Imperial College London Projects

Environmental Research Group

Breathe London network report October – December 2021

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clarity

Bloomberg Philanthropies

MAYOR OF LONDON

The Environmental Research Group

Founded in the early 1990s, the Environmental Research Group (ERG) is internationally renowned for its work on air quality. The ERG's approach to tackling air pollution is extensive, covering air quality measurement and modelling, testing and deploying portable sensors and policy development. The ERG established and continues to operate the London Air Quality Network, Europe's most advanced air quality monitoring network, with over 100 stations providing a comprehensive picture of air pollution across London. The ERG works closely with government at all levels to shape policy around air pollution. Over the last 15 years all major air pollution strategies in London, including the congestion charging scheme, have been devised and tested using emissions and air pollution models developed by ERG. It was the first UK organisation to make air quality information publicly available online, leading the way for the development of air quality apps used by thousands every day. The Environmental Research Group is led by Professor Frank Kelly, Humphrey Battcock Chair of Environment and Health. It is part of the School of Public Health at Imperial College London.

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Summary of key performance indicators

This quarterly report details work undertaken by the Environmental Research Group to deliver the Breathe London network contract awarded by the GLA in December 2020.

Work is described in relation to seven key performance indicators (KPIs), as specified in the contract and summarised in Table 1. The report is not intended to be an exhaustive description of the network and its outputs, which will be captured on the network website (www.breathelondon.org) and in associated reports.

This report delivers the seventh KPI: "Network evaluation report to be produced every three months including performance of sensors (e.g., number online, number of QA/QC issues) and number of visits to the website"

Table 1: Summary of key performance indicators.

KPI	Target	Status
Install, maintain and ensure air quality sensors at 100+ sites	100+	GLA-funded: 133 Other: 141
Demonstrate sensors continue to meet the uncertainty requirements of the EU Air Quality Directive for indicative (Class 1) methods for particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2)	NO_2: 25% uncertainty $PM_{2.5}$: 50% uncertainty	NO_2: 19% uncertainty $PM_{2.5}$: 25% uncertainty (network means)
Ensure a minimum 90% of sensors are in operation at any given time (target shows % of hours where >90% of sensors were operational).	100% of hours	88% of hours
Increase the number of sensors in the network by an additional 5% per year by allowing the website to integrate data from sensors owned by Londoners, businesses and organisations	5% expansion by January 2022	>100% expansion by January 2022
Website must be live continuously and display data in real time from the sensors	End of March 2021	Launched 15 March 2021
Data must also be available via an Application Programming Interface (API)	Not specified	Launched December 2021

1. Introduction

Breathe London is a new partnership between the Mayor of London, Imperial College London (facilitated via Imperial Projects) and Bloomberg Philanthropies. The Mayor initially provided funding for 130 air quality sensor nodes at hospitals, schools and other priority locations. This was subsequently increased to 136 to include Business Low Emission Neighbourhoods and other projects. Data are displayed on the network website – www.breathelondon.org.

Community groups, charities, businesses, individuals, academics, and boroughs are also able to “buy in” to the Breathe London network to source air pollution data for local projects or schemes.

This report summarises progress on building the network during October to December 2021.

2. Deployment of nodes

KPI: Install, maintain and insure air quality sensors at 100+ sites

133 GLA sponsored nodes were deployed by the end of December 2021, plus 140 additional nodes sponsored by the South London Partnership and one sponsored by a commercial organisation - The Cadogan Estate (Table 2). These nodes comprise of a mix of locations, including schools, hospitals, reference site co-locations, Local Authority designated community placements and other areas of interest such as hotspots and cold spots.

3. Quality assurance and quality control

KPI: Demonstrate sensors continue to meet the uncertainty requirements of the EU Air Quality Directive for indicative (Class 1) methods for particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2)

The quality performance of the nodes is assessed using the methodology recommended in EU guidance. Uncertainty is calculated at the hourly limit value (200 µg m^{-3}) for NO_2 and the indicative threshold is 25%, the uncertainty for $PM_{2.5}$ is calculated at the daily limit value of 35 µg m^{-3} and the indicative threshold is 50%.

The basic calibration and scaling process applied to Breathe London nodes is described in the first quarterly report (available at https://www.breathelondon.org/network-reports). In December we implemented phase 2 of our calibration process with the introduction of dynamic network scaling. To develop this method we needed a long time series of sensor data incorporating a wide range of meteorological conditions, thus it could not be applied from the network launch.

All network data, historical and ongoing, are now scaled using the new correction method. Users of the data prior to 1 January 2022 should note that they should update any historical data archives that they hold to reflect this change.

Table 2: Number of GLA and other sponsored nodes deployed and in operation in each London Borough as of the end of December 2021

Borough	Reference sites	Hospitals	Schools	Special projects[1]	Hot & cold spots	Local Authority designated	Other sponsored	Total
Barking and Dagenham						1		1
Barnet			2		1	1		4
Bexley	1				1	2		4
Brent	1				1	2		4
Bromley					1	1		2
Camden			2			1		3
City of London		2			1	1		4
Croydon				1		1	10	12
Ealing			1		2	1		4
Enfield						1		1
Greenwich	5	1	2			6		14
Hackney			1			1		2
Hammersmith & Fulham			1	1		1		3
Haringey		1	1			1		3
Harrow						1		1
Havering	1		1		1	2		5
Hillingdon						2		2
Hounslow			1		1	1		3
Islington			2			1		3
Kensington & Chelsea	1		3		2	1	1	7
Kingston		1			1	1	11	14
Lambeth			2					2
Lewisham	3	1	1	1		2		7
Merton					1	1	68	70
Newham				1		1		2
Redbridge	1	1	1	1		2		6
Richmond			1			1	45	47
Southwark	1		3		1	2		7
Sutton	1	1				2	7	11
Tower Hamlets	1		5	1	1			8
Waltham Forest		1		1	1	1		4
Wandsworth		1	2	1		1		5
Westminster	3		1		3	2		9
Totals	19	10	33	8	19	45	141	274

[1] Business Low Emission Neighbourhood, Greener Together and Ella Roberta Family Foundation

The basic correction method used a linear correction algorithm generated from the node and the reference instrument derived from an initial 10-14 day co-location at the Honor Oak Park London Supersite prior to deployment. These correction factors were applied to all subsequent data at the node's destination location. However, it is well established that electrochemical NO_2 sensors and light scattering $PM_{2.5}$ sensors of the type used in Clarity nodes, and most other low cost sensor units on the market, perform differently dependent on meteorological conditions. It is therefore necessary to use a dynamic correction method that can react to changes in conditions.

The dynamic network scaling method now implemented takes advantage of the network's partner reference monitoring network – the London Air Quality Network (LAQN). As shown in Table 2, 19 nodes are permanently co-located with LAQN reference monitoring sites. The These sites are in a range of locations from kerbside central London to suburban outer London. Every hour the previous 24 hours of data from the node and its paired reference monitor are compared to produce a multivariate correction factor incorporating relative humidity, regional ozone concentration, reference NO_2 concentration and reference $PM_{2.5}$ concentration. These factors are aggregated according to site classification – kerbside, roadside and background – and then applied to the node measurements across the network according to their own classification. Dynamically scaling is applied in real time and prior to dissemination on the network web pages and API. Thus, correction factors dynamically adjust to current meteorological conditions and pollution climate.

When uncertainties were recalculated for the previous quarter the number of nodes failing to meet the threshold for NO_2 dropped from 14 to 1, the network mean uncertainty decreased from 62% to 18% (one node was flagged as 'fail' and removed from service). This significant improvement in performance demonstrates the value of the dynamic approach.

This hybrid monitoring network approach, where a small number of expensive higher performance reference monitoring sites are used to improve the accuracy of a larger network of low cost sensor nodes, is now being presented as a way of rapidly increasing the scope and quality of air quality information in cities across the world without prohibitive associated direct costs (but dependency on suitable reference monitoring networks remains essential to the performance of this sensor network). Breathe London is a case study for the effectiveness of this method.

Network mean uncertainty at the EU Limit Value across the quarter is shown in

Table 3. These percentages are based on all nodes passing through the co-location dynamic calibration process during the reporting period. We can only report uncertainty for sensors when they are undergoing their 10-14 day calibration. After deployment, we use well established methods similar to those used to manage the LAQN and other UK reference monitoring networks to identify sensors that are not performing as they should.

The network experienced rapid expansion during the quarter and 155 nodes passed through the calibration process prior to deployment. All but five nodes were within the target uncertainty for $PM_{2.5}$ and these only breached the target by a small margin. 16% (25 nodes) failed the tougher NO_2 target, with a mean uncertainty of 19%.

Table 3: Uncertainty targets for indicative methods and corresponding uncertainties at the EU Limit Values during the reporting period (October to December 2021)

Pollutant	Target uncertainty (%)	Mean measured uncertainty (%)	Proportion of nodes not achieving target
NO_2	25	19	16% (25/155 nodes)
$PM_{2.5}$	50	25	3% (5/155 nodes)

4. Data capture

KPI: Ensure a minimum 90% of sensors are in operation at any given time

The data collection system created to interface between the nodes and Breathe London website is described in the first quarterly report (available at https://www.breathelondon.org/network-reports).

Data capture across the quarter is shown in Table 4. These percentages are based on a count of all valid hourly mean concentrations recorded by nodes deployed at permanent sites (i.e., not undergoing calibration at reference sites) throughout the period October to December 2021.

This quarter includes the shortest days of the year and the first full test of the ability of the nodes to run on solar power during the winter. As Table 4 shows, a small proportion of measurements were lost mainly due to reduced battery power – 88% of all hours in the quarter reported measurements from at least 90% of the network. During powers of low battery power the node will incrementally reduce its sampling frequency until, occasionally, it reports less than one measurement an hour. In these cases, a measurement will be reported the next hour ensuring that a continuous data series is maintained.

This relatively minor loss of data close to the winter equinox must be balanced against the practical benefits of not requiring a connection to a fixed power supply, thus severely restricting where a node can be placed and significantly increasing costs. We expect data capture rates to increase again in the next quarter when days lengthen.

Table 4: Data capture for all deployed nodes over the reporting period (October to December 2021)

Pollutant	Network mean data capture	Hours with 90% of nodes in operation
NO_2	96.7%	88.0%
$PM_{2.5}$	96.7%	88.0%

5. Network expansion

KPI: Increase the number of sensors in the network by an additional 5% per year by allowing the website to integrate data from sensors owned by Londoners, businesses and organisations

The Breathe London network expanded rapidly in the quarter, adding 135 nodes and almost doubling in size to 274. All GLA sponsored nodes have now been deployed.

Additional funding provided by Bloomberg Philanthropies to provide free nodes to disadvantaged communities was described in the first quarterly report (available at https://www.breathelondon.org/network-reports). The Breathe London Community Programme was launched in October 2021, offering the first 10 nodes to community groups who applied to the scheme. The closing date for applications was early December and the awardees will be announced in January. A second round of 30 further nodes will be launched in the summer of 2022. Further details can be found at https://www.breathelondon.org/apply.

6. Website development

KPI: Website must be live continuously and display data in real time from the sensors

The website launched on 15 March with a live map showing the location and current daily air quality index of each deployed node alongside a selectable layer of LondonAir reference sites. Inclusion of Air Quality England data has been delayed and will be added in January 2022. Further details were provided in the first quarterly report. The website is continually updated with community stories describing use of Breathe London data, feature enhancements and events, such as the Community Programme. One feature of note implemented during the quarter was the facility for users to download the data behind the time series graphs.

The launch of the Community Programme in October led to a marked increase in website visitors, as shown in Figure 1. Numbers peaked at around 3,200 visitors in that month, before settling back down to c. 2,000 in December after the programme had closed.

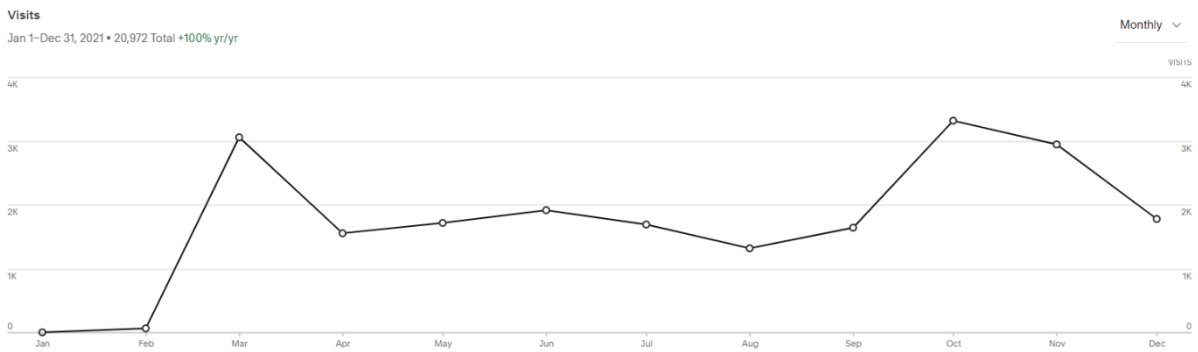

Figure 1: Monthly time series of visits to the breathelondon.org website year to December 2021.

7. Application Programming Interface (API)

KPI: Data must also be available via an Application Programming Interface (API)

An Application Programming Interface (API) for Breathe London data was launched in November 2021, following the update to our correction method. This allows users to request site details and data feeds from all nodes between specified dates. Technical details can be seen here: https://api.breathelondon.org/docs/. Users can register for use on the Breathe London website linked from the home page: https://www.breathelondon.org/developers.

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