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DATA NOTE

# Geographically distributed longitudinal nitrogen dioxide and other air pollution sensor measurements in the Avon Longitudinal Study of Parents and Children cohort catchment area [version 1; peer review: awaiting peer review]

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## Abstract

Longitudinal cohort studies provide unique opportunities to investigate the health impact of air pollution. We aimed to enhance the Avon Longitudinal Study of Parents and Children (ALSPAC) birth cohort study through the systematic collection of routinely monitored air pollution data collected by local authorities and the Department for Environment, Food and Rural Affairs (DEFRA) using a range of sensor technologies. These sensor data are in themselves not well suited for population epidemiology, rather these data are primarily used for validating and calibrating modelled air pollution concentration data over study areas. In this data note we describe the sources of routine air pollution monitoring data and detail data of pollutants including nitrogen dioxide, nitric oxide, nitrogen oxides, particulate matter, benzene and ozone collated from the local authorities that overlap the ALSPAC catchment area (Bristol, North Somerset, South Gloucestershire and part of Bath and North East Somerset).

## Keywords

Air pollution monitoring, nitrogen dioxide, sensors, birth cohort studies, ALSPAC.

## Open Peer Review

**Reviewer Status** *AWAITING PEER REVIEW*

Any reports and responses or comments on the article can be found at the end of the article.



This article is included in the [Avon Longitudinal Study of Parents and Children \(ALSPAC\)](#) gateway.

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(<http://www.bristol.ac.uk/alspac/external/documents/grant-acknowledgements.pdf>). This work was supported by the UK Natural Environment Research Council [R8/H12/83/NE/PO1830/1] as part of the ‘Enhancing Environmental data resources in Cohort studies: ALSPAC exemplar (ERICA) award (PI: Boyd). CMT is also supported by the Elizabeth Blackwell Institute for Health Research, University of Bristol.

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## Introduction

Systematic air pollution monitoring has been undertaken in the UK for nearly a hundred years, with extensive coverage from 1961 when the National Survey was established to monitor black smoke and sulphur dioxide at around 1200 sites<sup>1</sup>. In 1987, the European Union (EU) Limit and Guide Values and World Health Organisation (WHO, 1987) provided the framework for air pollution monitoring in the UK<sup>2</sup>, and in 1992, the Department of Environment in the UK established the Enhanced Urban Network (EUN), to measure five pollutants – carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), sulphur dioxide (SO<sub>2</sub>), ozone (O<sub>3</sub>) and particulate matter (PM<sub>10</sub>)<sup>3</sup>. The subsequent Environment Act 1995 requires UK governments to produce a national air quality strategy, and in 1998 the Automatic Urban and Rural Network (AURN) was formed to provide comprehensive and continuous monitoring of a range of pollutants including nitrogen dioxide (NO<sub>2</sub>). AURN sites also measure a range of other parameters including NO<sub>x</sub>, O<sub>3</sub>, CO and particles (PM<sub>10</sub> and PM<sub>2.5</sub>)<sup>4</sup>. There are currently 147 sites across the UK in the AURN network, and these sites are the source of the most granular routine measurements available - NO<sub>2</sub> hourly means. Additional NO<sub>2</sub> and other air pollution measurements, typically subject to monthly readings, are made by a network of non-automatic monitoring sites. These sites, managed by DEFRA between 1993 and 2005, are now managed by local authorities who, to fulfil the Environment Act 1995 are required to produce an annual Air Quality Status Report (ASR), containing monthly NO<sub>2</sub> measurements. Areas, where NO<sub>2</sub> levels are above those defined by the European Union (EU) Directive limits and the UK's national air quality objectives, are declared as Air Quality Management Area's (AQMA's) and require the implementation of a Local Air Quality Action Plan (LAQM) to reduce NO<sub>2</sub> to acceptable levels.

ALSPAC is a transgenerational prospective birth cohort study investigating influences on health and development across the life course<sup>5</sup>. In summary, 14,541 pregnant women who were resident in and around Bristol, England, and due to deliver between April 1, 1991 and December 31, 1992 were initially recruited, resulting in 14,062 live births and 13,988 children who were alive at one year. Subsequent phases of recruitment increased the number of enrolled children alive at one year to 14,899. The children and their families have been followed up intensively through questionnaires, study clinics and through linkage to routine datasets. Further information about ALSPAC is given on the study website. There is also a searchable dictionary of available data<sup>6</sup>.

ALSPAC maintain a lifelong database of participant residential addresses and other geographical data e.g. school addresses. Index participant addresses have been geocoded at the property and postcode centroid level and schools to postcode centroid. The ALSPAC geocoded database is updated iteratively. This database forms a foundation to which natural or social environment data with a geospatial aspect (e.g. air pollution) can be mapped to participants<sup>7</sup>.

The ERICA (Enhancing Environmental data Resources in Cohort studies: ALSPAC exemplar) project aimed to transfer

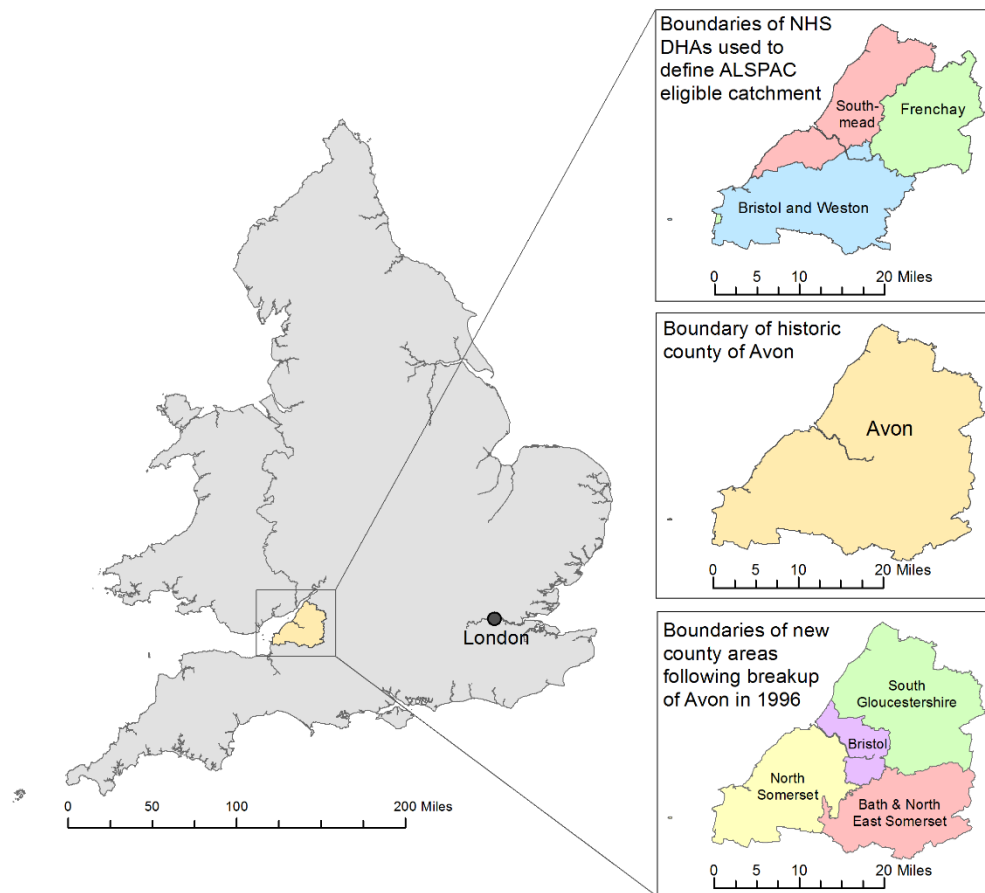
the expertise available within the natural environment research community to the medical research community: particularly the data managers of longitudinal cohort studies. ERICA also sought to understand the governance and data management requirements needed to manage the provision of natural environment exposure data in health outcome investigations – to enable cohort studies such as ALSPAC to operate as effective platforms for investigating health outcomes of environmental exposures. To help inform the development of this platform, and to demonstrate its processes, ERICA included an exemplar research strand aiming to investigate the impact of NO<sub>2</sub> air pollution exposure - particularly *in utero* – on later child respiratory outcomes. To inform this investigation ERICA collected data on outdoor, fixed site NO<sub>2</sub> concentrations and other air pollution monitored within the study catchment. NO<sub>2</sub> concentrations were used to calibrate separate work to model detailed NO<sub>2</sub> exposure for the participants of ALSPAC using a diverse set of information sources and a methodology developed in a previous ALSPAC project<sup>8</sup>. Staff from the Bristol City Council Geographical Information Systems (GIS) team collaborated with this project to provide expertise on local authority NO<sub>2</sub> monitoring.

## Methods

We sought to collect sensor data from four local authorities – Bristol City Council (BCC), Bath and North East Somerset (BaNES), North Somerset and South Gloucestershire – which correspond approximately with ALSPAC's original catchment area: the Bristol and Weston, Southmead and Frenchay District Health Authorities (Figure 1). We used two methods to obtain data: 1) searching online via publicly accessible repositories and local authority websites and downloading the publicly available datasets we found; and, 2) directly approaching the local authorities. Within this latter category there was a distinction in our relationship with BCC as they had contributed to the development of our project plan and were project collaborators. There was no formal relationship with the other three local authorities. We developed a framework defining which data and aligned metadata that were of interest to this project (Table 1) using insights from meetings with BCC. We provided the framework to our partners at BCC and asked that they identify and extract all the relevant data between 1990 and 2017. There was an individual funded to work on this at BCC, but not at the other three local authorities. A member of the ERICA team used the framework to inform their internet search strategy to identify relevant data and metadata relating to BaNES, North Somerset and South Gloucestershire. We then approached these three local authorities (via email) to request granular air pollution records.

### Internet search protocol for routine air pollution data collected in the ALSPAC catchment area

The purpose of the internet search was to collect air pollution monitoring data for the ALSPAC eligible area from publicly available online repositories in the most granular form available. Air pollution monitoring data are tables of numeric data, often Excel spread sheets that can be imported to Stata and merged with a master data set of monitoring data. However, tabulated data in PDF reports are another source. These cannot be



**Figure 1.** ALSPAC eligible area.

abstracted in an automated manner, but PDF reports containing monitoring data can at least be collated in the first instance.

We searched for additional metadata based on the item list developed with Bristol City Council (See [Table 1](#) Data framework and aligned metadata). Rich metadata are provided in annual monitoring reports that each Local Authority are obliged to report. The strategy was to use internet search engines with consistent search terms and to supplement this through directly contacting the Local Authority teams responsible for air quality management to provide links and direct data/metadata. Google was used to conduct the search given this is a non-specialist material likely to be hosted on local authority and government websites. The search was carried out between June and September 2018 with some further searching during March 2019. The keywords were ‘air pollution’ and ‘air quality’ prefixed by the name of the local authorities ‘North Somerset’, ‘BaNES’ or Bath & North East Somerset, ‘South Gloucestershire’. Our objective was not to select a representative set of responses, but rather to locate online datasets with prior knowledge of the information we were seeking based on our joint work with Bristol City Council. We therefore took an exploratory approach where the researcher investigated the returned links, and

onward links from those sites, for access to air quality assessment records.

When searching for ‘air pollution’ prefixed with the name of the local authority the first links listed were typically for the given Local Authorities ‘Air Quality Status Reports’. These reports are produced annually and are a main source of local air pollution data and metadata. We also identified links to the Department for the Environment Food and Rural Affairs (DEFRA) website describing the local authority’s Local Plan for ‘atmospheric pollution’ which in turn links to the ‘UK AIR’ site. Selecting the ‘data’ page and then ‘Data Selector’ a main source of national air pollution data was identified. Repeated searching using slightly different terms did not yield other main sources of data other than the local authority websites and DEFRA. (Communications with local environmental monitoring teams at local authorities confirmed these sources as being the key sources of internet data). The search was broadened by checking if ‘Air Quality Status Reports’ were previously but no longer available on local authority websites was possible using a longitudinal online snapshot resource called the ‘Way Back Machine’ (<https://archive.org/web/>). After using this we could be confident that our collation of ‘Air Quality Status Reports’ was comprehensive.

**Table 1. Data framework and aligned metadata.**

Data Items	Status	Notes
<ul style="list-style-type: none"> <li>Aggregate annual NO<sub>2</sub> exposure measurements</li> <li>Granular NO<sub>2</sub> pollution measurements from diffusion tube recording devices</li> <li>Granular NO<sub>2</sub> pollution measurements from automatic sites (including BCC operated NO<sub>2</sub> chemiluminescence sites and the AURN urban background site – and previously used monitoring equipment)</li> <li>Associated meteorological readings from the site at the Create Centre</li> </ul>	Delivered Pending  Pending  Pending	A .csv text file or .xls excel file (other formats on arrangement)
Metadata Items	Status	Notes
<i>Site:</i> <ul style="list-style-type: none"> <li>Address (including postcode)</li> <li>Grid Reference (Easting and Northing, Lat/Long)</li> <li>Altitude (metres)</li> <li>Height of measurement above/below ground</li> <li>Distance of measurement from middle of road/kerb/carriageway</li> <li>Description (e.g. residential, commercial, industrial, location in proximity to street, nature of immediate surroundings, local affects such as 'street canyons' or overhanging trees)</li> <li>Photos of site</li> <li>Cabinet details (e.g. vents etc)</li> <li>Start and End dates for sites</li> </ul>	Pending	Evidence can come in the form of protocols, Air quality monitoring site classifications, spreadsheets, photos, installation reports, site review reports etc
<i>Monitor:</i> <ul style="list-style-type: none"> <li>Type (e.g. Palmes-Diffusion Tube)</li> <li>Specification</li> <li>Pollutants/Environment factors measured</li> <li>Reagents used</li> <li>Start and End date for each type of monitor</li> </ul>	Pending	Evidence can come in the form of protocols, contract specifications for outsourcing, spreadsheets, report annex's etc
<i>Assaying:</i> <ul style="list-style-type: none"> <li>Monitoring technique</li> <li>Assay process (including details on protocol followed, reagents equipment used and equipment handling)</li> <li>Calibration (including QC/QC protocols, site details if using duplicate tube strategies)</li> <li>How to interpret missing data</li> <li>Start and End dates for different processes</li> </ul>	Pending	Evidence can come in the form of protocols, QA and service records, SLA documents, anecdotal guidance, historical insights, corporate knowledge from BCC staff
<i>Local Policy:</i> <ul style="list-style-type: none"> <li>Known changes that will impact on NO<sub>2</sub> data collection or pollutant volumes.</li> </ul>	Pending	Reports (e.g. AQMAs, air quality assessment reports for planning) and anecdotal guidance, historical insights, corporate knowledge from BCC staff

Please note: Metadata information can be presented annually (e.g. in 1991 the measurement was X meters from the kerb) or in date ranges (e.g. between 1991 and 1998 the measurement was X meters from the kerb).

### UK air pollution data sources background

The main national resource for air pollution is provided by DEFRA and is called. This site provides historic data that pre-dates the transfer of monitoring responsibility to local authorities. From around 2009, the local authority reports have been published in the standardised format of Air Quality Annual Status Reports (ASR's), and monthly mean NO<sub>2</sub> readings are routinely presented, as well as the type and locations of the monitors. (LA's are also invited to on a voluntary basis to upload

monthly NO<sub>2</sub> readings to the [Local Air Quality Management section of the Defra website](#)).

### Air pollution dataset

#### Data collected

Our dataset contains 3,362,846 records (Table 2). Each record is a point in time where a measurement may be expected – where the interval is monthly then a record will exist for each month, and where the interval is hourly a record will

**Table 2. Data Sources.**

Source	Data description	Format	Sites	Full range of years included	Number of records
Bristol City Council	Hourly NO <sub>2</sub> mean measurements from continuous sites	csv (1 file)	15	1993–2017	1,285,736
Bristol City Council	Monthly NO <sub>2</sub> means from DEFRA and LA operated diffusion tubes	csv (1 file)	408	1991–2017	64,932
DEFRA	Hourly means of various pollutants other than NO <sub>2</sub>	xls (18 files)	44	1993–2018	750,870
South Gloucestershire Council, Environment Protection	Hourly NO <sub>2</sub> mean measurements from continuous sites	xls (2 files)	2	2010–2017	102,039
DEFRA	Monthly NO <sub>2</sub> means from DEFRA operated diffusion tubes in South Gloucestershire	xls (10 files)	10	1993–2005	1,295
South Gloucestershire Council, Environment Protection and available online	Monthly NO <sub>2</sub> means from LA operated diffusion tubes	PDF (8 files)	Between 95 and 105 for each calendar year	2010–2017	11,880*
North Somerset Council, Development and Environment	Monthly NO <sub>2</sub> means from DEFRA and LA operated diffusion tubes	xls (1 file)	76	1993–2017	6,335
North Somerset Council, Development and Environment	Monthly Benzene measurement means	xls (1 file)	91	2000–2014	1,344
Bath and North East Somerset, Environmental Monitoring	Hourly NO <sub>2</sub> , NO, NO <sub>x</sub> , CO, PM <sub>10</sub> , PM <sub>2.5</sub> and O <sub>3</sub> mean measurements from continuous sites	csv and xls (30 files)	3	2000–2017	350,660
Bath and North East Somerset, Environmental Monitoring	Hourly O <sub>3</sub> mean measurements from Royal Victoria Park	xls (14 files)	1	2000–2014	131,496
DEFRA	Hourly NO <sub>2</sub> , NO <sub>x</sub> , NO and CO measurements from Bath Roadside	xls (18 files)	1	1996–2008	646,584
Bath and North East Somerset, Environmental Monitoring	Monthly means from DEFRA and LA operated diffusion tubes	xls (1 files)	31	1996–2009	4,650
Bath and North East Somerset, Environmental Monitoring	Fortnightly means from DEFRA and LA operated diffusion tubes	xls (1 files)	69	1999–2010	16,905
Online – <a href="http://www.bathnes.gov.uk">www.bathnes.gov.uk</a>	Monthly means from LA operated diffusion tubes in Bath and North East Somerset	xls (8 files)	Between 61 and 96 for each calendar year	2010–2017	7,716*

\*not included in the dataset -

exist for each hour. Measurements may be missing for a given record, and there are multiple measurements for each record for sites where several pollutants are continuously monitored. The dataset is not cleaned, and all measures including apparent errors (sub-zero measurements) are included (Figure 2). The data set was processed using Stata version 15<sup>9</sup>.

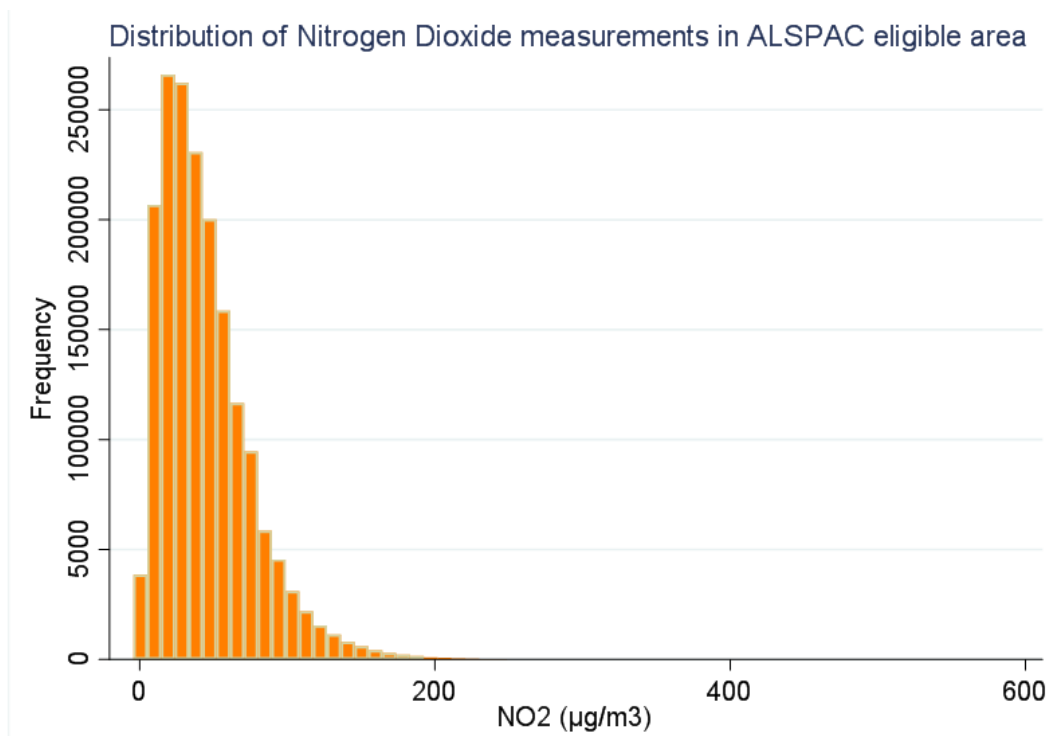
#### Types of air pollution monitoring

In the study catchment area air pollutants are monitored using various methods and equipment. In this section we describe the data by three categories of monitor type and measured pollutant: 1) NO<sub>2</sub> diffusion tubes (measuring NO<sub>2</sub>), 2) Non-AURN automatic monitoring (measuring a range of pollutants including NO<sub>2</sub>, NO, NO<sub>x</sub>, CO PM<sub>10</sub>, PM<sub>2.5</sub>, O<sub>3</sub> and Benzene) and

3) AURN automatic monitoring (measuring a comprehensive set of pollutants including those measured at non-AURN sites with additional methodologies and set of meteorological measures).

#### 1. NO<sub>2</sub> diffusion tube monitoring

Diffusion tubes are 7cm acrylic or polypropylene tube that contain a chemical reagent to absorb NO<sub>2</sub><sup>10</sup>, which is measured in units of micrograms per cubic metre (µg/m<sup>3</sup>). LA's are responsible for fulfilling the requirements of the Local Air Quality Management (LAQM) process as part of fulfilling the Environment Act of 1995. For NO<sub>2</sub> this has meant one hour mean measurements not exceeding 200 µg/m<sup>3</sup> more than 18 times in a year, and an annual mean not exceeding 40 µg/m<sup>3</sup>. We



**Figure 2. Distribution of NO<sub>2</sub> measurements (µg m<sup>-3</sup>).** Values excluded measurements taken from 3 Bath and North East Somerset in the calendar years 2000 and 2014 that were recorded in ppb/m.

have collected a total of 78,556 NO<sub>2</sub> records directly from LA's for LA run NO<sub>2</sub> monitoring sites in the ALSPAC eligible area, and an additionally 1,344 Benzene records from monthly monitored sites in North Somerset.

The records we received from Environmental Monitoring at BaNES Council (n = 4,650), Development and Environment at North Somerset (n = 7,679) and Environmental Protection at South Gloucestershire (n = 1,295) dated from 1993 and were supplementary to those presented in the routinely published Air Quality Management Progress Report's available from 2009 (Table 3). We have collated these reports and the monthly NO<sub>2</sub> monitoring data contained within – these could be transcribed if needed. The records we received from Bristol City Council (n = 64,932) cover the entire period of NO<sub>2</sub> diffusion tube monitoring in Bristol from 1991 to 2017. For these sites our dataset contains easting and northing coordinates, location type (kerbside, roadside façade, rural, urban background, urban centre) and the distance of either the diffusion tube or the receptor to the kerbside.

For BaNES, North Somerset and South Gloucestershire sites, easting and northing coordinates and geolocation data are presented for all sites in Table 2.2 of the Air Quality Management Progress Report of any given year since 2009.

## 2. Automatic monitoring (non-AURN)

The Automatic Urban and Rural Network (AURN), run by the Department for Environment Food and Rural Affairs (DEFRA) monitors air pollution continuously (producing hourly mean data) using standardised methods produced by the European Commission<sup>11</sup>. The monitoring of the 5 sites that area or were part of the AURN in the ALSPAC eligible area (Bath Roadside, Bristol Centre, Bristol Old Market, Bristol St Pauls, and Temple Gate) are described in the following section (Table 4). In this section we describe the monitoring records we have collected on the remaining 17 sites in the ALSPAC eligible area that monitor data continuously but are not part of the AURN and thus not subject to the standardised AURN reference methods. The pollutants monitored by these sites are at the discretion of the local authority who run the sites.

The monitoring techniques and geolocations by all automatic monitoring sites (irrespective of AURN affiliation) are outlined in the LA produced Air Quality Management Progress Report's (Table 2.1 Details of Automatic Monitoring Sites). For Bristol sites our dataset contains easting and northing coordinates, location type (kerbside, roadside façade, rural, urban background, urban centre) and the distance of either the diffusion tube or the receptor to the kerbside. For BaNES sites the dataset



**Table 3. Nitrogen Dioxide (ug/m<sub>3</sub>) Monitoring Data by Site Obtained From Alspac Catchment Local Authorities.** R D = Raw data from DEFRA, R LA = Raw data sent directly from the local authority, R RO = Raw data from other source S = Summary data from published local authority reports.

	Bristol City sites		Bath and North East Somerset sites		North Somerset sites		South Gloucestershire sites	
	Hourly	Monthly	Hourly	Monthly	Hourly	Monthly	Hourly	Monthly
1990	0	0	N/A	0	N/A	0	N/A	
1991	0	20 R LA	N/A	0	N/A	0	N/A	
1992	0	20 R LA	N/A	4 R D	N/A	5 R D	N/A	7 R D
1993	1 R LA + 1 R D	54 R LA + 4 R D	N/A	4 R D	N/A	5 R D	N/A	7 R D
1994	1 R LA + 1 R D	91 R LA + 4 R D	N/A	9 R LA + 4 R D	N/A	5 R D	N/A	8 R D
1995	1 R LA + 1 R D	57 R LA + 4 R D	N/A	11 R LA + 4 R D	N/A	5 R D	N/A	8 R D
1996	1 R LA + 2 R D	57 R LA + 4 R D	1 R D	14 R LA + 4 R D	N/A	5 R D	N/A	8 R D
1997	2 R LA + 2 R D	66 R LA + 4 R D	1 R D	14 R LA + 4 R D	N/A	5 R D	N/A	8 R D
1998	3 R LA + 2 R D	70 R LA + 4 R D	1 R D	14 R LA + 4 R D	N/A	5 R D	N/A	8 R D
1999	5 R LA + 2 R D	74 R LA + 4 R D	1 R D	21 R LA + 4 R D	N/A	5 R D	N/A	8 R D
2000	6 R LA + 2 R D	150 R LA + 4 R D	1 R D + 2 R LA	27 R LA + 4 R D	N/A	5 R D	N/A	8 R D
2001	5 R LA + 2 R D	202 R LA + 5 R D	1 R D + 2 R LA	32 R LA + 3 R D	N/A	5 R D	N/A	10 R D
2002	5 R LA + 2 R D	240 R LA + 4 R D	1 R D + 2 R LA	41 R LA + 3 R D	N/A	5 R D	N/A	9 R D
2003	7 R LA + 2 R D	252 R LA + 4 R D	1 R D + 2 R LA	47 R LA + 3 R D	N/A	5 R D	N/A	9 R D
2004	7 R LA + 2 R D	265 R LA + 4 R D	1 R D + 1 R O + 2 R LA	43 R LA + 3 R D	N/A	40 R LA + 5 R D	N/A	9 R D
2005	9 R LA + 2 R D	267 R LA + 4 R D	1 R D + 1 R O + 2 R LA	49 R LA + 3 R D	N/A	40 R LA + 5 R D	N/A	9 R D
2006	10 R LA + 2 R D	186 R LA + 4 R D	1 R D + 1 R O + 2 R LA	56 R LA	N/A	40 R LA	N/A	9 R D
2007	9 R LA + 2 R D	187 R LA	1 R D + 1 R O + 2 R LA	72 R LA	N/A	41 R LA	N/A	0
2008	10 R LA + 2 R D	162 R LA	1 R D + 1 R O + 2 R LA	71 R LA	N/A	41 R LA	N/A	86 S
2009	10 R LA	174 R LA	1 R D + 2 R O + 3 R LA	89 R LA	N/A	43 R LA	N/A	105 S
2010	10 R LA	129 R LA + 127 S	1 R D + 2 R O + 3 R LA	92 S	N/A	41 R LA	2 R LA	105 S
2011	9 R LA	122 R LA + 122 S	1 R D + 2 R O + 3 R LA	77 S	N/A	42 R LA	2 R LA	95 S
2012	9 R LA	102 R LA + 103 S	1 R D + 2 R O + 3 R LA	76 S	N/A	28 R LA	2 R LA	96 S
2013	7 R LA	103 R LA + 103 S	1 R D + 2 R O + 3 R LA	61 S	N/A	30 R LA + 28 S	2 R LA	97 S
2014	7 R LA	106 R LA + 103 S	1 R D + 3 R LA	64 S	N/A	30 R LA + 26 S	2 R LA	96 S
2015	7 R LA	107 R LA + 103 S	1 R D + 3 R LA	76 S	N/A	30 R LA + 26 S	1 R LA	101 S
2016	5 R LA	108 R LA + 107 S	1 R D + 3 R LA	90 S	N/A	30 R LA	1 R LA	105 S
2017	4 R LA	105 R LA + 106 S	1 R D + 1 R LA	107 S	N/A	28 R LA	1 R LA	104 S

contains sensor locations (longitude and latitude) for Guildhall (157,800 records), Chelsea House (70,128 records), Windsor Bridge (122,977 records) and Royal Victoria Park (131,496 records). For South Gloucestershire sites, easting and northing coordinates and geolocation data are presented for all sites in Table 2.2 of the Air Quality Management Progress Report of any given year since 2009.

In BaNES the monitoring techniques for each pollutant are the same for each year since 2009 - NO<sub>2</sub> (chemiluminescent), Benzene (pumped BTX tubes), CO, (Infra Red), PM<sub>10</sub> (BAM1020 Beta-Attenuated Mass Monitor), PM<sub>2.5</sub> (BAM1020 Beta-Attenuated Mass Monitor unheated). In South Gloucestershire PM<sub>10</sub> was monitored at two sites using different monitors, a BAM1020 Beta-Attenuated Mass Monitor (unheated) at Yate, and an

**Table 4. AURN coverage – pollutants and time period covered.**

Site	Pollutant	Years of data collected
Bath Roadside	NO <sub>2</sub>	1997–2018 (n = 178,367)
	NO	1997–2009, 2015–2018 (n = 159,037)
	NO <sub>x</sub>	1997–2018 (n = 178,391)
	CO	1997–2007 (n = 83,905)
Bristol Centre	NO <sub>2</sub>	1993–2005 (103,892)
	NO	1993–2005 (n = 106,171)
	NO <sub>x</sub>	1993–2005 (n = 103,892)
	SO <sub>2</sub>	1993–2005 (n = 321,414)
Bristol St Pauls	NO <sub>2</sub>	2006–2016 (n = 89,186)
	NO	2006–2016 (n = 89,190)
	NO <sub>x</sub>	2006–2016 (n = 89,186)
	SO <sub>2</sub>	2007–2012 (n = 187,332)
	O <sub>3</sub>	2013–2016 (n = 34,482)
	PM <sub>10</sub>	2013–2016 (n = 32,873)
	PM <sub>10</sub> non volatile	2013–2016 (n = 32,872)
	PM <sub>10</sub> volatile	2013–2016 (n = 32,873)
	PM <sub>2.5</sub>	2013–2016 (n = 29,338)
	PM <sub>2.5</sub> non volatile	2013–2016 (n = 29,338)
Bristol Old Market	NO <sub>2</sub>	1996–2006 (n = 71,385)
	NO	1996–2006 (n = 71,501)
	NO <sub>x</sub>	1996–2006 (n = 71,385)
	CO	1996–2006 (n = 72,745)
Bristol Temple Gate	NO <sub>2</sub>	2003, 2017–2018 (n = 21,508)
	NO	2003 (n = 6,342)
	NO <sub>x</sub>	2003, 2017–2018 (n = 21,508)
	PM <sub>10</sub>	2017–2018 (n = 9,575)
Former AURN site:		
Bristol East	Ethane	1994–2000 (n = 40,173)
	Ethene	1994–2000 (n = 39,891)
	Ethyne	1994–2000 (n = 49,728)
	Propane	1994–2000 (n = 45,449)
	Propene	1994–2000 (n = 44,877)
	Isobutane	1994–2000 (n = 32,903)
	Nbutane	1994–2000 (n = 45,441)
	Butene	1994–2000 (n = 43,165)
	Trans-2-butene	1994–2000 (n = 43,534)
	Cis-2-butene	1994–2000 (n = 44,351)
	Isopentane	1994–2000 (n = 44,934)
	Npentane	1994–2000 (n = 44,601)
	Trans-2-pentene	1994–2000 (n = 44,405)
	Cis-2-pentene	1994–2000 (n = 42,723)
	Isoprene	1994–2000 (n = 34,273)
	Nhexane	1994–2000 (n = 35,913)
	Nheptane	1994–2000 (n = 43,954)
	Benzene	1994–2000 (n = 45,519)
	Toulene	1994–2000 (n = 41,090)
	Ethylbenzene	1994–2000 (n = 34,230)
Mp-xylene	1994–2000 (n = 33,886)	
Oxylene	1994–2000 (n = 33,840)	

R&P TEOM at Filton. Different chemiluminescent analysers for NO<sub>2</sub> monitoring were operated at these sites (API200A and API200E). Ozone was measured using an API Model 400a Absorption Analyser. South Gloucestershire collected heavy metals (Cd, Cu, Zn, Pb). These are not included in our dataset. There is no automatic monitoring in North Somerset.

There are 1,567,531 records for the 17 continuous sites that are not part of the AURN, featuring 1,243,565 NO<sub>2</sub> records, 1,143,706 NO records, 1,146,885 NO<sub>x</sub> records, 207,110 CO records, 172,278 PM<sub>10</sub> records, 120,948 O<sub>3</sub> records (all from the Royal Victoria Park site in BaNES), 41,845 PM<sub>10</sub> (gravimetric) records, and 12,103 PM<sub>2.5</sub> records in our dataset.

### 3. Air Quality Management Area's (AQMA's)

A local authority will declare an AQMA where NO<sub>2</sub> levels are above those defined by the European Union (EU) Directive limits and the UK's national air quality objectives. The UK's national air quality objectives are legally binding EU parameters that must not be exceeded<sup>12</sup>. For nitrogen dioxide, the objectives are that measures of 200 µg m<sup>-3</sup> are not exceeded more than 18 times a year, and that the annual mean of a site does not exceed 40 µg m<sup>-3</sup>. The local authority is required to formulate a Local Air Quality Action Plan, and report monitoring data to DEFRA's Local Air Quality Management Report Submission Website. Thus, the siting of NO<sub>2</sub> sensors can be dependent on different, non-random factors (e.g. for Local Air Quality Management (LAQM) monitoring purposes)<sup>10</sup>. Local and/or temporal change in policy may impact on how the sensor readings should be inferred.

There are 11 AQMA's declared in the ALSPAC catchment as of 31 October 2018 (Table 5). ALSPAC have archived copies of these AQMA maps:

#### AQMA's in the ALSPAC catchment

##### Bristol

Bristol: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=10](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=10)

##### Bath and North East Somerset

Saltford: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=1536](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1536)

Bath (Roadside): [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=7](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=7)

Keynsham: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=650](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=650)

Temple Cloud: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=1755](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1755)

Farrington Gurney: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=1756](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1756)

##### North Somerset

Banwell: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=1383](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1383)

##### South Gloucestershire

Cribbs Causeway: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=655](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=655)

Kingswood Warmley: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=656](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=656)

Staple Hill: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=657](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=657)

M4, M5, M32, M49 Motorway Corridors: [https://uk-air.defra.gov.uk/aqma/details?aqma\\_ref=1396](https://uk-air.defra.gov.uk/aqma/details?aqma_ref=1396)

**Table 5. Air Quality Management Area's in ALSPAC catchment.** The following AQMA's in the ALSPAC catchment remain unrevoked at 31 October 2018.

Local Authority	AQMA site	Pollutant(s)	Date declared
Bristol	Bristol	PM <sub>10</sub> , NO <sub>2</sub>	01.05.2001
Bath and North East Somerset	Bath	NO <sub>2</sub>	01.02.2002
	Keynsham		31.07.2010
	Saltford		02.07.2013
	Temple Cloud		20.08.2018
	Farrington Gurney		20.08.2018
North Somerset	Banwell	NO <sub>2</sub>	01.05.2002
South Gloucestershire	Cribbs Causeway	NO <sub>2</sub>	14.04.2010
	Kingswood Warmley		14.04.2010
	Staple Hill		14.04.2010
	M4, M5, M32, M49 corridors		01.11.2001

## Data availability

### Underlying data

The ALSPAC databank is accessible as a managed access resource for the international research community. Prospective data users are encouraged to: 1) browse the catalogue of existing projects (<http://bristol.ac.uk/alspac/researchers/publications/>); data use is non-exclusive and it is the applicant's duty to maintain awareness of duplicate or overlapping initiatives; 2) consider the ALSPAC data access policy<sup>6</sup>; and 3) apply for access (<https://proposals.epi.bristol.ac.uk/>). Standard geolocated data (e.g. IMD, urban/rural status, pseudonymized geographies for multi-level modeling) are available at each data time point. Selected sub sets of location based data are available via the UK Data Archive (<https://www.data-archive.ac.uk/>). Those considering bespoke linkages of spatially-indexed information should contact PEARL who manage ALSPAC data linkages ([alspac-linkage@bristol.ac.uk](mailto:alspac-linkage@bristol.ac.uk)). All applications are assessed for compliance with ALSPAC's governance and third-party data-use arrangements. Data users are required to return newly generated or derived data along with rigorous metadata for future reuse in ALSPAC. All users must abide by information security and governance requirements and uphold participant confidentiality. Published outputs are reviewed for conformance to a publication checklist (<http://www.bristol.ac.uk/media-library/sites/alspac/documents/alspac-publications-checklist.pdf>). ALSPAC withholds

the right to request changes to publication to address risks relating to participant disclosure or bringing the study into disrepute.

## Ethical statement

Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees.

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