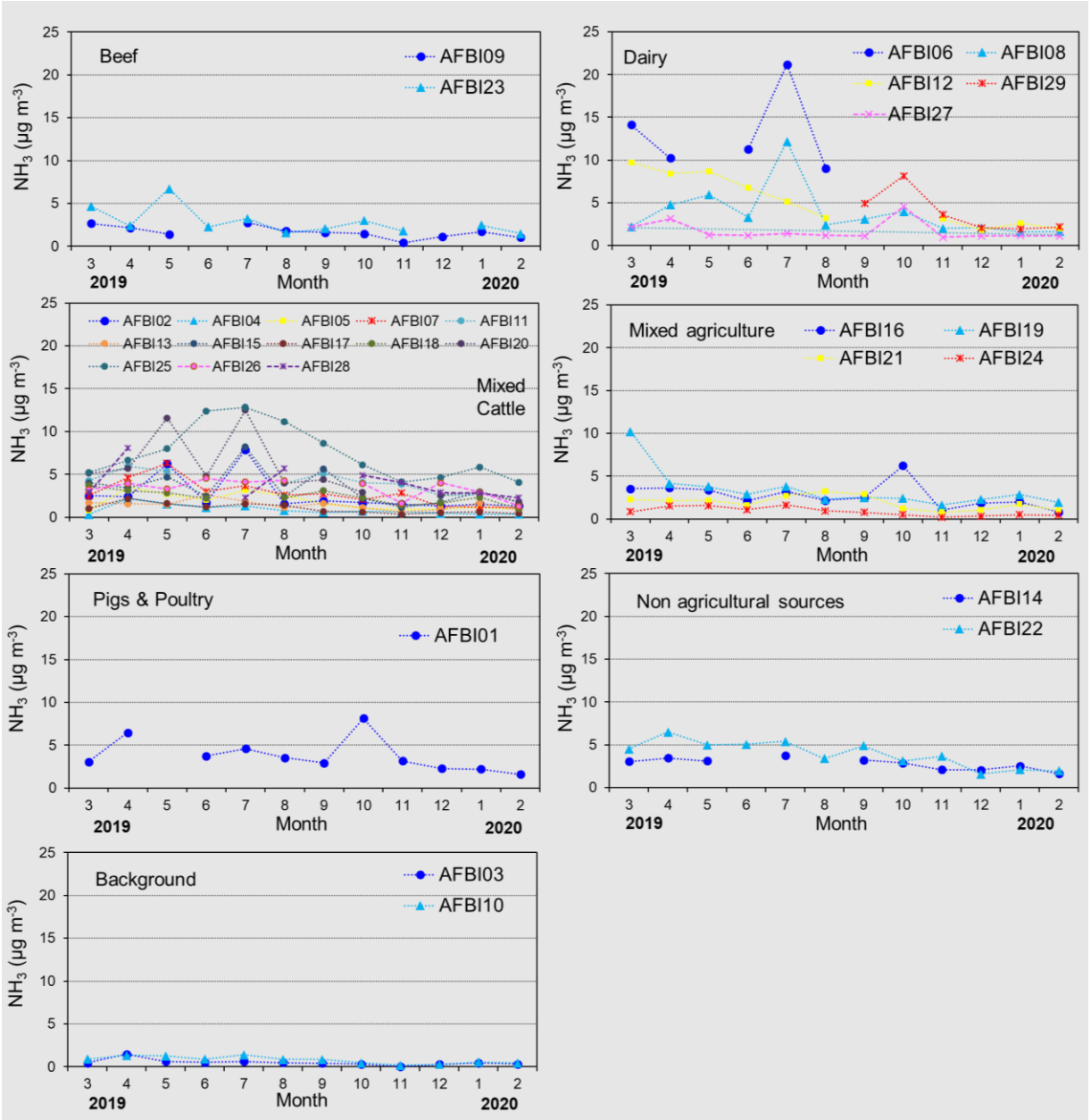
3.2.2 New NI network data

Sites are further categorized on the basis of the AENEID model output according to dominant modelled NH_3 source for each 5 km grid cell (see Section 2.4), to aid interpretation of seasonal patterns in NH_3 concentrations. Since there are no 5 km grid squares in NI with emissions dominated by either sheep or fertilizers, these two categories have no representation.
The five dominant emission source sectors covered by the new network sites in NI are:

- Cattle (beef, dairy, mixed)
- Pigs & Poultry (combined for data disclosivity reasons)
- Non-agricultural sources
- Mixed (where no single source dominates, i.e. contributes >45%)
- Background (very low NH_3 emissions of <1 kg N ha^{-1} y^{-1}).

The time series of monthly NH_3 concentrations measured at all 28 sites in the new network are shown in Figure 13. The sites are grouped according to their dominant emission source categories in each of the graphs. This allows a visual comparison of seasonal patterns between the different categories, and also between sites in each of the categories. The first 12 months of data (March 2019 to February 2020) show informative differences in concentrations between months and differences in the magnitude of concentrations between sites from different source categories.

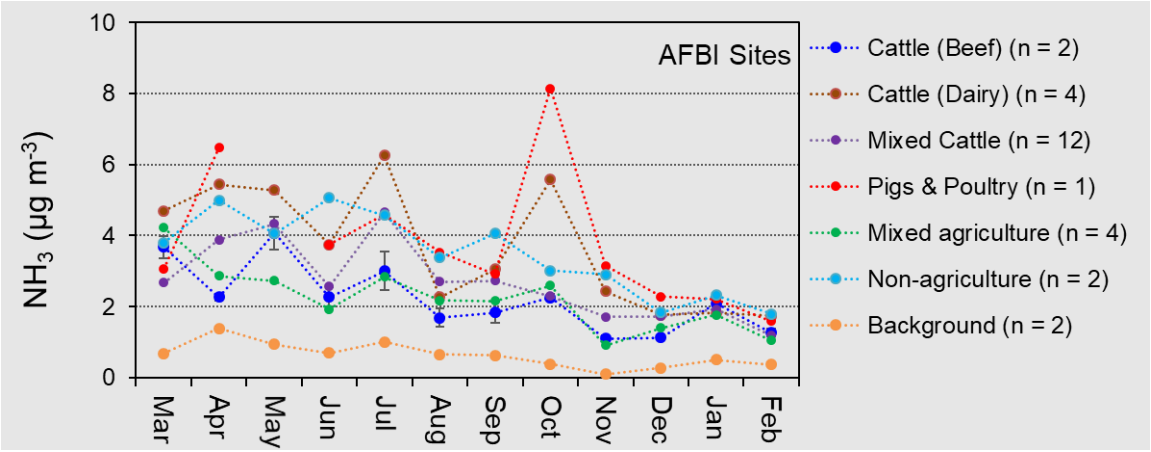
Figure 13: Time series of monthly NH_3 concentrations measured at sites (12 months of data from Mar 2019 to Feb 2020) in the NI ALPHA® and DELTA® networks, grouped according to dominant emission source sectors. The graphs are plotted on the same scale, to permit comparison of the magnitude of concentrations. N.B. Sites AFBI06 (Drumclamph) was discontinued in August 2019 due to a large local source, and AFBI25 (Hillsborough) is not representative for the surrounding area as it was deliberately set up close to a large emission source.



The average time series of grouped site data from the different NH_3 emission source categories are also plotted together in

Figure 14 to allow a direct comparison. A number of broad patterns can be seen that is related to emission source types and to seasonal changes in weather.

Figure 14: Seasonal cycles of NH_3 concentrations from the mean data (12 months of available data from Mar 2019 to Feb 2020) of all sites in the NI ALPHA® and DELTA® networks, grouped according to dominant emission source sectors. Sites AFBI06 (Drumclamph: cattle dairy) was discontinued in August 2019 due to a large local source, and AFBI25 (Hillsborough: mixed cattle) is not representative for the surrounding area as it was deliberately set up close to a large emission source. These two sites were excluded from the above analysis.



Background sites

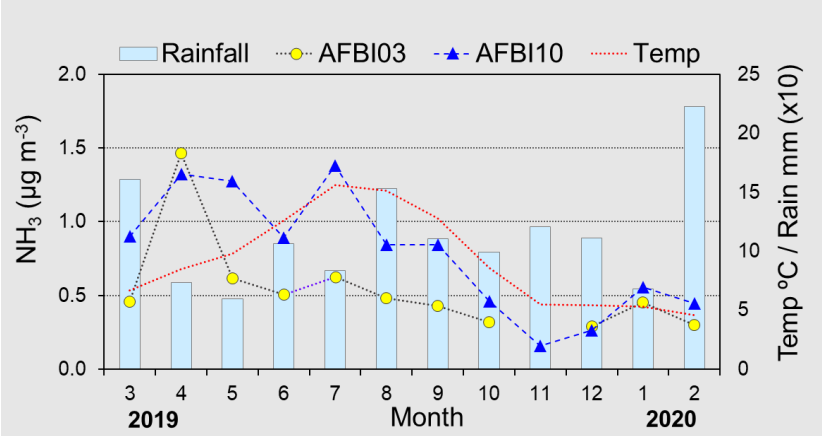
The smallest NH_3 concentrations in the network are seen at the two background sites AFBI03 Beaghs Burn and AFBI10 Bencrom River, with mean monitored concentrations of 0.54 (*n* = 11) and 0.78 µg NH_3 m^{-3} (*n* = 11, August and September 2019 = 2 month exposure), respectively. Monthly mean concentrations at these two sites ranged between 0.16 – 1.46 µg NH_3 m^{-3} over the 12 month period between March 2019 and February 2020. There are two peaks in the seasonal cycle, in April (mean = 1.4 µg NH_3 m^{-3}, *n* = 2) and in July (mean = 1.0 µg NH_3 m^{-3}, *n* = 2) (Figure 13,

Figure 14).

The large NH_3 concentrations in July (Figure 15) may be attributed to an unusually warm and relatively dry month in Northern Ireland (

Figure 16), while the presence of the April peak at both background sites suggests the influence of agricultural emissions (e.g. from land spreading of manures from housed livestock to spring growth) even at these background sites. It is also notable that the April peak at AFBI03 Beaghs Burn (1.5 μg NH_3 m^{-3}) is almost 2.5 times larger than the summer peak (0.6 μg NH_3 m^{-3}).

Figure 15: Temporal trends in monthly monitored NH_3 concentrations at two background sites (AFBI03 Beaghs Burn and AFBI10 Bencrom River) between March 2019 and February 2020. Monthly mean rainfall and temperature data (https://www.metoffice.gov.uk/pub/data/weather/uk/climate/datasets/; accessed 01/02/2021) for the whole of Northern Ireland over the same period are also plotted for comparison.



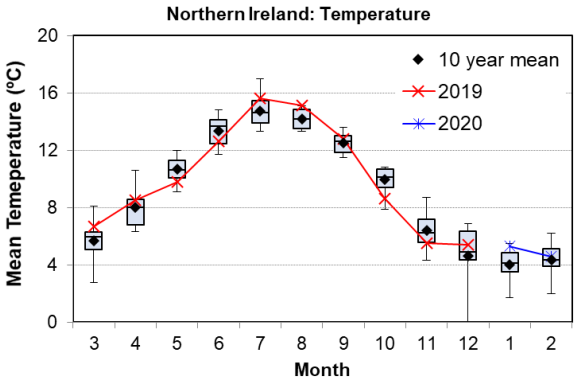
Cattle sites

At sites in cattle areas (beef, dairy and mixed cattle), there is a very pronounced peak in concentrations in July that is larger than the spring peak. This is surprising since the spring peak from manure spreading is usually expected to be larger than land surface emissions in summer (*cf*. Figure 12). A possible reason for the large July peak could be an unusually hot, dry July in 2019 (
Figure 16), with below average rainfall and record-breaking temperatures from 22 – 26 July (https://www.metoffice.gov.uk/pub/ data/weather/uk/, accessed 01/02/2021). A high pressure system over the country for parts of this month may also have created more stable than usual conditions, resulting in a build-up of NH_3 concentrations over this time.

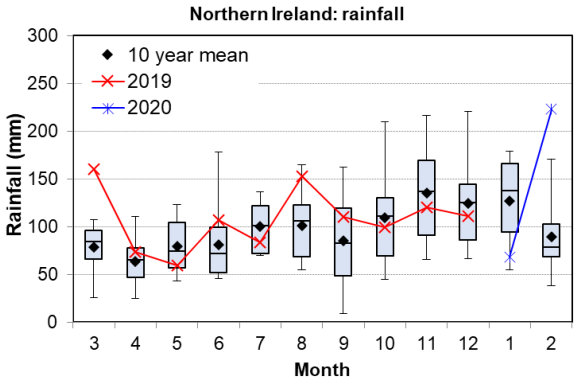
The July peak is followed by a dip in concentrations in August across all sites and is most likely attributed to a very wet August where rainfall was 162% of average. Increases in precipitation decrease NH_3 emissions because rain events dilute the available NH_3 pool, and the potential to wash urea and nitrogen species in solution from the surface. As NH_3 is soluble and is washed out of the atmosphere by rainfall, this should also contribute to reduced atmospheric NH_3 concentrations during wet periods.

Figure 16: Comparison of 2019 (Mar to Dec) and 2020 (Jan to Feb) mean monthly temperature and rainfall data with 10-year averaged monthly data (2009 to 2018) in Northern Ireland (https://www.metoffice.gov.uk/pub/ data/weather/uk/climate/datasets/, accessed 01/02/2021). The diamonds in the boxplots show the mean, with grey box indicating the median and interquartile range, while the error bars show the range (minimum and maximum). July 2019 was drier (86.7 mm cf. mean = 101 mm for 2009-2018) and August 2019 was wetter (158 mm cf. mean = 102 mm for 2009-2018) compared with the 10 year average (2009-2018).

(a)



(b)



Pigs & poultry site

AFBI01 University of Ulster met station is the only site which is located in a grid square classed as dominated by emissions from pigs & poultry. The annual mean concentration from this site was 3.8 μg NH_3 m^{-3}, with peak concentrations in October (8.1 μg NH_3 m^{-3}) and also in April (6.5 μg NH_3 m^{-3}) likely associated with manure spreading to fields. Like at all other sites, a third, smaller peak in July (4.6 μg NH_3 m^{-3}) is likely weather-related, with increased emissions of NH_3 in warmer, drier conditions.

3.3 Monitored vs modelled NH_3

In this report, the first full year of NH_3 data (March 2019 to February 2020) from the ALPHA® and DELTA® networks are compared with modelled NH_3 concentrations from FRAME 2016 (see Sect. 2.3). The FRAME model output is a transformed FRAME NH_3 concentration field for the UK at a 1 km grid resolution. A scaling factor based on the median model bias from calibration with annual mean UK NAMN network site concentrations is applied to the FRAME estimates for each grid square to provide a calibrated NH_3 concentration field. The transformed FRAME model output is considered to provide the best high-resolution estimate of the NH_3 air concentration field nationally for application in nitrogen deposition models.
For the comparisons, the following sites were excluded:

- **AFBI06 Drumclamph**, affected by close proximity to local sources and therefore considered not to be a representative location for the 1 km x 1 km grid square.
- **AFBI25 Hillsborough**, since the intention of this site is to assess spatial variability at the Hillsborough intensive site and not to provide a representative monitoring location for the 1 km x 1 km grid square.

The comparison of year 1 annual mean NH_3 concentrations (Mar19 – Feb20) with the modelled surface concentrations from the FRAME atmospheric transport model (2016) show broad agreement (

Table 8, Figure 17), regarding both magnitude and spatial variability. The good agreement between 2016 FRAME data and the results of the new network therefore broadly support the model predictions.

In the comparison plot (Figure 17), the sites are also further identified by their estimated dominant NH_3 emission source sector for the 5 km grids in which sampling sites occur. Apart from mixed agriculture sites, there appears to be no systematic difference in the comparison between measured and modelled data. At mixed agriculture sites (n = 3), there is a systematic difference, with all sites having smaller concentrations than predicted by FRAME.

Differences between measured and modelled concentrations reflect the large local variability in NH_3 concentrations and the comparison of a point measurement with a model grid square average (e.g. due to nearness of monitoring point to sources at a local scale), or to uncertainties in the emissions estimates for different source sectors within the grid square.

Uncertainties in this approach include:

1. Local scale variability: over-estimation or under-estimation of emissions and concentrations due to spatial uncertainty, particularly in complex source areas which may require the development of emission estimates at finer scale.
2. Accuracy of the emission data for each source sector,
3. Accuracy of the model dispersion scheme,
4. Other non-linear effects such as the effects of NH_3 compensation points in regulating NH_3 concentrations.

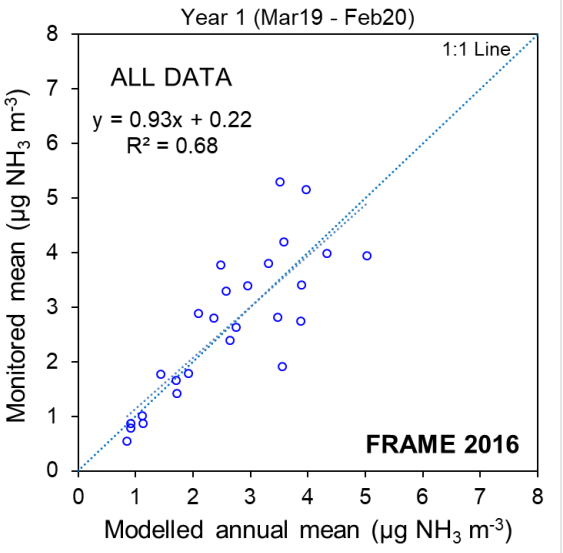
The year 1 annual data from 28 sites were compared with the UK national FRAME output (2016 emission year) which is calibrated with NAMN NH_3 data only (3 sites in NI). More recently available transformed FRAME outputs are also available for the emission years 2017 and 2018. Ongoing analysis will provide a new calibrated FRAME concentration surface using the NI-wide network rather than the current standard NAMN network with only three sites located in Northern Ireland. This surface will then be compared with the standard model calibration method (NAMN only).

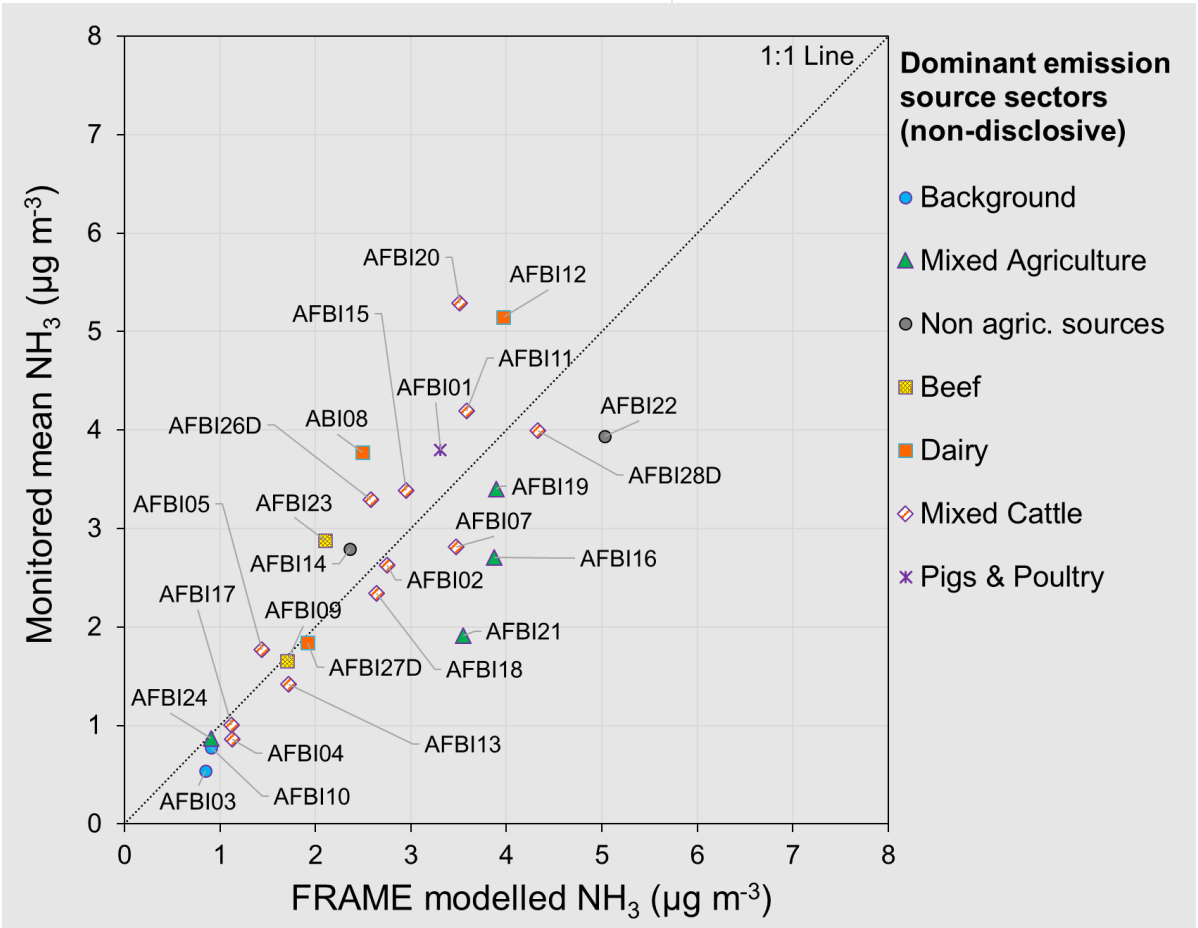
Table 8. Comparison of mean monitored NH_3 concentrations with FRAME modelled concentrations.

ID	Method	2016 FRAME NH_3	12 months: Mar19 – Feb20		Ratio
			Annual mean NH_3 (µg m^{-3})	*n*	*Monitored/measured*
AFBI01	ALPHA	3.31	**3.80**	11	1.1
AFBI02	ALPHA	2.75	**2.63**	12	1.0
AFBI03	ALPHA	0.85	**0.54**	11	0.6
AFBI04	ALPHA	1.13	**0.86**	12	0.8
AFBI05	ALPHA	1.44	**1.77**	12	1.2
#AFBI06	ALPHA	3.27	**13.7**	6	n/a
AFBI07	ALPHA	3.47	**2.82**	12	0.8
AFBI08	ALPHA	2.49	**3.77**	12	1.5
AFBI09	ALPHA	1.70	**1.66**	11	1.0
AFBI10	ALPHA	0.91	**0.78**	12	0.9
AFBI11	ALPHA	3.58	**4.20**	9	1.2
AFBI12	ALPHA	3.97	**5.15**	10	1.3
AFBI13	ALPHA	1.72	**1.43**	12	0.8
AFBI14	ALPHA	2.36	**2.80**	10	1.2
AFBI15	ALPHA	2.95	**3.39**	12	1.1
AFBI16	ALPHA	3.87	**2.75**	12	0.7
AFBI17	ALPHA	1.12	**1.01**	12	0.9
AFBI18	ALPHA	2.64	**2.39**	11	0.9
AFBI19	ALPHA	3.89	**3.41**	12	0.9
AFBI20	ALPHA	3.51	**5.30**	11	1.5
AFBI21	ALPHA	3.55	**1.92**	12	0.5
AFBI22	ALPHA	5.03	**3.94**	12	0.8
AFBI23	ALPHA	2.10	**2.89**	11	1.4
AFBI24	ALPHA	0.91	**0.87**	12	1.0
#AFBI29	ALPHA		**3.82**	6	n/a
*AFBI25	ALPHA	2.54	**7.49**	12	n/a
*AFBI25	DELTA	2.54	**6.43**	7	n/a
AFBI26	DELTA	2.58	**3.29**	8	1.3
UWT3	ALPHA	2.58	**3.46**	10	1.3
AFBI27	DELTA	1.92	**1.78**	10	0.9
AFBI28	DELTA	4.33	**3.99**	9	0.9
S44	DELTA		**2.68**	7	
S45	DELTA		**0.55**	*9*	
S79	ALPHA		**3.15**	12	

*AFBI25 Hillsborough ALPHA/DELTA site is not intended to be included in the spatial assessment for Northern Ireland. The purpose of this site is for co-location with the Picarro CRDS continuous NH_3 measurements, for comparison between the methods. #AFBI06 Drumclamph was discontinued after five months in summer 2019 as not representative and replaced with AFBI29. Site AFBI29 does not have a full year's data yet (see column "n").

Figure 17: Top: Comparison of annual mean monitored NH_3 concentrations (March 2019 to February 2020) at the new ALPHA® and DELTA® sites in Northern Ireland, with annual average transformed NH_3 concentrations from the FRAME model (2016 emission year). Bottom: Same plot, but with each data point colour-coded according to the estimated dominant NH_3 emission source category for the 5 km by 5 km grid square.



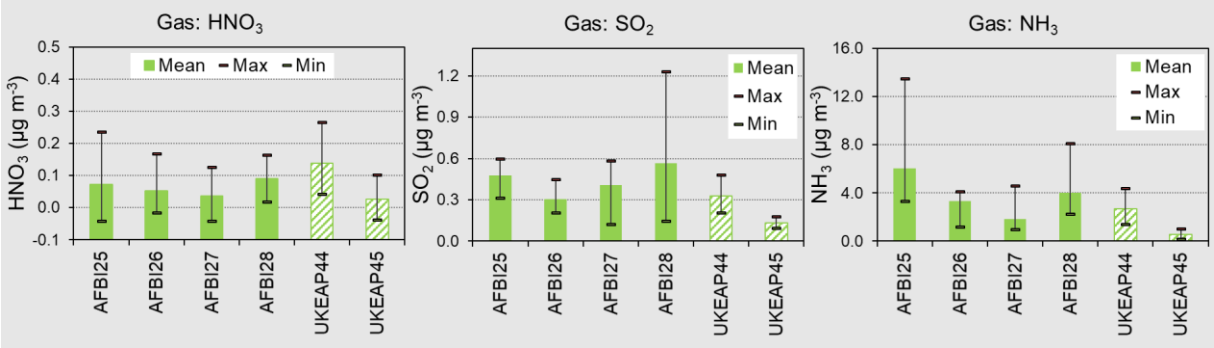


3.4 DELTA measurements

The new DELTA® network provides monthly concurrent measurement data on gaseous NH_3, HNO_3, SO_2 and particulate NH_4^+, NO_3^-, SO_4^{2-}, Cl^-, plus base cations Na^+, Ca^{2+} and Mg^{2+}. The first year of data from the new DELTA® sites is summarised in Figure 18 (gases: HNO_3, SO_2, NH_3 and related aerosols: NO_3^-, SO_4^{2-}, NH_4^+) and Figure 19 (Aerosols: Cl^-, Na^+, Ca^{2+}, Mg^{2+}). Measurement data from the two UKEAP NAMN/AGANet sites S44 Hillsborough and S45 Lough Navar made with the same DELTA® method and by the same UKCEH laboratory were also included to extend the dataset.

Figure 18: Annual mean measured concentrations of reactive gases (NH_3, HNO_3 and SO_2) and related aerosols (particulate NH_4^+, NO_3^- and SO_4^{2-}). Each data point represents the averaged concentrations of monthly measurements made at each site over the 12-month period between March 2019 to February 2020, with the error bars showing the minimum and maximum concentrations. Rejected data (see appendix) are excluded from the analysis.

Name	Nitric Acid: µg HNO_3 m^{-3}						Sulphur Dioxide: µg SO_2 m^{-3}						Ammonia: µg NH_3 m^{-3}					
	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N
AFBI25	0.09	-0.04	0.24	0.14	154	4	0.49	0.42	0.60	0.07	14	6	6.82	3.57	13.48	3.71	54	6
AFBI26	0.05	-0.02	0.17	0.06	114	7	0.30	0.20	0.45	0.07	23	8	3.29	1.19	4.10	0.97	29	8
AFBI27	0.01	-0.05	0.13	0.07	681	6	0.33	0.12	0.53	0.16	47	8	1.93	1.00	4.57	1.30	67	8
AFBI28	0.09	0.02	0.16	0.05	61	6	0.57	0.15	1.23	0.34	60	9	3.99	2.27	8.10	1.94	49	9
UKEAP44	0.14	0.04	0.27	0.09	61	6	0.33	0.21	0.48	0.09	29	7	2.68	1.42	4.37	1.02	38	7
UKEAP45	0.03	-0.04	0.10	0.05	177	8	0.13	0.10	0.18	0.03	20	9	0.54	0.19	1.05	0.32	59	9



Name	Nitrate: µg NO_3^- m^{-3}						Sulphate: µg SO_4^{2-} m^{-3}						Ammonium: µg NH_4^+ m^{-3}					
	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N
AFBI25	2.60	1.02	7.59	2.80	108	5	0.91	0.55	2.17	0.70	77	5	0.98	0.38	2.82	1.04	106	5
AFBI26	1.69	0.56	6.17	1.84	109	8	0.65	0.15	1.91	0.53	81	8	0.84	0.25	2.41	0.71	85	8
AFBI27	1.64	0.29	4.78	1.51	92	8	0.54	0.17	1.62	0.48	88	8	0.68	0.17	1.88	0.57	84	8
AFBI28	1.15	0.32	3.02	0.86	75	9	0.42	0.21	0.76	0.19	44	9	0.51	0.28	1.12	0.30	60	9
UKEAP44	2.69	1.05	6.89	2.01	75	7	0.65	0.32	1.67	0.46	71	7	1.17	0.38	2.64	0.81	69	8
UKEAP45	1.46	0.19	4.92	1.42	97	9	0.57	0.21	1.64	0.43	75	9	0.61	0.19	1.98	0.55	91	9

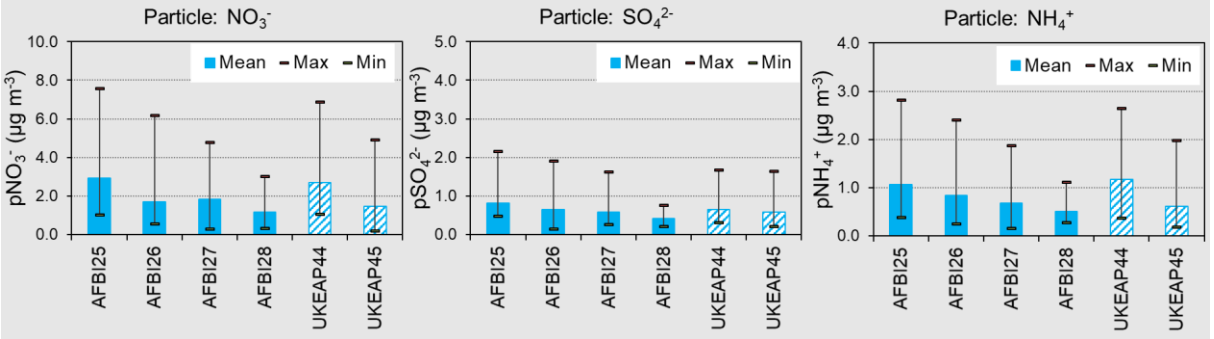
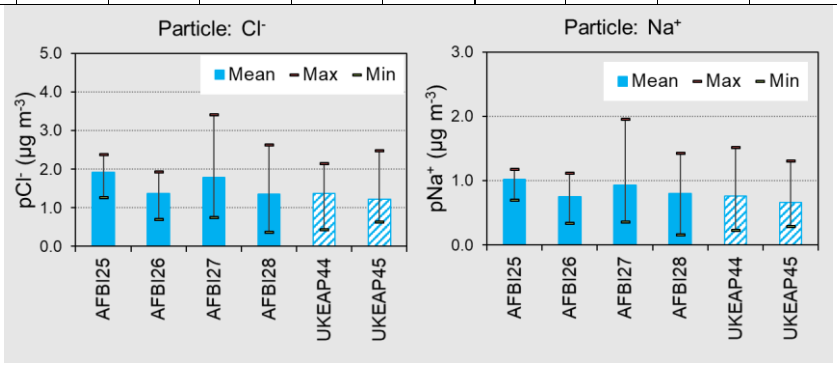
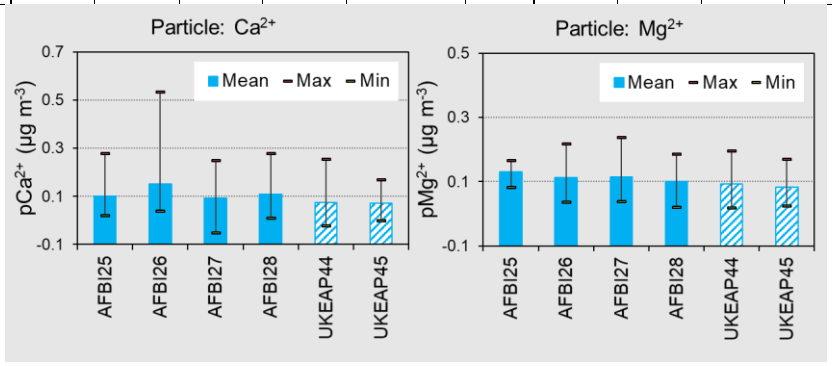


Figure 19: Annual mean measured concentrations of particulate Cl- and base cations (Ca^{2+}, Mg^{2+} and Na^{+}). Each data point represents the averaged concentrations of monthly measurements made at each site over the 12-month period between March 2019 to February 2020, with the error bars showing the minimum and maximum concentrations. Rejected data (see appendix) are excluded from the analysis.

	Chloride: µg Cl^{-} m^{-3}						Sodium: µg Na^{+} m^{-3}					
Name	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N
AFBI25	1.73	1.28	2.00	0.29	17	5	0.97	0.70	1.12	0.17	17	5
AFBI26	1.37	0.71	1.93	0.48	35	8	0.75	0.34	1.12	0.29	38	8
AFBI27	1.46	0.58	3.42	0.94	64	8	0.77	0.23	1.96	0.57	74	8
AFBI28	1.35	0.37	2.63	0.78	57	9	0.84	0.16	1.43	0.52	62	9
UKEAP44	1.37	0.44	2.15	0.61	45	8	0.76	0.23	1.53	0.42	56	8
UKEAP45	1.23	0.64	2.49	0.58	47	10	0.67	0.29	1.31	0.36	54	10

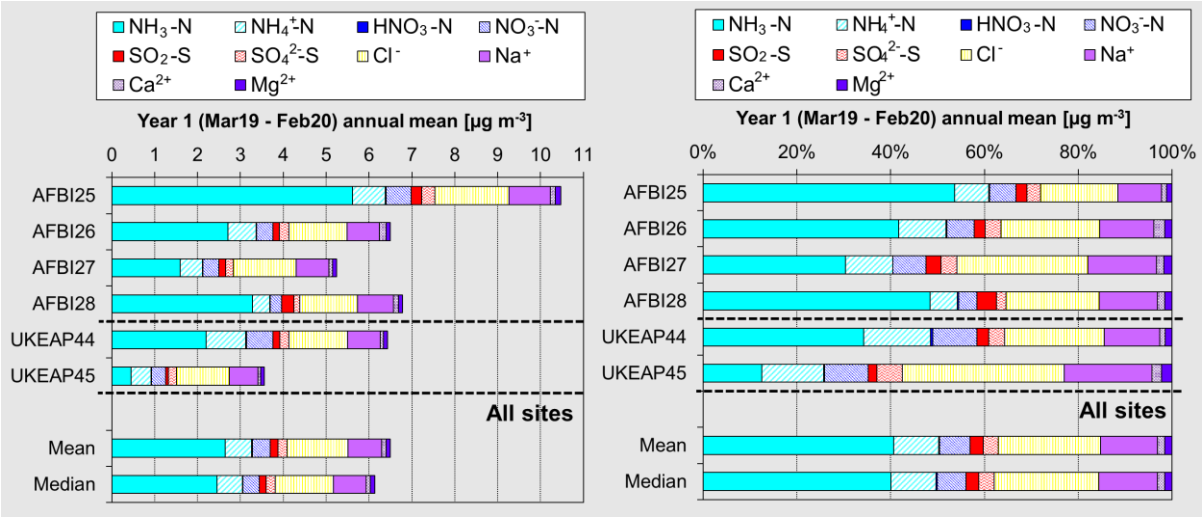


	Calcium: ug Ca^{2+} m^{-3}						Magnesium: ug Mg^{2+} m^{-3}					
Name	Mean	Min	Max	SD	CV (%)	N	Mean	Min	Max	SD	CV (%)	N
AFBI25	0.12	0.02	0.28	0.10	82	5	0.13	0.08	0.17	0.03	25	5
AFBI26	0.15	0.04	0.53	0.17	111	8	0.10	0.04	0.15	0.04	38	8
AFBI27	0.08	-0.05	0.20	0.07	95	8	0.10	0.03	0.24	0.07	73	8
AFBI28	0.11	0.01	0.28	0.08	74	9	0.10	0.02	0.19	0.07	63	9
UKEAP44	0.07	-0.02	0.25	0.08	112	8	0.09	0.02	0.20	0.06	62	8
UKEAP45	0.07	0.00	0.17	0.05	69	10	0.08	0.02	0.17	0.05	59	10



A comparison of the gas phase annual mean concentrations shows that there is much more NH_3 (1.8 – 6.0 µg NH_3 m^{-3}) than either SO_2 (0.30 – 0.57 µg SO_2 m^{-3}) or HNO_3 (0.03 – 0.09 µg HNO_3 m^{-3}) at these sites (Figure 19 and Figure 20). The smallest NH_3, HNO_3 and SO_2 concentrations are seen at Lough Navar, in the west of Northern Ireland. This is a remote site located away from sources (e.g. agriculture for NH_3 and combustion for HNO_3 and SO_2), and where the influence of continental Europe (long-range transboundary transport of atmospheric pollutants) is also smallest.

Figure 20: (LEFT) Annual averaged gas and aerosol concentrations (Mar2019 – Feb2020) of sites in Northern Ireland from the new NI DELTA® network (4 sites) and from UK Acid Gas and Aerosol Network (AGANet; 2 sites S44 Hillsborough and S45 Lough Navar). (RIGHT) the same data expressed as percentage composition of total mass of inorganic gas and aerosol components measured.



There are significant correlations between the concentrations of the different aerosol components (on a molar basis; Figure **21** and Figure 22). The molar concentrations of the basic particulate NH_4^+ from all DELTA sites are highly correlated with the sum of the acidic particulate NO_3^- and SO_4^{2-} (slope = 0.97, R^2 = 0.92;), demonstrating the close coupling between NH_4^+ with both NO_3^- and SO_4^{2-} (Figure **21**). Particulate NH_4^+ concentrations (28 – 65 nmoles) are in molar excess over NO_3^- (19 – 43 nmoles) and SO_4^{2-} (4.4 – 9.5 nmoles). This suggests that ammonium aerosols in Northern Ireland is more nitrate- than sulfate-rich, similar to that observed in the wider UK (Tang et al. 2018b).

The near 1:1 relationship and high correlation between Cl^- and Na^+ (slope = 0.97, R^2 = 0.91) on the other hand is consistent with a marine origin (sea salt NaCl) for these ions in the UK (Figure 22). The high correlations between the aerosol species also indicate the quality of the measurements, since uncertainty in the measurements on a monthly basis would propagate through to scatter in these plots. For the base cations Ca^{2+} and Mg^{2+}, there is high uncertainty in the measurements as the concentrations are mainly at or below the method limit of detection. The Ca^{2+} and Mg^{2+} data should therefore be treated with caution.

Figure 21: Scatter plots showing the relationships between concentrations of (a) NH_4^+ and sum (NO_3^-, SO_4^{2--}), (b) NH_4^+ and NO_3^-, and (c) NH_4^+ and SO_4^{2-}, from the monthly measurements (March

2019 to Feb 2020) at the 4 AFBI and UK national network DELTA sites. Rejected data (see appendix) are excluded from the analysis.

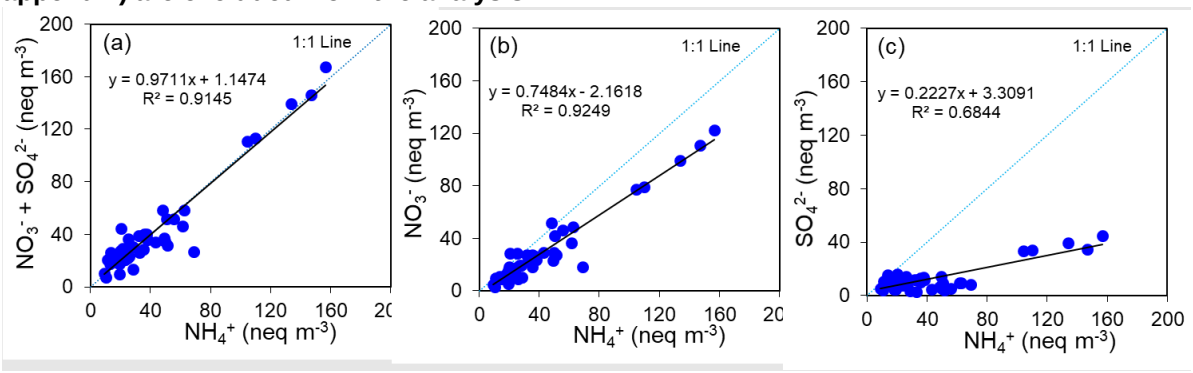


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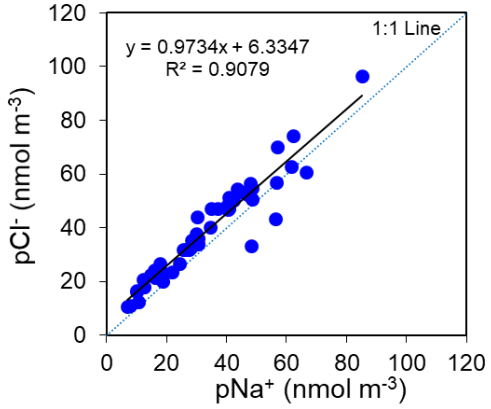
Figure 22: **Scatter plot showing the relationship between concentrations of Na^+ and Cl^- from the monthly measurements (March 2019 to Feb 2020) at the 4 AFBI and UK national network DELTA sites. Rejected data (see appendix) are excluded from the analysis.**



3.4.1 Seasonal trends

The seasonal profile derived for NH_3 from the four NI DELTA and two UK AGANet DELTA sites (Figure 23) show largest concentrations in July (increased emissions in hot, dry conditions). Smaller peaks in the autumn and spring may be related to manure spreading activities, as discussed in Section 3.2.

For HNO_3, the following processes will influence its seasonal distribution:

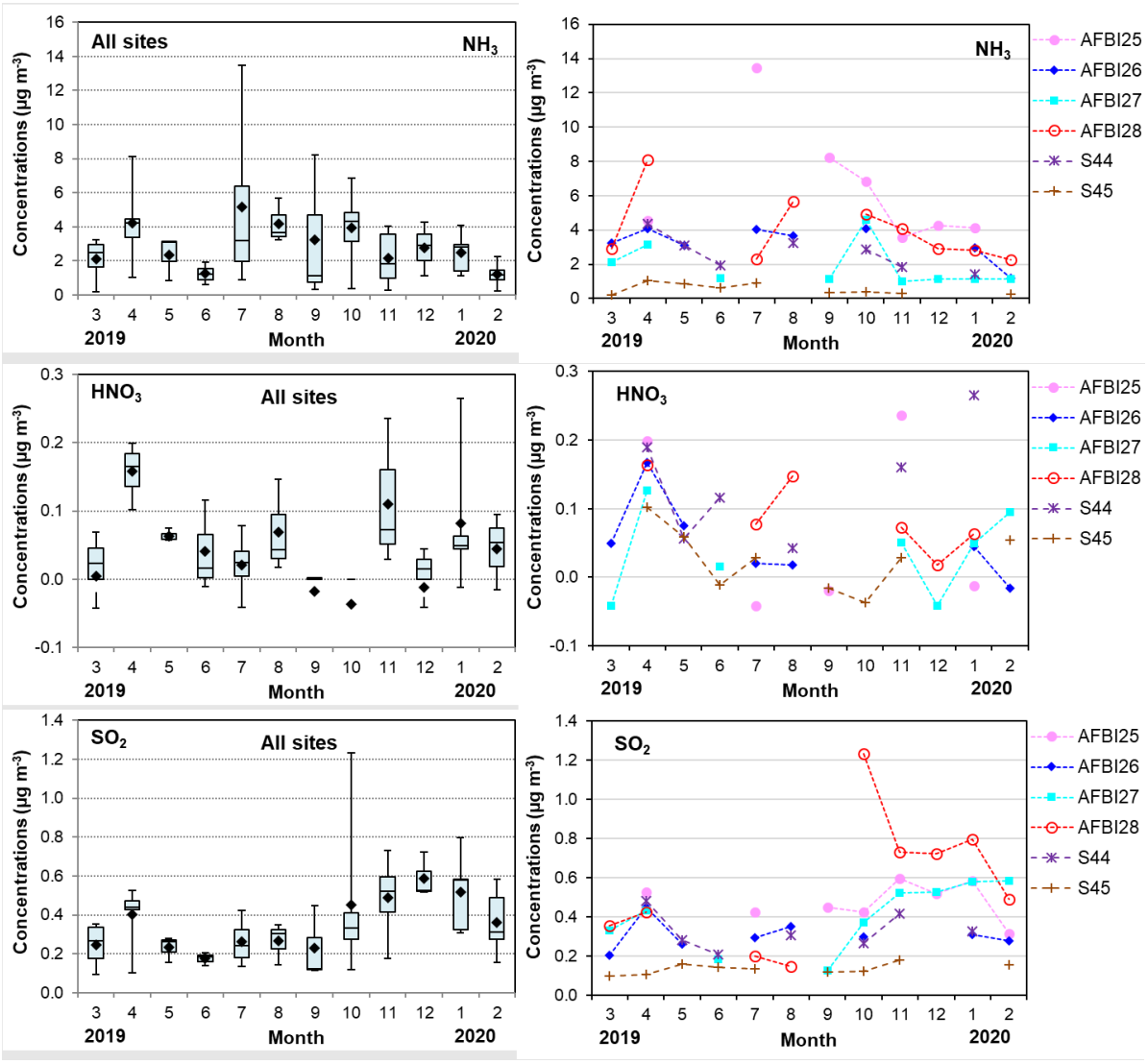
i) formation of HNO_3 from NO_x through photochemical processes (Pope et al., 2016), enhanced by elevated ozone concentrations in spring in the UK (AQEG 2009),

ii) removal of HNO_3 by reaction with NH_3 to form NH_4NO_3 (semi-volatile),

iii) temperature and humidity effects on the equilibrium that exists between the gas phase HNO_3 (and NH_3) and aerosol phase NH_4NO. Cooler, more humid conditions favours the aerosol phase, whereas warmer, drier conditions will see the re-volatilisation to the gas phase.

iv) Long-range transboundary transport of NH_4NO_3 into the country (Vieno et al., 2014).

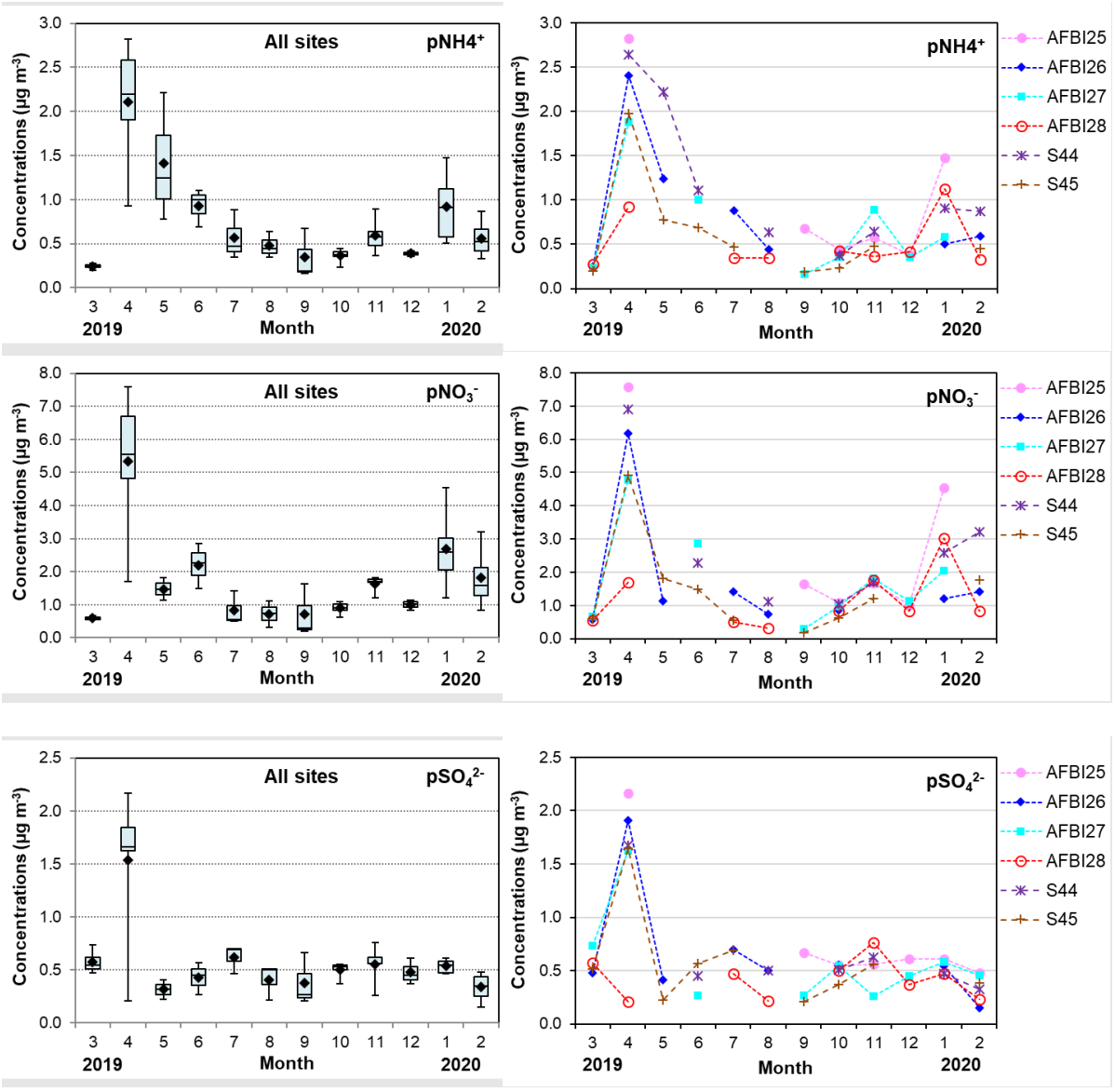
Figure 23: (left) boxplot showing mean seasonal cycle, and (right) seasonal cycles of individual sites in the gases measured (NH_3, HNO_3 and SO_2).



There is, however, no clear seasonality in the HNO_3 data (Figure 23). This is likely due to uncertainties in the measurements at the very low monthly concentrations (< 0.3 µg HNO_3 m^{-3}) measured at all sites. SO_2 concentrations are highest in the colder months of the year, related to combustion processes (heating). Stable atmospheric conditions in winter can also lead to a build-up of concentrations at ground level, leading to winter peaks in SO_2 concentrations (Figure 23).

By contrast, ammonium aerosols (NH_4NO_3, $(NH_4)_2SO_4$) are secondary reaction products that are slowly formed from reactions between the precursor gases (NH_3, HNO_3 and SO_2). They have longer atmospheric lifetimes, and vary on a regional rather than on a local scale. This is reflected by the temporal correlations between ammonium, nitrate and sulphate in their seasonal cycles for all sites (
Figure 24), with peak concentrations of NH_4^+, NO_3^- and SO_4^{2-} coinciding in April 2019.

Figure 24: (left) boxplot showing mean seasonal cycle, and (right) seasonal cycles of individual sites in the aerosols measured (NH_4^+, NO_3^- and SO_4^{2-}).

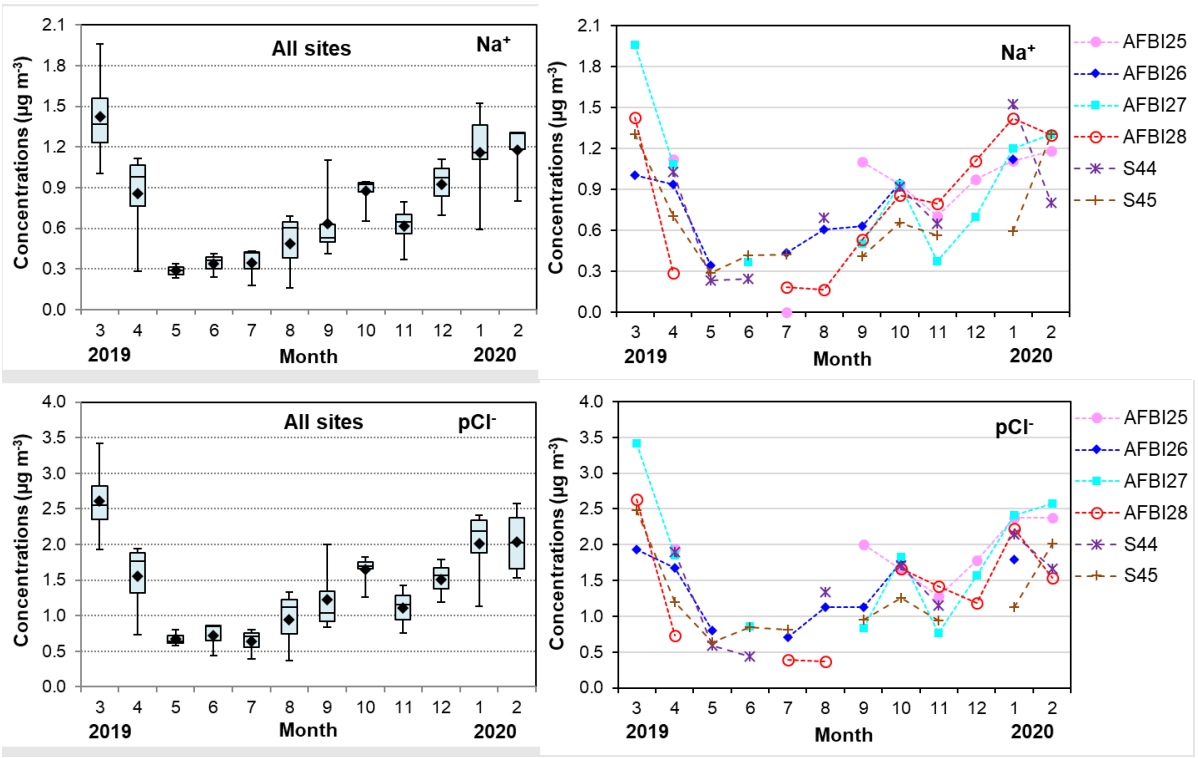


The springtime peak in aerosol concentrations may be explained as follows:

- increased availability of NH_3, SO_2 and HNO_3 in April (Figure 23) for reaction to form ammonium aerosols.
- the ratio of the concentrations of SO_2 and SO_4^{2-} is largely governed by the availability of SO_2 and NH_3 to form $(NH_4)_2SO_4$, since the reaction of SO_2 with NH_3 to form $(NH_4)_2SO_4$ is effectively irreversible.
- NH_4NO_3 is semi-volatile; low temperature and high humidity shifts the equilibrium to formation of NH_4NO_3 from the gas-phase HNO_3 and NH_3.

In the case of Na^+ and Cl^-, the seasonal plots also show high correlations (Figure 25). The largest concentrations occur during winter, highlighting the importance of marine sources (more stormy weather) in winter for sea salt aerosol to be transported inland across NI.

Figure 25: (left) boxplot showing mean seasonal cycle, and (right) seasonal cycles of individual sites in Na^+ and Cl^-.



4 Next steps

- Maintenance of operation and collection of data from ALPHA® and DELTA® networks across Northern Ireland (set up at the beginning of March 2019).

- Continuation of the analysis of year 2 (March 2020 to February 2021), as data become available from the laboratory analysis, including quarterly reporting.

- Continuation of monitoring network into year 3, with extension of current monitoring commissioned to the end of February 2022.

- The comparison of year 1 annual data from 28 sites with the UK national FRAME output (2016 emission year) reported here was carried out by calibration with the NAMN NH_3 network data only. Ongoing analysis will provide a new calibrated FRAME concentration surface using the NI-wide network rather than the current standard NAMN network with only three sites located in Northern Ireland. This surface will then be compared with the standard model calibration method (NAMN only). .

- Reporting on data from the addition of 3 sites along a transect away from the main NH_3 sources at Hillsborough (set up at the beginning April 2020) to assess spatial variability.

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6 Appendix A: ALPHA NH_3 data tables

Period 1: March 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/02/27 12:00:00	2019/03/28 11:20:00	695.3	2.38	2.49	2.52	2.46	3.2%	0.078	**3.07**
AFBI02	Castle Enigan	2019/02/22 13:55:00	2019/04/04 10:30:00	980.6	2.70	2.93	2.92	2.85	4.5%	0.078	**2.53**
AFBI03	Beaghs Burn	2019/03/04 15:20:00	2019/04/07 08:30:00	809.2	0.51	0.48	0.49	0.49	3.0%	0.078	**0.46**
AFBI04	Slieve Beagh	2019/03/03 14:20:00	2019/03/28 12:10:00	597.8	0.30	0.28	0.31	0.30	5.5%	0.078	**0.33**
AFBI05	Moninea Bog	2019/03/04 08:35:00	2019/03/30 10:50:00	626.3	0.64	0.64	0.61	0.63	3.1%	0.078	**0.79**
AFBI06	Drumclamph parish church	2019/03/01 11:19:00	2019/04/02 12:20:00	769.0	12.05	12.27	12.42	12.25	1.5%	0.078	**14.1**
AFBI07	Seekinore	2019/03/05 14:50:00	2019/03/28 13:50:00	551.0	1.60	1.62	1.63	1.62	0.8%	0.078	**2.50**
AFBI08	Lisbellaw	2019/03/03 11:50:00	2019/03/28 10:25:00	598.6	1.53	ND[1]	1.60	1.57	3.3%	0.078	**2.22**
AFBI09	Glenwherry COSMOS	2019/02/22 14:27:00	2019/04/01 11:00:00	908.5	2.85	ND[2]	2.77	2.81	1.9%	0.078	**2.68**
AFBI10	UWMN bencrom River	2019/02/25 11:10:00	2019/04/04 11:20:00	912.2	0.99	0.99	1.01	1.00	1.3%	0.078	**0.90**
AFBI11	Blackwater town	2019/02/27 11:00:00	2019/03/28 12:00:00	697.0	3.31	3.47	3.49	3.42	2.9%	0.078	**4.30**
AFBI12	Ratarnet Rd	2019/02/21 15:00:00	2019/03/28 08:45:00	833.7	9.56	8.83	9.05	9.15	4.1%	0.078	**9.74**
AFBI13	Inch Abbey	2019/03/01 10:45:00	2019/04/04 11:50:00	817.1	1.54	1.62	1.68	1.61	4.3%	0.078	**1.68**
AFBI14	AURN Belfast centre	2019/02/26 11:05:00	2019/03/29 10:23:00	743.3	2.83	2.52	2.53	2.63	6.6%	0.078	**3.07**
AFBI15	Ballylinney Presbyterian Church	2019/02/22 15:03:00	2019/03/29 11:10:00	836.1	3.84	ND[2]	ND[2]	3.84	-	0.078	**4.03**
AFBI16	West of Crumlin	2019/02/22 12:32:00	2019/03/29 13:03:00	840.5	3.56	3.33	3.35	3.42	3.8%	0.078	**3.55**
AFBI17	Loughmore River	2019/03/01 13:07:00	2019/03/29 11:00:00	669.9	0.84	0.88	0.80	0.84	4.4%	0.078	**1.02**
AFBI18	Caldanagh Bog	2019/02/25 14:25:00	2019/04/01 12:30:00	838.1	3.50	3.52	3.60	3.54	1.6%	0.078	**3.69**
AFBI19	Cloughmills	2019/02/25 13:40:00	2019/04/01 12:15:00	838.6	9.18	9.84	9.94	9.65	4.3%	0.078	**10.2**
AFBI20	Caddy Rd	2019/02/28 12:28:00	2019/03/29 12:03:00	695.6	4.18	4.03	3.97	4.06	2.6%	0.078	**5.12**
AFBI21	Turmennan Rd	2019/03/01 11:15:00	2019/04/04 12:00:00	816.8	2.23	2.10	2.20	2.18	3.2%	0.078	**2.30**
AFBI22	Carrowbane Rd	2019/02/27 10:30:00	2019/03/28 09:24:00	694.9	3.51	3.36	3.93	3.60	8.2%	0.078	**4.54**
AFBI23	Creggan	2019/02/27 11:30:00	2019/04/04 09:55:00	862.4	4.83	4.33	4.62	4.59	5.5%	0.078	**4.68**
AFBI24	Corramore Rd	2019/02/27 15:15:00	2019/03/29 10:00:00	714.8	0.74	0.76	0.78	0.76	2.2%	0.078	**0.86**
AFBI25	Hillsborough	2019/03/05 11:00:00	2019/03/29 10:50:00	575.8	3.43	3.40	3.53	3.46	2.0%	0.078	**5.25**

ND[1] Sample leaked during extraction,

ND[2] = missing

Period 2: April 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/03/28 11:20:00	2019/04/29 14:30:00	771.2	5.67	5.76	5.53	5.65	2.0%	0.073	**6.47**
AFBI02	Castle Enigan	2019/04/04 11:30:00	2019/05/02 11:15:00	671.7	1.93	1.82	1.91	1.89	3.0%	0.073	**2.41**
AFBI03	Beaghs Burn	2019/04/07 09:30:00	2019/04/29 12:30:00	531.0	0.94	0.97	0.92	0.94	2.4%	0.073	**1.46**
AFBI04	Slieve Beagh	2019/03/28 12:10:00	2019/05/03 07:55:00	859.8	2.06	2.23	2.15	2.15	3.8%	0.073	**2.16**
AFBI05	Moninea Bog	2019/03/30 10:50:00	2019/05/02 07:25:00	788.6	3.42	2.99	3.12	3.18	6.9%	0.073	**3.52**
AFBI06	Drumclamph parish church	2019/04/02 13:26:00	2019/04/30 13:55:00	672.5	7.87	7.73	7.73	7.78	1.0%	0.073	**10.3**
AFBI07	Seekinore	2019/03/28 13:50:00	2019/05/03 09:30:00	859.7	4.35	4.40	4.81	4.52	5.6%	0.073	**4.63**
AFBI08	Lisbellaw	2019/03/28 10:25:00	2019/05/03 08:45:00	862.3	4.88	4.63	4.50	4.67	4.2%	0.073	**4.77**
AFBI09	Glenwherry COSMOS	2019/04/01 12:00:00	2019/05/01 11:05:00	719.1	1.70	1.90	1.83	1.81	5.7%	0.073	**2.16**
AFBI10	UWMN bencrom River	2019/04/04 12:35:00	2019/05/01 12:00:00	647.4	1.01	1.03	1.06	1.03	2.5%	0.073	**1.32**
AFBI11	Blackwater town	2019/03/28 12:00:00	2019/04/29 15:00:00	771.0	5.07	5.00	5.52	5.20	5.4%	0.073	**5.95**
AFBI12	Ratarnet Rd	2019/03/28 09:30:00	2019/04/29 11:45:00	770.3	7.45	7.31	7.20	7.32	1.7%	0.073	**8.42**
AFBI13	Inch Abbey	2019/04/04 12:50:00	2019/05/02 15:05:00	674.3	1.26	1.27	1.21	1.25	2.4%	0.073	**1.56**
AFBI14	AURN Belfast centre	2019/03/29 10:23:00	2019/05/02 09:50:00	815.4	3.16	3.21	3.36	3.24	3.3%	0.073	**3.48**
AFBI15	Ballylinney Presbyterian Church	2019/03/29 11:10:00	2019/05/02 11:00:00	815.8	3.23	3.23	3.14	3.20	1.7%	0.073	**3.43**
AFBI16	West of Crumlin	2019/03/29 13:10:00	2019/05/02 12:15:00	815.1	3.35	3.35	3.45	3.39	1.7%	0.073	**3.64**
AFBI17	Loughmore River	2019/03/29 11:10:00	2019/05/03 11:10:00	840.0	2.11	2.10	ND[2]	2.10	0.5%	0.073	**2.16**
AFBI18	Caldanagh Bog	2019/04/01 13:30:00	2019/05/01 08:45:00	715.2	2.43	2.41	2.77	2.54	7.9%	0.073	**3.08**
AFBI19	Cloughmills	2019/04/01 13:15:00	2019/05/01 10:00:00	716.8	3.30	3.50	3.37	3.39	2.9%	0.073	**4.14**
AFBI20	Caddy Rd	2019/03/29 12:04:00	2019/05/02 11:34:00	815.5	5.42	5.18	5.10	5.24	3.2%	0.073	**5.67**
AFBI21	Turmennan Rd	2019/04/04 13:00:00	2019/05/02 14:55:00	673.9	1.71	1.68	1.64	1.68	1.9%	0.073	**2.13**
AFBI22	Carrowbane Rd	2019/03/28 09:24:00	2019/04/29 12:19:00	770.9	5.54	5.87	5.65	5.68	3.0%	0.073	**6.51**
AFBI23	Creggan	2019/04/04 10:55:00	2019/05/02 10:35:00	671.7	1.95	1.87	1.76	1.86	5.3%	0.073	**2.38**
AFBI24	Corramore Rd	2019/03/29 10:00:00	2019/05/03 10:00:00	840.0	1.43	1.60	1.50	1.51	5.4%	0.073	**1.53**
AFBI25	Hillsborough	2019/03/29 10:50:00	2019/05/01 10:55:00	792.1	5.95	5.84	6.02	5.94	1.5%	0.073	**6.62**

ND[2] = missing

Period 3: May 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/04/29 14:30:00	2019/05/29 14:00:00	719.5	-	-	-	-	-	0.059	ND[3]
AFBI02	Castle Enigan	2019/05/02 11:15:00	2019/05/30 12:10:00	672.9	4.90	4.57	4.78	4.75	3.5%	0.059	**6.24**
AFBI03	Beaghs Burn	2019/04/29 12:30:00	2019/06/03 12:20:00	839.8	0.65	0.63	0.63	0.64	1.5%	0.059	**0.62**
AFBI04	Slieve Beagh	2019/05/03 07:55:00	2019/05/31 12:30:00	676.6	1.27	1.20	1.25	1.24	3.2%	0.059	**1.56**
AFBI05	Moninea Bog	2019/05/02 07:25:00	2019/05/31 10:25:00	699.0	2.09	2.19	2.17	2.15	2.6%	0.059	**2.68**
AFBI06	Drumclamph parish church	2019/04/30 13:57:00	2019/06/04 11:10:00	837.2	-	-	-	-	-	0.059	ND[4]
AFBI07	Seekinore	2019/05/03 09:30:00	2019/05/31 13:45:00	676.3	4.54	4.83	5.07	4.82	5.5%	0.059	**6.29**
AFBI08	Lisbellaw	2019/05/03 08:45:00	2019/05/31 11:45:00	675.0	4.72	4.31	4.55	4.53	4.6%	0.059	**5.92**
AFBI09	Glenwherry COSMOS	2019/05/01 11:05:00	2019/05/28 13:45:00	650.7	1.26	1.02	0.97	1.08	14.3%	0.059	**1.41**
AFBI10	UWMN bencrom River	2019/05/01 12:15:00	2019/06/03 11:55:00	791.7	1.11	1.27	1.18	1.19	6.7%	0.059	**1.28**
AFBI11	Blackwater town	2019/04/29 15:00:00	2019/05/29 14:45:00	719.7	0.08[a]	4.22	4.55	4.38	5.3%	0.059	**5.38**
AFBI12	Ratarnet Rd	2019/04/29 11:45:00	2019/05/29 11:00:00	719.3	7.61	6.61	6.88	7.03	7.4%	0.059	**8.68**
AFBI13	Inch Abbey	2019/05/02 15:05:00	2019/05/31 13:45:00	694.7	1.22	1.22	1.20	1.21	1.0%	0.059	**1.48**
AFBI14	AURN Belfast centre	2019/05/02 09:50:00	2019/06/03 10:20:00	768.5	2.69	2.89	2.64	2.74	4.9%	0.059	**3.12**
AFBI15	Ballylinney Presbyterian Church	2019/05/02 11:00:00	2019/06/03 11:00:00	768.0	4.08	4.01	4.13	4.07	1.4%	0.059	**4.68**
AFBI16	West of Crumlin	2019/05/02 12:15:00	2019/06/03 12:00:00	767.7	2.94	3.03	2.94	2.97	1.8%	0.059	**3.39**
AFBI17	Loughmore River	2019/05/03 11:10:00	2019/05/31 10:30:00	671.3	1.28	1.23	1.22	1.24	2.8%	0.059	**1.58**
AFBI18	Caldanagh Bog	2019/05/01 08:45:00	2019/05/31 12:45:00	724.0	2.21	2.29	2.57	2.36	7.9%	0.059	**2.84**
AFBI19	Cloughmills	2019/05/01 10:00:00	2019/05/31 13:15:00	723.2	3.18	3.00	3.20	3.13	3.6%	0.059	**3.80**
AFBI20	Caddy Rd	2019/05/02 11:35:00	2019/06/03 11:45:00	768.2	10.84	9.79	9.33	9.99	7.8%	0.059	**11.6**
AFBI21	Turmennan Rd	2019/05/02 14:55:00	2019/05/31 13:35:00	694.7	1.69	1.87	1.70	1.75	5.6%	0.059	**2.18**
AFBI22	Carrowbane Rd	2019/04/29 12:19:00	2019/05/29 11:50:00	719.5	4.01	4.13	ND[2]	4.07	2.0%	0.059	**4.99**
AFBI23	Creggan	2019/05/02 10:35:00	2019/05/30 11:35:00	673.0	4.72	5.22	5.45	5.13	7.3%	0.059	**6.74**
AFBI24	Corramore Rd	2019/05/03 10:00:00	2019/05/31 11:30:00	673.5	1.18	1.29	1.25	1.24	4.4%	0.059	**1.57**
AFBI25	Hillsborough	2019/05/01 10:55:00	2019/05/30 15:55:00	701.0	6.19	6.59	6.19	6.32	3.6%	0.059	**8.00**

ND[2] = missing

ND[3] = all samples retrieved from ground – not analysed,

ND[4] = no data reported

[a]Blank value – rejected (not included in calculation of NH_3 concentrations)

Period 4: June 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/06/04 14:00:00	2019/07/01 14:20:00	648.3	2.85	2.69	2.85	2.80	3.4%	0.077	**3.75**
AFBI02	Castle Enigan	2019/05/30 12:10:00	2019/06/27 13:50:00	673.7	1.45	1.33	1.31	1.36	5.5%	0.077	**1.71**
AFBI03	Beaghs Burn	2019/06/03 12:20:00	2019/07/01 10:30:00	670.2	0.45	0.48	0.44	0.46	4.2%	0.077	**0.51**
AFBI04	Slieve Beagh	2019/05/31 12:30:00	2019/06/28 09:52:00	669.4	0.94	0.97	0.93	0.95	2.2%	0.077	**1.16**
AFBI05	Moninea Bog	2019/05/31 10:25:00	2019/06/28 08:28:00	670.0	1.57	1.65	1.51	1.58	4.4%	0.077	**2.00**
AFBI06	Drumclamph parish church	2019/06/04 11:11:00	2019/07/02 12:55:00	673.7	8.98	8.14	8.66	8.59	5.0%	0.077	**11.31**
AFBI07	Seekinore	2019/05/31 13:45:00	2019/06/28 11:20:00	669.6	2.21	2.43	2.34	2.32	4.8%	0.077	**3.00**
AFBI08	Lisbellaw	2019/05/31 11:45:00	2019/06/28 15:20:00	675.6	2.64	2.56	2.53	2.58	2.3%	0.077	**3.31**
AFBI09	Glenwherry COSMOS	2019/05/28 13:45:00	2019/06/26 12:00:00	694.2	-	-	-	-	-	0.077	ND[3]
AFBI10	UWMN bencrom River	2019/06/03 12:10:00	2019/07/03 12:45:00	720.6	0.78	0.81	0.79	0.79	2.1%	0.077	**0.89**
AFBI11	Blackwater town	2019/05/29 14:45:00	2019/07/03 11:00:00	836.3	-	-	-	-	-	0.077	ND[3]
AFBI12	Ratarnet Rd	2019/05/29 11:00:00	2019/07/01 09:00:00	790.0	5.56	6.26	6.26	6.03	6.7%	0.077	**6.74**
AFBI13	Inch Abbey	2019/05/31 13:45:00	2019/06/27 11:55:00	646.2	2.03	2.12	1.75	1.97	9.8%	0.077	**2.62**
AFBI14	AURN Belfast centre	2019/06/03 10:20:00	2019/07/05 10:30:00	768.2	-	-	-	-	-	0.077	ND[2]
AFBI15	Ballylinney Presbyterian Church	2019/06/03 11:00:00	2019/07/04 11:15:00	744.3	2.21	2.03	2.09	2.11	4.4%	0.077	**2.44**
AFBI16	West of Crumlin	2019/06/03 12:30:00	2019/07/04 12:40:00	744.2	1.87	1.84	1.86	1.85	0.8%	0.077	**2.14**
AFBI17	Loughmore River	2019/05/31 10:30:00	2019/06/28 11:30:00	673.0	0.96	0.95	0.95	0.96	0.8%	0.077	**1.17**
AFBI18	Caldanagh Bog	2019/05/31 12:45:00	2019/06/26 09:30:00	620.7	1.60	-	-	1.60	-	0.077	**2.19**
AFBI19	Cloughmills	2019/05/31 13:15:00	2019/06/26 11:00:00	621.8	2.13	2.08	2.06	2.09	1.9%	0.077	**2.90**
AFBI20	Caddy Rd	2019/06/03 11:45:00	2019/07/04 11:50:00	744.1	4.13	4.12	3.92	4.05	3.0%	0.077	**4.78**
AFBI21	Turmennan Rd	2019/05/31 13:35:00	2019/06/27 11:25:00	645.8	1.28	1.28	1.20	1.25	3.7%	0.077	**1.63**
AFBI22	Carrowbane Rd	2019/05/29 11:50:00	2019/07/01 11:15:00	791.4	4.53	4.58	-	4.55	0.8%	0.077	**5.06**
AFBI23	Creggan	2019/05/30 11:35:00	2019/06/27 15:50:00	676.2	1.85	1.77	1.76	1.79	2.7%	0.077	**2.27**
AFBI24	Corramore Rd	2019/05/31 11:30:00	2019/06/28 10:15:00	670.7	0.91	0.90	0.86	0.89	2.9%	0.077	**1.08**
AFBI25	Hillsborough	2019/05/30 15:55:00	2019/07/01 11:25:00	763.5	10.40	10.82	10.77	10.66	2.1%	0.077	**12.41**

ND[2] = missing

ND[3] = samples damaged – not analysed

Period 5: July 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/07/01 14:20:00	2019/08/05 11:00:00	836.7	4.69	4.37	4.04	4.37	7.4%	0.073	**4.59**
AFBI02	Castle Enigan	2019/06/27 13:50:00	2019/08/02 13:00:00	863.2	7.07	8.08	7.84	7.66	6.9%	0.073	**7.87**
AFBI03	Beaghs Burn	2019/07/01 10:35:00	2019/08/01 08:50:00	742.3	0.57	0.64	0.57	0.59	6.5%	0.073	**0.63**
AFBI04	Slieve Beagh	2019/06/28 09:52:00	2019/08/02 09:30:00	839.6	1.33	1.27	1.32	1.31	2.4%	0.073	**1.32**
AFBI05	Moninea Bog	2019/06/28 08:28:00	2019/08/02 08:15:00	839.8	3.23	2.91	2.97	3.03	5.7%	0.073	**3.16**
AFBI06	Drumclamph parish church	2019/07/02 12:55:00	2019/07/30 13:47:00	672.9	15.59	15.68	16.77	16.01	4.1%	0.073	**21.20**
AFBI07	Seekinore	2019/06/28 11:20:00	2019/08/02 11:15:00	839.9	3.44	3.59	3.53	3.52	2.1%	0.073	**3.67**
AFBI08	Lisbellaw	2019/06/28 15:20:00	2019/08/02 13:20:00	838.0	11.80	11.45	11.20	11.48	2.6%	0.073	**12.18**
AFBI09	Glenwherry COSMOS	2019/06/26 12:00:00	2019/08/01 10:45:00	862.8	2.71	2.68	2.83	2.74	2.9%	0.073	**2.77**
AFBI10	UWMN bencrom River	2019/07/03 12:50:00	2019/07/31 10:40:00	669.8	1.05	1.14	1.14	1.11	4.9%	0.073	**1.38**
AFBI11	Blackwater town	2019/07/03 11:00:00	2019/08/05 12:00:00	793.0	0.085[a]	0.082[a]	0.072[a]	-	-	0.073	**-**
AFBI12	Ratarnet Rd	2019/07/01 09:00:00	2019/08/02 11:00:00	770.0	4.71	4.35	4.45	4.50	4.2%	0.073	**5.15**
AFBI13	Inch Abbey	2019/06/27 11:55:00	2019/08/02 11:55:00	864.0	1.80	1.92	1.90	1.87	3.2%	0.073	**1.86**
AFBI14	AURN Belfast centre	2019/07/05 10:30:00	2019/07/31 09:45:00	623.3	2.91	2.66	2.48	2.68	8.0%	0.073	**3.75**
AFBI15	Ballylinney Presbyterian Church	2019/07/04 11:20:00	2019/07/31 10:15:00	646.9	5.84	6.22	5.97	6.01	3.2%	0.073	**8.21**
AFBI16	West of Crumlin	2019/07/04 12:40:00	2019/07/31 11:40:00	647.0	2.37	2.42	2.35	2.38	1.3%	0.073	**3.19**
AFBI17	Loughmore River	2019/06/28 11:30:00	2019/08/01 12:45:00	817.2	1.54	1.44	1.56	1.51	4.3%	0.073	**1.57**
AFBI18	Caldanagh Bog	2019/06/26 09:30:00	2019/07/30 12:00:00	818.5	-	-	-	-	-	0.073	ND[2]
AFBI19	Cloughmills	2019/06/26 11:00:00	2019/08/01 09:30:00	862.5	3.63	3.90	3.74	3.75	3.6%	0.073	**3.82**
AFBI20	Caddy Rd	2019/07/04 11:50:00	2019/07/31 10:30:00	646.7	9.90	8.57	8.81	9.09	7.8%	0.073	**12.5**
AFBI21	Turmennan Rd	2019/06/27 11:25:00	2019/08/02 11:07:00	863.7	2.69	-	-	2.69	-	0.073	**2.71**
AFBI22	Carrowbane Rd	2019/07/01 11:15:00	2019/08/02 11:40:00	768.4	-	4.13	5.29	4.71	17.5%	0.073	**5.40**
AFBI23	Creggan	2019/06/27 15:50:00	2019/08/02 13:50:00	862.0	3.19	3.24	3.17	3.20	1.0%	0.073	**3.24**
AFBI24	Corramore Rd	2019/06/28 10:30:00	2019/08/01 14:00:00	819.5	1.66	1.49	1.53	1.56	6.0%	0.073	**1.62**
AFBI25	Hillsborough	2019/07/01 11:25:00	2019/08/01 11:55:00	744.5	10.54	10.50	11.21	10.75	3.7%	0.073	**12.83**

ND[2] = missing

[a]unused samples – treat as field blanks

Period 6: August 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/08/05 11:00:00	2019/09/03 11:22:00	696.4	2.82	-	-	2.82	-	0.065	**3.54**
AFBI02	Castle Enigan	2019/08/02 13:00:00	2019/09/03 11:25:00	766.4	1.39	1.42	1.43	1.41	1.4%	0.065	**1.57**
AFBI03	Beaghs Burn	2019/08/01 08:50:00	2019/09/02 12:35:00	771.8	0.48	0.50	0.47	0.48	3.3%	0.065	**0.48**
AFBI04	Slieve Beagh	2019/08/02 09:30:00	2019/08/30 11:30:00	674.0	0.60	0.61	0.71	0.64	9.8%	0.065	**0.76**
AFBI05	Moninea Bog	2019/08/02 08:15:00	2019/08/30 09:50:00	673.6	1.89	2.05	1.95	1.96	4.1%	0.065	**2.52**
AFBI06	Drumclamph parish church	2019/07/30 13:48:00	2019/08/30 11:08:00	741.3	7.62	7.39	7.57	7.53	1.6%	0.065	**9.01**
AFBI07	Seekinore	2019/08/02 11:15:00	2019/08/30 13:05:00	673.8	1.92	1.97	2.09	2.00	4.3%	0.065	**2.57**
AFBI08	Lisbellaw	2019/08/02 13:20:00	2019/08/30 14:25:00	673.1	1.95	1.90	1.81	1.89	3.8%	0.065	**2.43**
AFBI09	Glenwherry COSMOS	2019/08/01 10:45:00	2019/09/03 14:00:00	795.2	1.79	-	1.50	1.64	12.5%	0.065	**1.78**
AFBI10	UWMN bencrom River	2019/07/31 10:50:00	2019/10/01 11:00:00	1488.2	1.54	1.53	1.33	1.46	7.9%	0.065	0.84[a]
AFBI11	Blackwater town	2019/08/05 12:00:00	2019/09/03 12:23:00	696.4	3.03	3.09	3.33	3.15	5.2%	0.065	**3.96**
AFBI12	Ratarnet Rd	2019/08/02 11:00:00	2019/09/03 09:00:00	766.0	2.86	2.72	2.86	2.82	2.9%	0.065	**3.21**
AFBI13	Inch Abbey	2019/08/02 11:55:00	2019/09/03 12:20:00	768.4	1.01	1.04	1.06	1.03	2.4%	0.065	**1.13**
AFBI14	AURN Belfast centre	2019/07/31 09:45:00	2019/08/30 14:00:00	724.2	-	-	-	-	-	0.065	ND[2]
AFBI15	Ballylinney Presbyterian Church	2019/07/31 10:15:00	2019/08/28 10:30:00	672.3	1.76	1.87	1.95	1.86	5.1%	0.065	**2.38**
AFBI16	West of Crumlin	2019/07/31 11:40:00	2019/08/28 12:15:00	672.6	1.67	1.74	1.67	1.69	2.4%	0.065	**2.17**
AFBI17	Loughmore River	2019/08/01 12:45:00	2019/08/30 14:00:00	697.2	1.09	1.19	1.17	1.15	4.5%	0.065	**1.40**
AFBI18	Caldanagh Bog	2019/07/30 12:00:00	2019/08/27 14:00:00	674.0	1.86	1.70	1.79	1.78	4.6%	0.065	**2.28**
AFBI19	Cloughmills	2019/08/01 09:30:00	2019/08/27 11:30:00	626.0	1.67	1.68	1.75	1.70	2.5%	0.065	**2.33**
AFBI20	Caddy Rd	2019/07/31 10:50:00	2019/08/28 11:20:00	672.5	3.10	2.98	3.06	3.05	2.0%	0.065	**3.97**
AFBI21	Turmennan Rd	2019/08/02 11:07:00	2019/09/03 12:45:00	769.6	2.86	-	-	2.86	-	0.065	**3.25**
AFBI22	Carrowbane Rd	2019/08/02 11:40:00	2019/09/03 09:36:00	765.9	2.99	2.94	-	2.97	1.0%	0.065	**3.39**
AFBI23	Creggan	2019/08/02 13:50:00	2019/09/03 10:45:00	764.9	1.43	1.44	1.40	1.42	1.3%	0.065	**1.59**
AFBI24	Corramore Rd	2019/08/01 14:00:00	2019/08/30 10:00:00	692.0	0.85	0.77	0.76	0.79	6.2%	0.065	**0.94**
AFBI25	Hillsborough	2019/08/01 11:55:00	2019/09/02 08:55:00	765.0	9.37	9.25	10.19	9.61	5.3%	0.065	**11.16**

ND[2] = missing

[a]exposed for 2 months (Aug+Sep)

Period 7: September 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/09/03 11:23:00	2019/09/30 14:00:00	650.6	2.16	2.29	2.09	2.18	4.5	0.055	**2.92**
AFBI02	Castle Enigan	2019/09/03 11:25:00	2019/10/01 12:35:00	673.2	1.46	1.49	1.47	1.48	1.2	0.055	**1.89**
AFBI03	Beaghs Burn	2019/09/02 12:35:00	2019/10/03 11:40:00	743.1	0.42	0.42	0.40	0.41	2.6	0.055	**0.43**
AFBI04	Slieve Beagh	2019/08/30 11:30:00	2019/10/02 15:35:00	796.1	0.58	0.53	0.58	0.56	5.4	0.055	**0.57**
AFBI05	Moninea Bog	2019/08/30 09:50:00	2019/10/02 08:55:00	791.1	1.53	1.39	1.40	1.44	5.6	0.055	**1.57**
AFBI06	Drumclamph parish church	Site closed – see AFBI29 Drumclamph 2-									
AFBI07	Seekinore	2019/08/30 13:05:00	2019/10/02 11:25:00	790.3	2.51	2.52	2.38	2.47	3.0	0.055	**2.73**
AFBI08	Lisbellaw	2019/08/30 14:25:00	2019/10/02 14:25:00	792.0	2.98	2.55	2.90	2.81	8.1	0.055	**3.11**
AFBI09	Glenwherry COSMOS	2019/09/03 14:00:00	2019/10/03 01:45:00	707.8	1.39	1.31	1.33	1.34	3.1	0.055	**1.63**
AFBI10	UWMN bencrom River	see Aug		1488.2	1.54	1.53	1.33	1.46	7.9%	0.065	0.84[a]
AFBI11	Blackwater town	2019/09/03 12:27:00	2019/09/29 14:37:00	626.2	3.42	3.63	3.82	3.62	5.5	0.055	5.10
AFBI12	Ratarnet Rd	2019/09/03 09:05:00	2019/10/03 13:45:00	724.7	-	-	-	-		0.055	ND[3]
AFBI13	Inch Abbey	2019/09/03 12:20:00	2019/09/30 12:00:00	647.7	1.20	1.26	1.22	1.23	2.2	0.055	**1.62**
AFBI14	AURN Belfast centre	2019/08/30 14:00:00	2019/10/04 09:45:00	835.8	2.85	3.04	3.34	3.08	7.9	0.055	**3.24**
AFBI15	Ballylinney Presbyterian Church	2019/08/28 11:00:00	2019/10/04 10:10:00	887.2	5.45	5.55	5.96	5.66	4.8	0.055	**5.65**
AFBI16	West of Crumlin	2019/08/28 12:15:00	2019/10/04 11:45:00	887.5	2.46	2.59	2.51	2.52	2.5	0.055	**2.48**
AFBI17	Loughmore River	2019/08/30 14:00:00	2019/10/03 11:45:00	813.8	0.65	0.69	0.68	0.68	3.0	0.055	**0.68**
AFBI18	Caldanagh Bog	2019/08/27 14:00:00	2019/10/02 08:30:00	858.5	2.81	3.30	2.92	3.01	8.6	0.055	**3.08**
AFBI19	Cloughmills	2019/08/27 11:30:00	2019/10/02 09:15:00	861.8	2.60	2.43	2.40	2.48	4.4	0.055	**2.52**
AFBI20	Caddy Rd	2019/08/28 11:45:00	2019/10/04 11:10:00	887.4	4.33	4.20	4.70	4.41	6.0	0.055	**4.39**
AFBI21	Turmennan Rd	2019/09/03 12:45:00	2019/09/30 11:50:00	647.1	2.23	2.07	-	2.15	5.3	0.055	**2.89**
AFBI22	Carrowbane Rd	2019/09/03 09:38:00	2019/09/30 11:50:00	650.2	3.31	3.84	3.69	3.61	7.5	0.055	**4.90**
AFBI23	Creggan	2019/09/03 10:45:00	2019/10/01 12:00:00	673.3	1.54	1.64	1.61	1.59	3.3	0.055	**2.04**
AFBI24	Corramore Rd	2019/08/30 10:00:00	2019/10/03 10:15:00	816.3	0.74	0.82	0.74	0.77	6.2	0.055	**0.78**
AFBI25	Hillsborough	2019/09/02 08:55:00	2019/10/02 12:45:00	723.8	6.40	7.03	7.70	7.04	9.2	0.055	**8.64**
AFBI29	Drumclamph 2	2019/08/30 11:21:00	2019/10/01 10:50:00	767.5	4.10	4.66	4.04	4.27	8.1	0.055	**4.91**

ND[3] = samplers damaged

[a]exposed for 2 months (Aug+Sep)

Period 8: October 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/09/30 14:00:00	2019/11/04 13:45:00	839.8	7.36	8.13	7.61	7.70	5.1	0.055	**8.15**
AFBI02	Castle Enigan	2019/10/01 12:35:00	2019/10/30 11:05:00	694.5	1.48	1.37	1.26	1.37	8.2	0.055	**1.70**
AFBI03	Beaghs Burn	2019/10/03 11:40:00	2019/11/05 09:20:00	789.7	0.30	0.35	0.36	0.34	10.1	0.055	**0.32**
AFBI04	Slieve Beagh	2019/10/02 15:35:00	2019/11/07 13:20:00	861.8	0.72	0.74	0.72	0.73	1.4	0.055	**0.70**
AFBI05	Moninea Bog	2019/10/02 08:55:00	2019/11/07 10:20:00	865.4	1.03	1.07	1.15	1.08	5.9	0.055	**1.06**
AFBI06	Drumclamph parish church				-	-	-			0.055	
AFBI07	Seekinore	2019/10/02 11:25:00	2019/11/07 12:55:00	865.5	2.04	2.14	1.97	2.05	4.0	0.055	**2.06**
AFBI08	Lisbellaw	2019/10/02 14:25:00	2019/11/07 11:50:00	861.4	3.93	3.77	4.00	3.90	3.0	0.055	**3.99**
AFBI09	Glenwherry COSMOS	2019/10/03 01:45:00	2019/11/04 16:00:00	782.3	1.32	1.34	1.41	1.36	3.7	0.055	**1.49**
AFBI10	UWMN bencrom River	2019/10/01 11:15:00	2019/11/06 11:00:00	863.7	0.49	0.53	0.47	0.50	5.7	0.055	**0.46**
AFBI11	Blackwater town	2019/09/29 14:40:00	2019/11/04 14:25:00	863.7	4.08	3.96	3.81	3.95	3.3	0.055	**4.04**
AFBI12	Ratarnet Rd	2019/10/03 13:45:00	2019/11/04 11:10:00	765.4	-	-	-			0.055	ND[3]
AFBI13	Inch Abbey	2019/09/30 12:00:00	2019/10/29 12:35:00	696.6	0.89	0.98	0.91	0.93	5.0	0.055	**1.12**
AFBI14	AURN Belfast centre	2019/10/04 09:45:00	2019/11/04 12:45:00	747.0	2.46	2.49	2.43	2.46	1.2	0.055	**2.88**
AFBI15	Ballylinney Presbyterian Church	2019/10/04 10:10:00	2019/10/29 13:30:00	603.3	1.58	1.52	1.55	1.55	2.1	0.055	**2.22**
AFBI16	West of Crumlin	2019/10/04 11:45:00	2019/10/29 14:45:00	603.0	4.13	4.46	4.15	4.25	4.4	0.055	**6.22**
AFBI17	Loughmore River	2019/10/03 11:45:00	2019/11/01 11:10:00	695.4	0.52	0.58	0.49	0.53	8.4	0.055	**0.61**
AFBI18	Caldanagh Bog	2019/10/02 08:30:00	2019/10/29 14:00:00	653.5	1.84	1.61	1.72	1.73	6.9	0.055	**2.29**
AFBI19	Cloughmills	2019/10/02 09:15:00	2019/11/05 14:00:00	820.7	2.18	2.25	2.38	2.27	4.4	0.055	**2.42**
AFBI20	Caddy Rd	2019/10/04 11:13:00	2019/10/29 14:05:00	602.9	2.17	1.93	1.99	2.03	6.2	0.055	**2.93**
AFBI21	Turmennan Rd	2019/09/30 11:50:00	2019/10/29 12:20:00	696.5	1.01	1.04	1.00	1.01	2.0	0.055	**1.23**
AFBI22	Carrowbane Rd	2019/09/30 12:00:00	2019/11/04 11:44:00	839.7	3.05	2.97	2.99	3.00	1.5	0.055	**3.14**
AFBI23	Creggan	2019/10/01 12:00:00	2019/10/30 10:30:00	694.5	2.50	2.38	2.33	2.40	3.6	0.055	**3.03**
AFBI24	Corramore Rd	2019/10/03 10:30:00	2019/11/01 10:00:00	695.5	0.44	0.45	0.49	0.46	4.9	0.055	**0.52**
AFBI25	Hillsborough	2019/10/02 12:45:00	2019/11/01 12:05:00	719.3	5.13	4.81	5.01	4.98	3.2	0.055	**6.13**
AFBI29	Drumclamph 2	2019/10/01 10:50:00	2019/10/31 14:00:00	723.2	6.53	6.63	6.80	6.65	2.0	0.055	**8.17**

ND[3] = samplers damaged

Period 9: November 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/11/04 13:45:00	2019/12/03 14:00:00	696.2	2.54	2.61	2.40	2.51	4.2	0.06	**3.15**
AFBI02	Castle Enigan	2019/10/30 11:05:00	2019/12/02 11:00:00	791.9	1.42	1.30	1.48	1.40	6.3	0.06	**1.51**
AFBI03	Beaghs Burn	2019/11/05 09:20:00	2019/12/02 12:00:00	650.7	0.09	0.09	0.09	0.09	2.1	0.06	0.04[a]
AFBI04	Slieve Beagh	2019/11/07 13:20:00	2019/11/29 15:05:00	529.7	0.43	0.41	0.44	0.43	3.4	0.06	**0.62**
AFBI05	Moninea Bog	2019/11/07 10:20:00	2019/11/29 12:20:00	530.0	0.57	0.58	0.60	0.58	2.1	0.06	**0.88**
AFBI07	Seekinore	2019/11/07 12:55:00	2019/11/29 16:35:00	531.7	1.83	1.67	1.69	1.73	5.1	0.06	**2.80**
AFBI08	Lisbellaw	2019/11/07 11:50:00	2019/11/29 13:50:00	530.0	1.29	1.23	1.23	1.25	2.8	0.06	**2.01**
AFBI09	Glenwherry COSMOS	2019/11/04 16:00:00	2019/11/27 13:30:00	549.5	0.35	0.29	0.33	0.32	8.2	0.06	**0.42**
AFBI10	UWMN bencrom River	2019/11/06 11:15:00	2019/12/03 12:30:00	649.2	0.18	0.19	0.17	0.18	4.7	0.06	**0.16**
AFBI11	Blackwater town	2019/11/04 14:25:00	2019/12/03 15:00:00	696.6	3.16	2.96	3.13	3.08	3.6	0.06	**3.88**
AFBI12	Ratarnet Rd	2019/11/04 11:10:00	2019/12/03 09:00:00	693.8	2.40	2.70	2.39	2.50	6.9	0.06	**3.14**
AFBI13	Inch Abbey	2019/10/29 12:35:00	2019/11/28 11:35:00	719.0	0.57	0.53	0.55	0.55	3.4	0.06	**0.60**
AFBI14	AURN Belfast centre	2019/11/04 12:45:00	2019/12/03 11:00:00	694.2	1.64	1.64	1.84	1.71	6.6	0.06	**2.12**
AFBI15	Ballylinney Presbyterian Church	2019/10/29 13:30:00	2019/12/02 11:45:00	814.2	1.07	1.23	0.99	1.09	11.5	0.06	**1.13**
AFBI16	West of Crumlin	2019/10/29 14:45:00	2019/12/02 12:30:00	813.8	0.99	1.03	1.01	1.01	1.8	0.06	**1.04**
AFBI17	Loughmore River	2019/11/01 11:15:00	2019/11/28 10:50:00	647.6	0.29	0.26	0.35	0.30	14.6	0.06	**0.33**
AFBI18	Caldanagh Bog	2019/10/29 14:00:00	2019/11/27 15:15:00	697.3	1.18	1.13	1.09	1.13	4.1	0.06	**1.38**
AFBI19	Cloughmills	2019/11/05 14:00:00	2019/11/27 14:30:00	528.5	0.27	0.99	1.07	0.77	57.2	0.06	**1.64**
AFBI20	Caddy Rd	2019/11/01 14:15:00	2019/12/02 12:00:00	741.8	-	-	-			0.06	ND[3]
AFBI21	Turmennan Rd	2019/10/29 12:20:00	2019/11/28 11:20:00	719.0	0.69	0.71	0.72	0.71	2.4	0.06	**0.80**
AFBI22	Carrowbane Rd	2019/11/04 11:45:00	2019/12/03 11:30:00	695.8	0.05	2.88	2.97	1.97	84.6	0.06	**3.68**
AFBI23	Creggan	2019/10/30 10:30:00	2019/12/02 10:25:00	791.9	1.57	1.64	1.70	1.64	4.1	0.06	**1.78**
AFBI24	Corramore Rd	2019/11/01 10:00:00	2019/11/28 12:15:00	650.3	0.21	0.21	0.20	0.21	3.8	0.06	**0.20**
AFBI25	Hillsborough	2019/11/01 12:05:00	2019/12/02 13:30:00	745.4	3.35	3.56	3.57	3.49	3.5	0.06	**4.12**
AFBI29	Drumclamph 2	2019/10/31 14:00:00	2019/12/03 14:30:00	792.5	3.16	3.26	3.35	3.26	2.9	0.06	**3.61**

ND[3] = samplers damaged

[a]Blank value – rejected

Period 10: December 2019 (UKNAMN 2019 uptake rate applied: 0.0031665 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/12/03 14:00:00	2019/12/30 12:45:00	646.8	1.71	1.69	1.74	1.72	1.4%	0.063	**2.29**
AFBI02	Castle Enigan	2019/12/02 11:00:00	2020/01/07 12:45:00	865.8	1.29	1.23	1.36	1.29	5.1%	0.063	**1.27**
AFBI03	Beaghs Burn	2019/12/02 12:00:00	2020/01/02 14:45:00	746.7	0.30	0.28	0.33	0.30	8.9%	0.063	**0.29**
AFBI04	Slieve Beagh	2019/11/29 15:05:00	2020/01/03 16:05:00	841.0	0.48	0.46	0.55	0.50	9.0%	0.063	**0.46**
AFBI05	Moninea Bog	2019/11/29 12:20:00	2020/01/03 10:45:00	838.4	0.97	0.98	1.01	0.99	1.8%	0.063	**0.98**
AFBI07	Seekinore	2019/11/29 16:35:00	2020/01/03 14:25:00	837.8	1.24	1.23	1.23	1.23	0.2%	0.063	**1.25**
AFBI08	Lisbellaw	2019/11/29 13:50:00	2020/01/03 12:15:00	838.4	2.16	1.85	1.99	2.00	7.8%	0.063	**2.07**
AFBI09	Glenwherry COSMOS	2019/11/27 13:35:00	2020/01/06 15:00:00	961.4	1.19	1.35	1.31	1.28	6.3%	0.063	**1.14**
AFBI10	UWMN bencrom River	2019/12/03 12:40:00	2020/01/02 12:20:00	719.7	0.26	0.30	0.26	0.27	8.9%	0.063	**0.26**
AFBI11	Blackwater town	2019/12/03 15:00:00	2019/12/30 14:00:00	647.0	1.69	1.97	2.00	1.88	9.0%	0.063	**2.52**
AFBI12	Ratarnet Rd	2019/12/03 09:00:00	2019/12/30 09:30:00	648.5	1.35	1.43	1.36	1.38	3.2%	0.063	**1.81**
AFBI13	Inch Abbey	2019/11/28 11:35:00	2020/01/06 12:50:00	937.2	1.03	0.95	1.00	0.99	4.4%	0.063	**0.89**
AFBI14	AURN Belfast centre	2019/12/03 11:00:00	2020/01/06 09:45:00	814.8	1.87	2.03	1.99	1.96	4.3%	0.063	**2.08**
AFBI15	Ballylinney Presbyterian Church	2019/12/02 11:45:00	2019/12/31 09:28:00	693.7	1.32	1.57	1.37	1.42	9.4%	0.063	**1.75**
AFBI16	West of Crumlin	2019/12/02 12:30:00	2019/12/31 11:20:00	694.8	1.63	1.42	1.53	1.52	6.9%	0.063	**1.88**
AFBI17	Loughmore River	2019/11/28 10:50:00	2020/01/02 13:30:00	842.7	0.53	0.56	0.59	0.56	4.8%	0.063	**0.53**
AFBI18	Caldanagh Bog	2019/11/27 15:20:00	2020/01/02 10:00:00	858.7	1.68	1.79	1.50	1.66	8.9%	0.063	**1.66**
AFBI19	Cloughmills	2019/11/27 14:35:00	2020/01/02 11:05:00	860.5	2.39	2.17	2.21	2.26	5.3%	0.063	**2.28**
AFBI20	Caddy Rd	2019/12/02 13:15:00	2019/12/31 10:15:00	693.0	2.13	2.10	1.96	2.06	4.3%	0.063	**2.58**
AFBI21	Turmennan Rd	2019/11/28 11:20:00	2020/01/06 12:40:00	937.3	1.11	1.26	1.17	1.18	6.4%	0.063	**1.07**
AFBI22	Carrowbane Rd	2019/12/03 11:30:00	2019/12/30 11:00:00	647.5	-	1.26	1.17	1.21	5.0%	0.063	**1.59**
AFBI23	Creggan	2019/12/02 10:25:00	2020/01/07 11:55:00	865.5	-	-	-	-	-	0.063	ND[3]
AFBI24	Corramore Rd	2019/11/28 12:20:00	2020/01/03 11:15:00	862.9	0.39	0.46	0.36	0.40	12.1%	0.063	**0.35**
AFBI25	Hillsborough	2019/12/02 13:30:00	2019/12/31 15:57:00	698.4	3.49	3.77	3.76	3.67	4.3%	0.063	**4.63**
AFBI29	Drumclamph 2	2019/12/03 14:30:00	2019/12/31 12:35:00	670.1	1.65	1.60	1.61	1.62	1.6%	0.063	**2.08**

ND[3] = samplers damaged

Period 11: January 2020 (UKNAMN 2020 uptake rate applied: 0.0031277 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2019/12/30 12:45:00	2020/02/04 14:00:00	865.2	2.22	2.21	2.18	2.20	0.9%	0.055	**2.25**
AFBI02	Castle Enigan	2020/01/07 12:45:00	2020/02/03 11:00:00	646.2	1.17	1.15	1.18	1.16	1.4%	0.055	**1.56**
AFBI03	Beaghs Burn	2020/01/02 14:45:00	2020/02/06 13:25:00	838.7	0.49	0.44	0.51	0.48	7.8%	0.055	**0.46**
AFBI04	Slieve Beagh	2020/01/03 16:05:00	2020/02/01 11:30:00	691.4	0.32	0.37	0.31	0.33	8.9%	0.055	**0.37**
AFBI05	Moninea Bog	2020/01/03 10:45:00	2020/02/01 08:30:00	693.8	1.04	0.96	0.96	0.98	4.6%	0.055	**1.20**
AFBI07	Seekinore	2020/01/03 14:25:00	2020/02/01 15:45:00	697.3	0.94	0.98	1.02	0.98	4.5%	0.055	**1.62**
AFBI08	Lisbellaw	2020/01/03 12:15:00	2020/02/01 09:15:00	693.0	1.26	1.33	1.29	1.29	2.8%	0.055	**1.74**
AFBI09	Glenwherry COSMOS	2020/01/06 15:00:00	2020/02/06 10:00:00	739.0	1.58	1.37	1.49	1.48	7.3%	0.055	**0.56**
AFBI10	UWMN bencrom River	2020/01/02 12:30:00	2020/02/04 11:40:00	791.2	0.53	0.54	0.57	0.55	3.6%	0.055	**2.66**
AFBI11	Blackwater town	2019/12/30 14:00:00	2020/02/04 14:30:00	864.5	2.45	2.54	2.80	2.60	7.1%	0.055	**2.64**
AFBI12	Ratarnet Rd	2019/12/30 09:30:00	2020/02/04 09:14:00	863.7	2.64	2.40	2.68	2.57	5.8%	0.055	**1.69**
AFBI13	Inch Abbey	2020/01/06 12:50:00	2020/02/05 12:40:00	719.8	1.30	1.51	1.39	1.40	7.5%	0.055	**2.58**
AFBI14	AURN Belfast centre	2020/01/06 09:45:00	2020/02/07 10:15:00	768.5	2.11	2.12	2.49	2.24	9.8%	0.055	**3.03**
AFBI15	Ballylinney Presbyterian Church	2019/12/31 09:30:00	2020/02/07 10:30:00	913.0	2.90	2.97	3.45	3.11	9.6%	0.055	**2.02**
AFBI16	West of Crumlin	2019/12/31 11:20:00	2020/02/07 12:00:00	912.7	2.05	2.04	2.17	2.09	3.5%	0.055	**0.60**
AFBI17	Loughmore River	2020/01/02 13:30:00	2020/02/05 10:45:00	813.3	0.58	0.64	0.57	0.59	6.6%	0.055	**2.34**
AFBI18	Caldanagh Bog	2020/01/02 10:00:00	2020/02/06 14:00:00	844.0	2.34	2.07	2.28	2.23	6.3%	0.055	**2.90**
AFBI19	Cloughmills	2020/01/02 11:05:00	2020/02/06 13:00:00	841.9	2.76	2.66	2.82	2.75	3.0%	0.055	**2.97**
AFBI20	Caddy Rd	2019/12/31 10:15:00	2020/02/07 11:30:00	913.3	3.13	2.77	3.25	3.05	8.1%	0.055	**1.75**
AFBI21	Turmennan Rd	2020/01/06 12:40:00	2020/02/05 10:25:00	717.8	1.40	1.40	1.53	1.44	5.1%	0.055	**2.12**
AFBI22	Carrowbane Rd	2019/12/30 11:00:00	2020/02/04 12:00:00	865.0	1.98	2.24	2.03	2.08	6.6%	0.055	**2.49**
AFBI23	Creggan	2020/01/07 11:55:00	2020/02/03 10:25:00	646.5	1.90	1.82	1.77	1.83	3.5%	0.055	**0.51**
AFBI24	Corramore Rd	2020/01/03 11:15:00	2020/02/05 12:30:00	793.2	0.49	0.57	0.44	0.50	12.8%	0.055	**5.94**
AFBI25	Hillsborough	2019/12/31 15:58:00	2020/02/04 16:00:00	840.0	5.57	5.70	5.42	5.56	2.6%	0.055	**1.96**
AFBI29	Drumclamph 2	2019/12/31 12:37:00	2020/02/04 11:59:00	839.4	1.88	1.89	1.83	1.87	1.8%	0.055	**1.20**

ND[3] = samplers damaged

Period 12: February 2020 (UKNAMN 2020 uptake rate applied: 0.0031277 m^3 h^{-1})

ID	name	ALPHA_DATE_OUT	ALPHA_DATE_IN	Time (Hrs)	(1)NH_4^+ (ppm)	(2)NH_4^+ (ppm)	(3)NH_4^+ (ppm)	Mean NH_4^+ (ppm)	% CV	Blank NH_4^+ (ppm)	Calibrated NH_3 (µg m^{-3})
AFBI01	U of U met station (SNIFFER)	2020/02/04 14:00:00	2020/03/02 14:00:00	648.0	1.25	1.19	1.20	1.21	2.7%	0.057	**1.62**
AFBI02	Castle Enigan	2020/02/03 11:00:00	2020/02/28 13:15:00	602.3	0.85	0.99	1.03	0.96	9.7%	0.057	**1.35**
AFBI03	Beaghs Burn	2020/02/06 13:30:00	2020/03/04 12:30:00	647.0	0.25	0.27	0.30	0.27	10.1%	0.057	**0.30**
AFBI04	Slieve Beagh	2020/02/01 11:30:00	2020/02/28 13:15:00	649.7	0.35	0.30	0.33	0.32	7.0%	0.057	**0.37**
AFBI05	Moninea Bog	2020/02/01 08:30:00	2020/02/28 08:45:00	648.2	0.72	0.66	0.77	0.71	7.8%	0.057	**0.92**
AFBI07	Seekinore	2020/02/01 15:45:00	2020/02/28 15:10:00	647.4	0.81	0.87	0.87	0.85	3.9%	0.057	**1.11**
AFBI08	Lisbellaw	2020/02/01 09:15:00	2020/02/28 10:20:00	649.1	1.37	1.20	1.16	1.24	9.1%	0.057	**1.66**
AFBI09	Glenwherry COSMOS	2020/02/06 10:00:00	2020/03/05 12:15:00	674.3	0.81	0.85	0.89	0.85	5.2%	0.057	**1.06**
AFBI10	UWMN bencrom River	2020/02/04 11:55:00	2020/03/02 12:20:00	648.4	0.40	0.38	0.36	0.38	5.4%	0.057	**0.45**
AFBI11	Blackwater town	2020/02/04 14:30:00	2020/03/02 00:00:00	633.5	-	-	-	-	-	0.057	ND[3]
AFBI12	Ratarnet Rd	2020/02/04 09:14:00	2020/03/02 09:00:00	647.8	1.45	1.61	1.41	1.49	6.9%	0.057	**2.01**
AFBI13	Inch Abbey	2020/02/05 12:40:00	2020/02/25 12:55:00	480.2	0.53	0.50	0.49	0.51	3.1%	0.057	**0.85**
AFBI14	AURN Belfast centre	2020/02/07 10:15:00	2020/03/04 10:00:00	623.8	1.17	1.12	1.26	1.19	6.1%	0.057	**1.64**
AFBI15	Ballylinney Presbyterian Church	2020/02/07 10:30:00	2020/02/27 14:00:00	483.5	1.00	0.99	1.00	0.99	0.9%	0.057	**1.76**
AFBI16	West of Crumlin	2020/02/07 12:00:00	2020/02/28 09:30:00	501.5	0.77	0.75	-	0.76	2.0%	0.057	**1.27**
AFBI17	Loughmore River	2020/02/05 10:45:00	2020/03/04 11:00:00	672.2	0.38	0.39	0.38	0.38	2.1%	0.057	**0.44**
AFBI18	Caldanagh Bog	2020/02/06 14:00:00	2020/03/05 09:45:00	667.8	1.16	-	1.15	1.15	0.4%	0.057	**1.49**
AFBI19	Cloughmills	2020/02/06 13:00:00	2020/03/05 11:15:00	670.2	1.57	1.53	1.43	1.51	4.9%	0.057	**1.96**
AFBI20	Caddy Rd	2020/02/07 11:30:00	2020/02/27 14:30:00	483.0	1.06	1.00	0.97	1.01	4.1%	0.057	**1.79**
AFBI21	Turmennan Rd	2020/02/05 10:25:00	2020/02/25 12:40:00	482.3	0.60	0.63	0.61	0.61	2.1%	0.057	**1.04**
AFBI22	Carrowbane Rd	2020/02/04 12:00:00	2020/03/02 11:00:00	647.0	1.24	1.67	1.51	1.47	14.6%	0.057	**1.98**
AFBI23	Creggan	2020/02/03 10:25:00	2020/02/28 12:30:00	602.1	1.03	1.13	0.99	1.05	6.8%	0.057	**1.50**
AFBI24	Corramore Rd	2020/02/05 12:30:00	2020/03/04 09:45:00	669.3	0.41	0.36	0.38	0.38	5.7%	0.057	**0.44**
AFBI25	Hillsborough	2020/02/04 16:00:00	2020/03/02 15:55:00	647.9	3.29	2.87	2.84	3.00	8.3%	0.057	**4.12**
AFBI29	Drumclamph 2	2020/02/04 12:00:00	2020/03/03 13:45:00	673.8	1.67	1.76	1.70	1.71	2.8%	0.057	**2.22**

ND[3] = samplers damaged

7 Appendix B: DELTA data tables

	AFBI25 Hillsborough			Gas concentrations (µg m^{-3})			Particulate concentrations (µg m^{-3})						
Period	**Start**	**End**	**FR (LPM)**	**NH_3**	**HNO_3**	**SO_2**	**NH_4^+**	**NO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**
Mar-19	04/03/2019 16:30	02/04/2019 12:50	0.01[a]	(4.02)	(0.08)	(0.59)	(0.83)	(0.65)	(0.31)	(-0.55)	(-1.00)	(0.31)	(0.22)
Apr-19	02/04/2019 12:52	01/05/2019 16:04	0.28	4.52	0.20	0.53	2.82	7.59	2.17	1.95	0.28	0.17	1.12
May-19	01/05/2019 16:04	30/05/2019 11:00	0.29[b]	(0.00)	(0.13)	(0.01)	(0.00)	(-0.03)	(-0.01)	(0.15)	(0.00)	(-0.01)	(-0.01)
Jun-19	30/05/2019 11:00	01/07/2019 11:30	0.28[c]	(2.54)	(-0.04)	(0.12)	(0.59)	(0.48)	(0.09)	(0.24)	(0.02)	(0.01)	(0.03)
Jul-19	01/07/2019 11:30	01/08/2019 12:00	0.29[d]	13.48	-0.04	0.42	(0.81)	(0.97)	(0.19)	(0.88)	(0.08)	(0.05)	(0.22)
Aug-19	01/08/2019 12:05	02/09/2019 08:50	0.30[c]	(3.88)	(0.02)	(0.28)	(0.56)	(1.17)	(0.14)	(0.49)	(0.02)	(0.02)	(0.15)
Sep-19	02/09/2019 08:50	02/10/2019 12:35	0.30	8.23	-0.02	0.45	0.68	1.64	0.67	2.00	0.10	0.14	1.10
Oct-19	02/10/2019 12:39	01/11/2019 12:00	0.27	6.83	(-0.09)*	0.42	0.44	1.09	0.55	1.66	0.09	0.12	0.93
Nov-19	01/11/2019 12:00	02/12/2019 13:30	0.28	3.57	0.24	0.60	0.57	1.68	0.56	1.28	0.02	0.08	0.70
Dec-19	02/12/2019 13:30	31/12/2019 15:51	0.28	4.28	(-0.09)*	0.52	0.38	1.02	0.61	1.79	0.10	0.12	0.97
Jan-20	31/12/2019 15:54	04/02/2020 15:55	0.07[a]	(4.11)	(-0.01)	(0.58)	(1.48)	(4.53)	(0.61)	(2.38)	(0.03)	(0.14)	(1.11)
Feb-20	05/02/2020 16:00	02/03/2020 16:00	0.27[c]	(3.33)	(-0.06)	(0.31	(0.05)[e]	(0.81)[e]	(0.48)	(2.37)	(0.10)	(0.14)	(1.18)
			Mean	6.82	0.09	0.49	0.98	2.60	0.91	1.73	0.12	0.13	0.97
			N	6	4	6	5	5	5	5	5	5	5

	AFBI26 Ballynahone Bog			Gas concentrations (µg m^{-3})			Particulate concentrations (µg m^{-3})						
Period	**Start**	**End**	**FR (LPM)**	**NH_3**	**HNO_3**	**SO_2**	**NH_4^+**	**NO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**
Mar-19	07/03/2019 15:25	01/04/2019 12:08	0.37	3.22	0.05	0.20	0.25	0.56	0.48	1.93	0.04	0.13	1.01
Apr-19	01/04/2019 12:08	30/04/2019 12:03	0.37	4.08	0.17	0.45	2.41	6.17	1.91	1.67	0.25	0.13	0.94
May-19	30/04/2019 12:12	29/05/2019 11:40	0.37	3.08	0.08	0.26	1.24	1.14	0.41	0.80	0.11	0.04	0.34
Jun-19	29/05/2019 11:50	25/06/2019 13:00	0.38[c]	(0.30)	(-0.07)	(0.02)	(3.99)	(0.71)	(0.01)	(0.55)	(0.03)	(0.00)	(-0.03)
Jul-19	25/06/2019 13:10	31/07/2019 11:58	0.37	4.05	0.02	0.29	0.88	1.41	0.70	0.71	0.10	0.08	0.43
Aug-19	31/07/2019 12:00	28/08/2019 11:40	0.37	3.68	0.02	0.35	0.44	0.73	0.50	1.12	0.04	0.07	0.61
Sep-19	28/08/2019 11:44	30/09/2019 15:03	0.37[c]	(0.13)	(-0.07)	(0.03)	(4.17)	(0.83)	(0.35)	1.13	0.05	0.08	0.63
Oct-19	30/09/2019 15:10	31/10/2019 11:18	0.35	4.10	(-0.09)*	0.30	0.38	0.85	0.55	1.76	0.53	0.13	0.94
Nov-19	31/10/2019 11:23	28/11/2019 11:35	0.36[c]	(1.06)	(0.08)	(0.24)	(0.48)	(1.32)	(0.20)	(0.24)	(-0.01)	(0.03)	(0.27)
Dec-19	28/11/2019 11:43	18/12/2019 11:50	0.36[c]	(0.41)	(-0.21)	(0.19)	(0.26)	(0.51)	(0.22)	(0.83)	(0.04)	(0.06)	(0.38)
Jan-20	18/12/2019 11:55	28/01/2020 11:20	0.36	2.96	0.05	0.31	0.51	1.20	0.54	1.80	0.10	0.15	1.12
Feb-20	28/01/2020 11:25	26/02/2020 11:50	0.36	1.19	-0.02	0.28	0.59	1.42	0.15	(1.13)[d]	(0.14)[d]	(0.22)[d]	(1.73)[d]
			Mean	3.29	0.05	0.30	0.84	1.69	0.65	1.37	0.15	0.11	0.75
			N	8	7	8	8	8	8	8	8	8	8

[a]Power off most of month –rejected

[b]rejected – sample train disconnected inside holder

[c]rejected – suspect leak in sample train

[d]aerosols only rejected – ion balance checks suggest aerosol measurement issues

[e]values too low – outlier, rejected

*less than negative LOD (limit of detection) – rejected

	AFBI27 UoU Coleraine			Gas concentrations (µg m^{-3})			Particulate concentrations (µg m^{-3})						
Period	**Start**	**End**	**FR (LPM)**	**NH_3**	**HNO_3**	**SO_2**	**NH_4^+**	**NO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**
Mar-19	06/03/2019 16:00	29/03/2019 12:40	0.27	2.14	-0.04	0.33	0.25	0.67	0.74	3.42	0.12	0.24	1.96
Apr-19	29/03/2019 12:40	30/04/2019 10:10	0.28	3.14	0.13	0.43	1.88	4.78	1.62	1.86	0.20	0.14	1.08
May-19	30/04/2019 10:15	29/05/2019 10:45	0.28[c]	(1.25)	(0.18)	(0.12)	(0.45)	(0.84)	(0.17)	(0.50)	(0.01)	(0.02)	(0.27)
Jun-19	29/05/2019 10:50	02/07/2019 09:40	0.28	1.20	0.02	0.18	1.00	2.85	0.27	0.86	0.07	0.05	0.36
Jul-19	02/07/2019 09:40	30/07/2019 09:50	0.27[c]	(1.42)	(-0.13)	(0.06)	(0.51)	(1.03)	(0.04)	(0.34)	(0.01)	(0.01)	(0.05)
Aug-19	30/07/2019 10:00	28/08/2019 14:00	0.26[c]	(1.18)	-0.05	(0.18)	(0.51)	(0.63)	(0.17)	(0.58)	(0.11)	(0.03)	(0.23)
Sep-19	28/08/2019 14:00	01/10/2019 11:30	0.26	1.13	(-0.07)*	0.12	0.17	0.29	0.27	0.83	0.12	0.06	0.50
Oct-19	01/10/2019 11:35	05/11/2019 10:00	0.24	4.57	(-0.13)*	0.37	0.35	0.96	0.55	1.82	0.03	0.11	0.94
Nov-19	05/11/2019 10:05	03/12/2019 10:00	0.20	1.00	0.05	0.52	0.89	1.81	0.26	0.76	-0.05	0.04	0.37
Dec-19	03/12/2019 10:10	31/12/2019 11:45	0.13	1.12	-0.04	0.53	0.36	1.14	0.45	1.57	0.04	0.09	0.70
Jan-20	31/12/2019 11:45	04/02/2020 10:15	0.13[a,c]	(1.15)	(0.05)	(0.58)	(0.58)	(2.05)	(0.58)	(2.41)	(0.07)	(0.15)	(1.20)
Feb-20	04/02/2020 10:20	03/03/2020 12:00	0.13[a,c]	(1.13)	(0.10)	(0.58)	(-0.20)	(0.77)	(0.46)	(2.58)	(0.25)	(0.14)	1.30)
			Mean	1.93	0.01	0.33	0.68	1.64	0.54	1.46	0.08	0.10	0.77
			N	8	6	8	8	8	8	8	8	8	8

	AFBI28 Sandholes			Gas concentrations (µg m^{-3})			Particulate concentrations (µg m^{-3})						
Period	**Start**	**End**	**FR (LPM)**	**NH_3**	**HNO_3**	**SO_2**	**NH_4^+**	**NO_3^-**	**SO_4^{2-}**	**Cl^-**	**Ca^{2+}**	**Mg^{2+}**	**Na^+**
Mar-19	07/03/2019 12:45	27/03/2019 09:54	0.30	2.89	(-0.10)*	0.35	0.28	0.55	0.58	2.63	0.06	0.18	1.43
Apr-19	27/03/2019 09:55	30/04/2019 11:55	0.32	8.10	0.16	0.42	0.93	1.69	0.21	0.73	0.19	0.04	0.28
May-19	30/04/2019 11:55	30/05/2019 03:30	0.33[c]	(0.21)	(0.09)	(0.01)	(3.83)	(0.88)	(0.030	(0.10)	(0.00)	(-0.01)	(0.04)
Jun-19	30/05/2019 15:45	03/07/2019 10:00	0.00	-	-	-	-	-	-	-	-	-	-
Jul-19	03/07/2019 10:00	31/07/2019 10:00	0.33	2.31	0.08	0.20	0.35	0.51	0.47	0.40	0.04	0.02	0.18
Aug-19	31/07/2019 10:05	28/08/2019 11:00	0.33	5.68	0.15	0.15	0.35	0.32	0.22	0.37	0.01	0.02	0.16
Sep-19	28/08/2019 11:05	01/10/2019 12:15	0.33[c]	(0.04)	(-0.01)	(0.01)	(5.09)	(0.67)	(0.21)	(1.18)	(0.09)	(0.07)	(0.53)
Oct-19	01/10/2019 12:17	31/10/2019 11:00	0.32	4.91	(-0.07)*	1.23	0.42	0.84	0.50	1.67	0.11	0.10	0.85
Nov-19	31/10/2019 11:00	28/11/2019 13:35	0.32	4.06	0.07	0.73	0.37	1.77	0.76	1.42	0.28	0.10	0.79
Dec-19	28/11/2019 13:35	03/01/2020 12:00	0.32	2.90	0.02	0.72	0.42	0.82	0.37	1.18	0.14	0.14	1.11
Jan-20	03/01/2020 12:00	04/02/2020 13:46	0.32	2.81	0.06	0.80	1.12	3.02	0.47	2.22	0.09	0.19	1.42
Feb-20	04/02/2020 13:48	04/03/2020 13:00	0.30	2.27	(-0.06)*	0.49	0.33	0.84	0.23	1.54	0.09	0.16	1.30
			Mean	3.99	0.09	0.57	0.51	1.15	0.42	1.35	0.11	0.10	0.84
			N	9	6	9	9	9	9	9	9	9	9

[a]Power off most of month –rejected

[b]rejected – sample train disconnected inside holder

[c]rejected – suspect leak in sample train

[d]aerosols only rejected – ion balance checks suggest aerosol measurement issues

[e]values too low – outlier, rejected

[*]less than negative LOD (limit of detection) – rejected

8 Appendix C: NI NH_3 data (2003-2004)

1. Atmospheric NH_3 concentrations were monitored at 11 sites across Northern Ireland for one year (monthly: Apr 03 to Mar 04), and at a 12th site for 7 months (Sep 03 to Mar 04). Monitoring data (both gaseous NH_3 and aerosol NH_4^+) from 3 existing UK National Ammonia Monitoring Network (NAMN) sites were also used to complement the measurement data from this project.
2. A map of the monitoring sites is shown in Figure A1. Each site in the figure is given a number and the full network is noted in Table A1.
3. Several of the monitoring sites were deliberately located on the edge of Areas of Special Scientific Interest (ASSI), to assess potential impacts of NH_3 emissions and deposition. Other sites were located in mixed agricultural landscapes to identify representative NH_3 concentrations. Two other sites were located within 500 m of two existing UK NAMN monitoring sites, which aimed to give an indication of local variability in NH_3 concentration in the 5 km grid squares containing the sites.
4. Additional sites to assess spatial variability are given in Table A2, with table provided in Table A3.
5. Summary data are provided in Table A3 – A4 and Figure A2.

Figure A1: Map of ammonia monitoring sites in Northern Ireland (this includes 3 National Ammonia Monitoring Network (NAMN) sites funded by DEFRA and the Devolved Administrations).

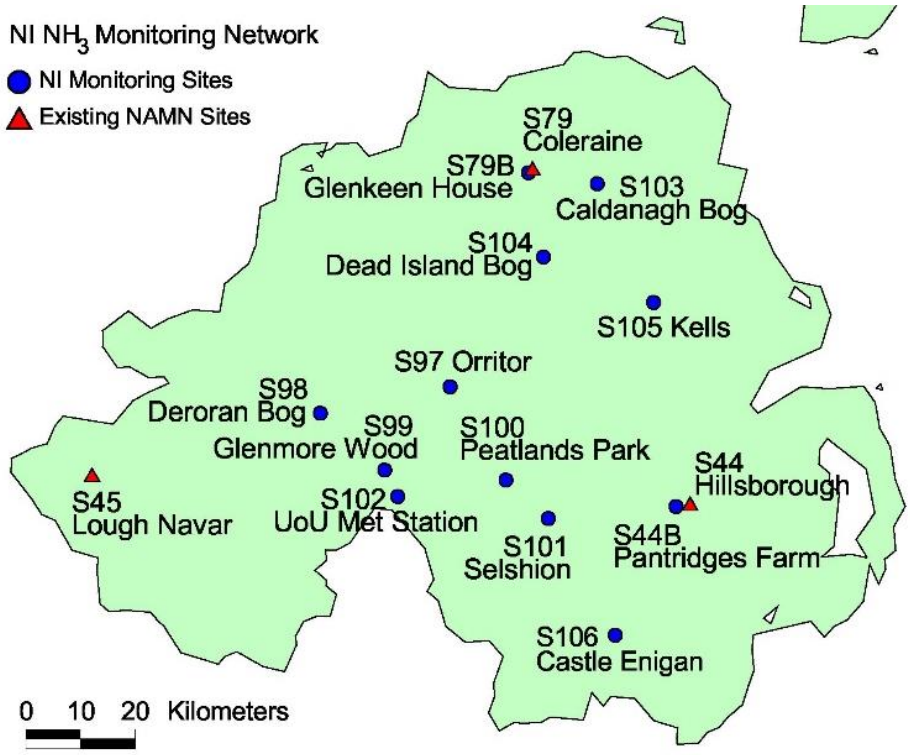

Table A1: Ammonia Monitoring sites set up in Northern Ireland in April 2003

Within 25 km radius of Dungannon				No. of measurements	
Site No.	Site Name	Grid ref. (irish)	Frequency	Agreed	Actual
97	Orritor (by Upper Ballenderry River ASSI)	H768782	monthly	12	12
98	Deroran Bog (ASSI)	H518709	monthly	12	12
99	Glenmore Wood (ASSI)	H654608	monthly	12	12
100	Peatlands Park (ASSI)	H893609	monthly	12	12
101	Selshion (ASSI)	H982541	monthly	12	12
102	UoU Met Station	H683558	monthly	12	12
Within 25 km radius of Ballymena					
Site No.	Site Name	Grid ref. (irish)	Frequency	No. of measurements	
103	Caldanagh Bog (ASSI)	D022205	monthly	12	12
104	Dead Island Bog (ASSI)	C929052	monthly	12	12
105	Kells	J152982	monthly	12	12
Close to existing NAMN sites					
Site No.	Site Name	Grid ref. (irish)	Frequency	No. of measurements	
79B	Glenkeen House (= Coleraine B)	C885215	monthly	6	12
44B	Pantridges Farm (= Hillsborough B)	J231585	monthly	6	12
Addtitonal site (set up Sep 2003)					
Site No.	Site Name	Grid ref. (irish)	Frequency	No. of measurements	
106	Castle Enigan (ASSI)	J125319	monthly	6	7

Table A2: Additional sites where ammonia monitoring was carried out.

Extra transect measurements	Grid ref. (irish)	Frequency	Month	No. of measurements
S98 Deroran Bog Transect				
S98B Outside of Bog (Lisboy Bridge)	H512706	Monthly	Apr-03	1
S98C Centre of Deroran Bog	H527714	Monthly	Apr-03	1
S100 Peatlands Park Bog Transect				
S100B Outside of Bog (Met station)	H895603	Monthly	Apr-03	1
S98C Centre of Peatlands Park Bog	H901610	Monthly	Apr-03	1
S101 Selshion Transect				
S101B Outside of Bog (Selshion orchard)	H979540	Monthly	Apr-03	1
S101C Centre of Selshion Bog	H985544	Monthly	Apr-03	1
S103 Caldanagh Bog Transect				
S103B Caldanogh Bog farm	D022202	Monthly	Apr-03	1
S103C Centre of Caldanogh Bog	D022207	Monthly	Apr-03	1
S103D Caldanogh Bog sewage works	D020198	Monthly	Apr-03	1
S106 Castle Enigan				
S106B: Western edge of Enigan ASSI	J123322	Monthly	Sep - Dec-03	4
S106C: 30m west of farm	J132324	Monthly	Sep - Dec-03	4
S106D: 100m west of farm	J131323	Monthly	Dec-03	1

Table A3: Data summary for ammonia monitoring sites in Northern Ireland between April 2003 and March 2004.

		2003	2003	2003	2003	2003	2003	2003	2003	2003	2004	2004	2004	12 months
ID	**Name**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**	**Annual mean**
44	Hillsborough	5.68	2.71	3.83	3.64	6.82	6.13	2.58	2.39	1.55	1.70	4.99	3.65	**3.81**
44B	Pantridges Farm	0.96	1.88	2.72	8.95	11.47	3.99	3.20	-	-	2.54	42.56	6.01	**8.43**
45	Lough Navar	1.04	0.37	0.55	0.58	0.86	0.35	0.42	0.30	0.21	0.15	0.29	0.55	**0.47**
79	Coleraine	3.39	1.44	3.03	2.39	2.39	1.64	1.19	1.61	1.76	-	4.23	2.51	**2.33**
79B	Glenkeen House	3.35	1.19	3.42	3.07	2.89	2.63	2.86	11.49	8.78	2.40	10.01	15.52	**5.64**
97	Orritor	4.62	1.85	4.71	-	4.34	11.99	3.92	4.48	3.80	2.63	23.93	4.73	**6.46**
98	Deroran Bog	1.80	0.84	1.91	1.67	1.65	1.85	1.61	1.57	1.74	1.50	3.56	1.94	**1.80**
99	Glenmore Wood	5.18	0.95	2.05	3.10	2.72	1.89	2.16	1.70	1.49	1.08	3.01	2.02	**2.28**
100	Peatlands Park	1.74	1.30	1.90	2.65	1.81	2.09	1.77	2.14	1.68	1.82	2.74	1.84	**1.96**
101	Selshion	2.30	1.21	2.87	3.39	3.02	2.78	2.08	2.24	2.37	2.21	3.82	2.83	**2.59**
102	UoU Met Station	2.70	1.25	2.65	3.17	2.32	2.28	2.17	1.63	1.73	1.74	3.65	2.19	**2.29**
103	Caldanagh Bog	2.93	1.20	2.87	2.21	2.71	2.19	2.36	2.06	3.03	2.04	4.05	3.36	**2.58**
104	Dead Island Bog	2.12	0.93	2.68	1.72	1.75	1.85	1.26	3.34	1.95	2.03	3.66	3.18	**2.21**
105	Kells	5.70	2.40	6.42	4.47	6.64	2.67	4.52	4.35	3.72	1.94	4.88	5.63	**4.44**
106	Enigan NNR						2.71	5.01	2.60	2.44	2.24	5.96	7.68	**4.09**

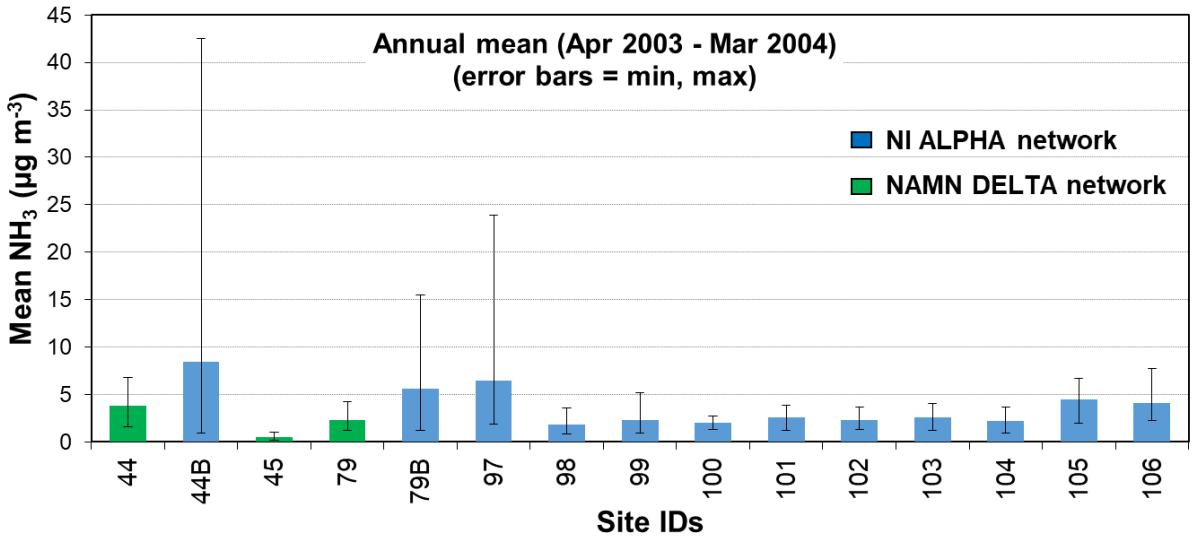

Figure A2: Summary of annual mean monitored data from sites between April 2003 and March 2004.

Table A4: Data summary for ammonia monitoring sites at additional short-term sites in Northern Ireland between April 2003 and March 2004.

		NH_3 ($mg\ m^{-3}$)				
Site Nº	**Site Name**	**Apr-03**	**Sep-03**	**Oct-03**	**Nov-03**	**Dec-03**
98	Deroran Bog	1.80				
98B	Outside of Bog (Lisboy Bridge)	-				
98C	Middle of Deroran Bog	2.10				
100	Peatlands Park	1.74				
100B	Outside of Bog (Met station)	2.30				
100C	Middle of Peatlands Park Bog	2.10				
101	Selshion	2.30				
101B	Outside of Bog (Selshion orchard)	2.50				
101C	Middle of Selshion Bog	1.97				
103	Caldanagh Bog	2.93				
103B	Caldanagh Bog farm	1.09				
103C	Caldanagh Bog nature reserve	2.64				
103D	Caldanagh Bog sewage works	1.32				
106	Enigan NNR		2.71	5.01	2.60	2.44
106B	Enigan: 30m West of farm		37.43	53.86	6.58	18.59
106C	Enigan nature reserve: centre		1.61	2.25	1.53	-
106D	Enigan: 100m West of farm					1.36

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