Imperial College London Projects

Environmental Research Group

# Breathe London network report January – March 2023

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clarity

Bloomberg Philanthropies

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## 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: 136<br>Other: 209 |
| 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<br>$PM_{2.5}$: 50% uncertainty | $NO_2$: 115% uncertainty<br>$PM_{2.5}$: 18% uncertainty<br>(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 | 97.5% of hours for $PM_{2.5}$<br>95.9% of hours for $NO_2$ |
| 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 year on year | 5% reduction so far in first quarter 2023 |
| 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 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 January to March 2023.

# 2. Deployment of nodes

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

During the first quarter of 2023 an additional fifty four nodes were deployed. Unfortunately, this was offset by a reduction in nodes in the Royal Borough of Richmond Upon Thames and the London Borough of Merton as their deployments were assessed and redistributed at the end of their term (Table 2).

The additional fifty four Nodes were a mix of Bloomberg sponsored Community programme nodes (Year 2 round), local authority buy ins and one from Clean Air London. With the reduction from the two above Boroughs the total number of nodes by the end of the first quarter or 2023 was 345 (down from 364 by 19 nodes).

*Table 2: Number of GLA and other sponsored nodes deployed and in operation in each London Borough as of the end of March 2023*

| Borough | Reference sites | Hospitals | Schools | Special projects[1] | Hot & cold spots | Local Authority designated | Other sponsored | Total |
|---|---|---|---|---|---|---|---|---|
| Barking and Dagenham | | | | | | 1 | 5 | 6 |
| Barnet | | | 2 | | 1 | 1 | | 4 |
| Bexley | 1 | | | | 1 | 2 | 1 | 5 |
| Brent | 1 | | | | 1 | 2 | 1 | 5 |
| Bromley | | | | | 1 | 1 | 3 | 5 |
| Camden | | 2 | 2 | | | 1 | 1 | 6 |
| City of London | | | | | 1 | 1 | | 2 |
| Croydon | | | | 1 | | 1 | 19 | 21 |
| Ealing | | | 1 | | 2 | 1 | 1 | 5 |
| Enfield | | | | | | 1 | | 1 |
| Greenwich | 5 | | 2 | | | 6 | 1 | 14 |
| Hackney | | | 1 | | | 1 | 3 | 5 |
| Hammersmith & Fulham | | 1 | 1 | 1 | | 1 | 53 | 57 |
| Haringey | | 1 | 1 | | | 1 | 2 | 5 |
| Harrow | | | | | | 2 | | 2 |
| Havering | 1 | | 1 | | 1 | 2 | 2 | 7 |
| Hillingdon | | | | | | 2 | | 2 |
| Hounslow | | | 1 | | 1 | 1 | | 3 |
| Islington | | | 2 | | | 1 | | 3 |
| Kensington & Chelsea | 1 | 1 | 3 | | 2 | 1 | 10 | 18 |
| Kingston | | | | | 1 | 1 | 11 | 13 |
| Lambeth | | 1 | 1 | | | 1 | 3 | 6 |
| Lewisham | 3 | | 1 | 1 | | 2 | 11 | 18 |
| Merton | | | | | 1 | 1 | 20 | 22 |
| Newham | | 1 | | 1 | | 1 | 2 | 5 |
| Redbridge | 1 | | 1 | 1 | | 2 | 11 | 16 |
| Richmond | | | 1 | | | 1 | 21 | 23 |
| Southwark | 1 | 1 | 3 | | 1 | 2 | 4 | 12 |
| Sutton | 1 | | | | | 2 | 7 | 10 |
| Tower Hamlets | 1 | 1 | 5 | 1 | 1 | | 3 | 12 |
| Waltham Forest | | 1 | | 1 | 1 | 1 | 2 | 6 |
| Wandsworth | | | 3 | 1 | | 1 | 3 | 8 |
| Westminster | 3 | | 1 | | 3 | 2 | 9 | 18 |
| Totals | 19 | 10 | 33 | 8 | 19 | 47 | 209 | 345 |

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

# 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 below and in the first quarterly report (available at https://www.breathelondon.org/network-reports). In December 2021 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.

*Figure 1 Co-location testing at Honor Oak Park. Photo by Environmental Research Group*

### Phase 1 - Node specific correction algorithm

This calibration and scaling procedure is designed to correct for deviations between the node (NO2 or PM2.5) and the reference measurement as well as any identified impact of meteorological variables such as relative humidity and temperature. Prior to deployment each node is collocated at the Honor Oak Park London Supersite, shown in Figure 1, and Node behaviour is standardised against instrumentation at the reference site.

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 lower capital cost sensor units on the market, perform differently dependent on meteorological conditions. Breathe London therefore developed and uses a dynamic correction method that can react to changes in conditions.

### Phase 2 Dynamic Network Correction Algorithm

Node response is influenced by the concentration of the target pollutant as well as other environmental factors. It is not always possible to represent these in the initial correction algorithm, so they are corrected for dynamically using information from the nodes routinely collocated at reference monitoring stations as part of Breathe London.

As described in our previous report, 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.

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. Dynamic scaling is applied in real time and prior to dissemination on the network web pages and API. Thus, correction factors dynamically adjust to current for meteorological conditions and pollution climate.

All network data, historical and ongoing, are now scaled using the new dynamic network correction algorithm 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.

This hybrid monitoring network approach, where data from selected high resolution 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. 83 nodes passed through the calibration process during this quarter. All passed the $PM_{2.5}$ target uncertainty of 50%, but an unusually high number did not pass the tougher $NO_2$ target of 25%. Closer analysis has shown the cause to be particularly low ambient levels of $NO_2$ pollution during the analysis period, being close to the detection limit of small sensors for long periods and exaggerating the uncertainty in the reference instrument readings. E.g 1ppb uncertainty at 4ppb ambient levels is a much higher percentage than 1ppb uncertainty at 20ppb ambient levels. Given the extremely low levels of the underlying data uncertainty in both the reference comparison instrument and Nodes during this time have been unrepresentatively high in these statistics. Seven nodes were rejected during this quarter due to actual poor $NO_2$ calibration results. Performance of the other Nodes when field deployed does not indicate any performance issues. The mean uncertainties are shown in Table 3.

*Table 3: Uncertainty targets for indicative methods and corresponding uncertainties at the EU Limit Values during the reporting period (January to March 2023)*

| Pollutant | Target uncertainty (%) | Mean measured uncertainty (%) | Proportion of nodes not achieving target |
|---|---|---|---|
| $NO_2$ | 25 | 115 | 60% (53/88 nodes) |
| $PM_{2.5}$ | 50 | 18 | 0% (0/88 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) for the period January 1st to March 31st 2023.

During this quarter data capture rates slightly decreased in comparison to the previous quarter. 97.5% of all hours in the quarter reported measurements from at least 90% of the network for $PM_{2.5}$, 95.9% of all hours in the quarter reported measurements from at least 90% of the network for $NO_2$.

Reduced solar power was largely the cause, with poor solar charging in the first three weeks of January which dropped below 90% on 39 hours, 87.3% being the minimum. Power interruptions, missing nodes or solar panels and communication issues were also experienced. The Node at Marner primary school has been temporarily removed for safekeeping during building works. Also, $NO_2$ data from the node at Lisson Grove is being investigated and is therefore currently invalid.

During periods 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.

*Table 4: Data capture for all deployed nodes over the reporting period (January to March 2023)*

| Pollutant | Network mean data capture | Hours with 90% of nodes in operation |
|---|---|---|
| $NO_2$ | 96% | 95.9% |
| $PM_{2.5}$ | 96.3% | 97.5% |

# 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 continued to add nodes in the first quarter of 2023, adding 54 Nodes. However, with the reduction of nodes in the London Borough of Merton and the Royal Borough of Richmond Upon Thames the total number of nodes by the end of March 2023 were 345, a decrease of 5% compared to the total number of nodes deployed at the end of 2022 (364 nodes).

This reduction is set to be positively offset by the redeployment of 14 of these nodes to the London Borough of Wandsworth in the coming weeks.

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. A second round of 30 further nodes was launched in the summer of 2022 and installation is expected to be complete in the coming months. Round three was launched during April 2023 for the award of a further 20 Nodes. 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 in March 2021 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. Air Quality England data has been included since February 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. Following feedback, updates to the website are being considered. The number of visitors to the website has increased during the last quarter averaging just over 1000 per week.

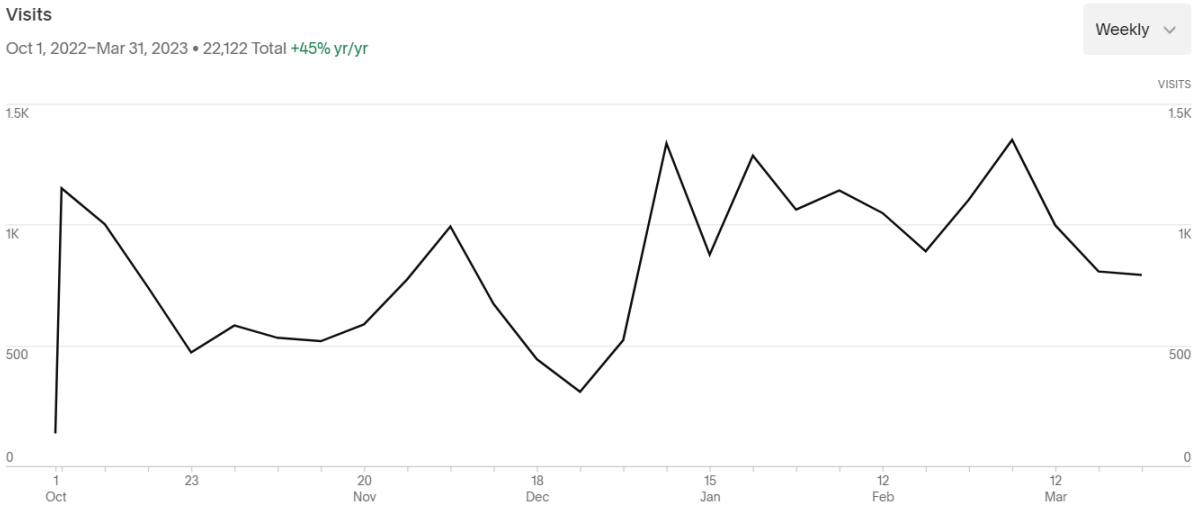


*Figure2: Weekly time series of visits to the breathelondon.org website Oct 2022 to Mar 2023*

# 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 has been available since 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.

The full launch was in June 2022 and the developers page now includes the new automated key sign-up flow. A caching layer has also been developed to ensure load resilience as more users come on board.

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