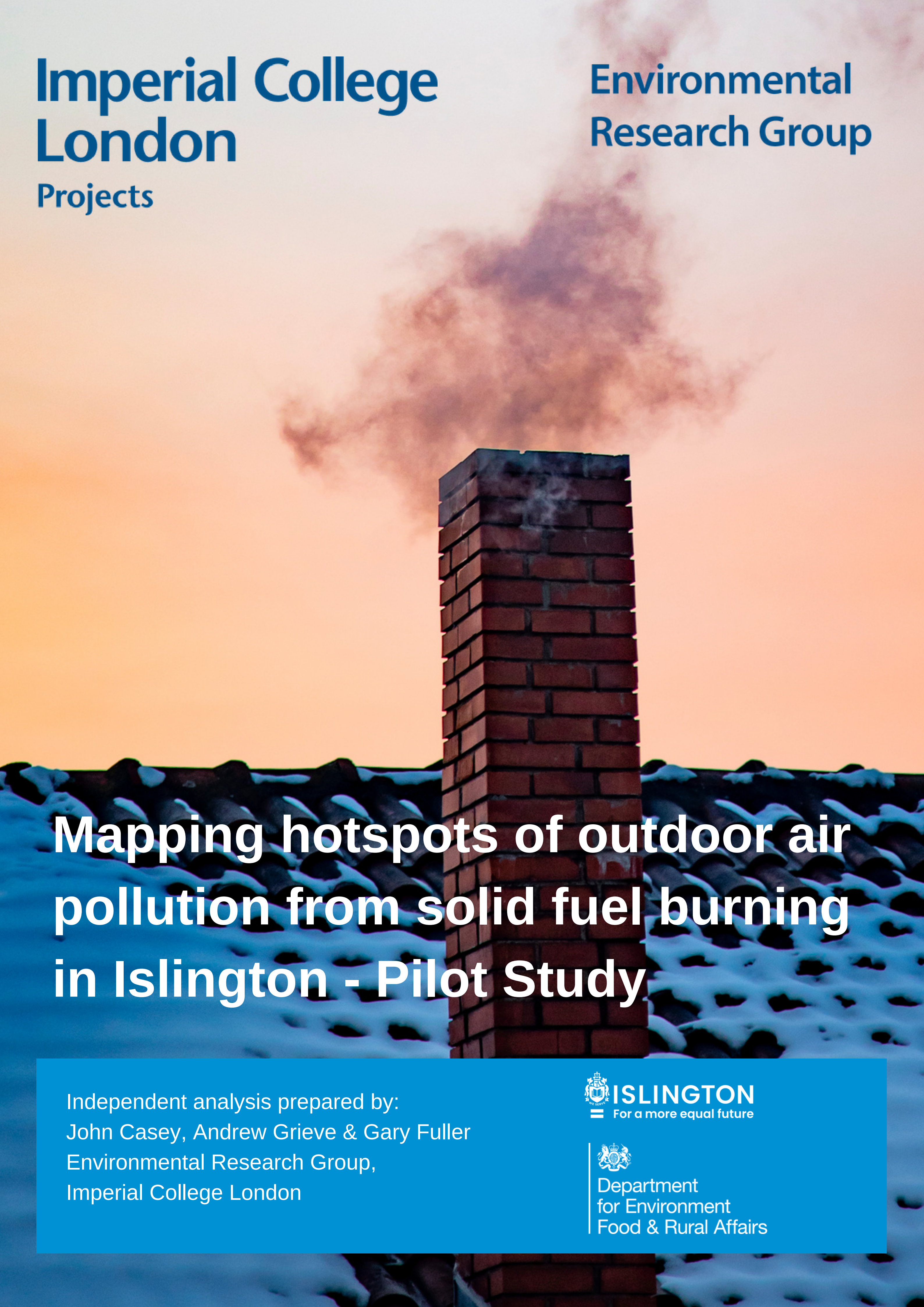


Imperial College London
Projects

Environmental Research Group

Mapping hotspots of outdoor air pollution from solid fuel burning in Islington - Pilot Study

Independent analysis prepared by:
John Casey, Andrew Grieve & Gary Fuller
Environmental Research Group,
Imperial College London

ISLINGTON
For a more equal future

Department for Environment Food & Rural Affairs

Contents

1. Lay summary

When we think of air pollution hotpots, we often think of busy road junctions or places downwind of industry, but the popularity of home wood burning may be creating new air pollution hotspots in our residential streets. Around 150,000 to 200,000 wood stoves are sold in the UK each year. Along with burning in open fires, the UK government estimates suggest that home heating with solid fuels (mainly wood) is now the largest single source of particle pollution (PM2.5) in the UK.

Air pollution hotspots from wood and coal burning have been found in towns and cities in Canada, New Zealand, Ireland and Australia. This is concerning since smoke from homes that burn wood can drift inside houses over a whole neighbourhood. This has been linked to health problems such as asthma in children.

This project aimed to survey some of Islington's streets to see if there are pollution hotspots caused by wood or solid fuel burning. Between December 2020 and March 2021 scientists from Imperial College London walked a network of roads close to Tufnell Park carrying air pollution measurement equipment. These walks took place on Friday, Saturday and Sunday evenings, the most popular times for home wood burning, when there is less traffic on the roads. Measurements from each walk were linked to GPS data and then overlayed to find any areas of persistent pollution.

An area of particle pollution was found around Whittington Park. This was most likely due to the wood-chip boiler that provides heat and hot water for the sports pavilion at the western side of the park. Other areas of persistent particle pollution were found along some of the residential streets, especially along Mercers Road and Highwood Roads. These may be due to homes burning wood or coal. As expected, the roads close to Holloway Road had more traffic pollution than the quieter residential streets.

Home fires were the main source of the infamous pea-souper smogs that were a regular part of London life up to the 1960s. Today, we have many more ways to heat our homes. For those people that do burn wood, some simple steps can be taken to reduce the neighbourhood impacts. These include using plenty of kindling to get the fire going quickly and burning only dry wood. Building on existing regulations, sales of house coal are being phased out to be replaced by smokeless fuels that produce less particle pollution. Most stoves and especially those that carry Defra or Eco-design approvals, will produce less particle pollution compared with an open fire however all types of solid fuel heating will produce much more particle pollution than using gas or electricity.

2. Main findings & recommendations

Localised emissions from solid fuel burning are not well captured in existing emission inventories and current measurement networks. A better understanding of solid fuel exposure hotspots will be necessary to enable a focus on interventions.

In this pilot study, a walking sampling strategy proved an effective tool for mapping relative concentrations of black carbon – a tracer for solid fuel burning, successfully mapping hot spots for outdoor pollution due to solid fuel burning on residential streets in Islington.

- Hot spot mapping identified areas with higher relative black carbon measurements.

    - A pollution hotspot zone was identified on streets bordering Whittington Park including Foxford Rd, Rupert Rd, Yerbury Rd and Wedmore St, as well as on a pathway within the park. Emissions from a biomass boiler at the Sports Pavilion in Whittington Park was identified as the likely source of this pollution hotspot.

    - A mapped pollution hotspot at the junction of Mercers Rd and Highwood Rd and along Highwood Rd was found. Residential solid fuel burning was identified as the likely source.

    - Higher pollution levels mapped close to Holloway Rd were thought to be due to vehicular traffic emissions on the heavily trafficked Holloway Rd.

    - A source for higher pollution mapped along Foxford Rd, bordering an industrial estate was not obvious and requires further investigation.

    - Lower pollution was seen on residential streets in the south-west of the Islington pilot study area.

- Complimentary measurements of UVPM and PM2.5 were not available at the required quality for this pilot study. These would provide additional information to help characterise pollution and identify sources in future studies.

- Five amendments to the method used for mapping hotspots in this pilot study were proposed, to improve data capture quantity and quality for future projects:
    1. Increased environmental conditioning time for the micro-aethalometer before a walk commences.
    2. Note taking by walkers to identify any fuel burning smells or visible smoke from chimneys along streets monitored.
    3. Improved description and walking instructions for the streets in the study area to ensure each walk is replicated completely on different days.
    4. Aim to walk on days and times when pollution signal is likely to be strongest.
    5. Aim to have data from 10 replicate walks to create a pollution map.

3. Background

Islington solid fuel burning

Particle air pollution is a major health concern in the UK and has been linked with around 29,000 attributable deaths annually. Home burning of solid fuel (wood and coal) is now estimated to produce around 39% of the particle pollution (PM2.5) emitted in the UK, greater than that from road transport.

Possible interventions include improvements to fuels, upgrading fireplaces and stoves along with softer measures encouraging better fire lighting and refuelling techniques, use of existing Clean Air Act powers and bans on solid fuel heating. The proposed new Environment Act includes provisions for fixed penalty fines for smoky chimneys.

Much attention was given to air pollution from solid fuel heating in the immediate decades after the 1952 smog but since the 1990s air quality management has focused on transport and industry. Local air pollution hotspots have been identified by the local air quality management process, but these have focused mainly on major roads, enclosed streets and busy road junctions. Localised emissions from solid fuel burning are not well captured in existing emission inventories and current measurement networks. A better understanding of solid fuel exposure hotspots will therefore be necessary to enable a focus on interventions.

Limited street mapping of wood burning has been undertaken in Auckland, and in small communities in New Zealand. This pilot project in Islington set out to test the feasibility of creating street-by-street mapping of solid fuel black carbon concentrations using a mobile (walking) measurement strategy.

Black Carbon

Black carbon (BC) is a primary pollutant i.e. it is emitted directly into the atmosphere. It exists as particles and is formed by the incomplete combustion of fossil fuels, wood and other biomass. (UNEP, 2011). In urban areas, BC emissions arise mainly from diesel vehicles (AQEG, 2012). Residential heating (e.g. small coal or wood burning stoves) are also considered to be a major source of BC. (EEA, 2013)

In urban areas BC is considered a better indicator of harmful particulate substances from combustion sources than either PM10 or PM2.5 (Particulate matter less than 10 µm or 2.5 µm in aerodynamic diameter). (WHO, 2012).

BC particles are very small, typically less than 50 nm in diameter (Wang et al 2015) and are an individual component of PM2.5. As a fine particle, BC can be inhaled and consequently deposited in the lungs and there is evidence this it may therefore be more harmful to people than contaminants such as PM10, PM2.5 (Kumar et al 2018).

At the North Kensington urban background air quality monitoring station, for 2020, the annual mean for $PM_{2.5}$ was 8 µg/m^3 of which 0.8 µg/m^3 or approximately 10% was BC. (londonair.org.uk)

4. Method

Street Mapping

This pilot solid fuel burning study builds on previous successful methods used to map spatial air pollution from transport in the Marylebone Low Emissions Neighbourhood and determining the effectiveness of localised interventions. Portable measurements of black carbon were made while walking a fixed route over different days. The results were normalised to reduce the impact of weather on the survey before each walk was combined to produce a map of relative concentrations.

This approach combines small sensors for black carbon with personal sampling. The streets within the pilot study area were walked periodically by a scientist carrying a portable micro-aethalometer. During each walk, concentrations of black carbon particles were continuously measured and averaged at regular set time intervals.

This type of assessment has been effective in previous studies that have investigated change in pollution exposure during Regents / Oxford Street closure days (Barratt, 2011) and elsewhere to show the effects of landscaping on pollution from major roads (Brantley et al 2014). This measurement approach can an additional benefit of local engagement if community members are involved in carrying out the pollution walks.

Micro - Aethalometer

For the study a microAeth MA300 was used to measure black carbon (BC) concentrations along streets in the study area. The MA300 is a miniature, portable, highly sensitive five-wavelength Aethalometer designed for measuring light absorbing carbon ('LAC') particles. Measurement at 880nm is interpreted as the concentration of black carbon ('BC'). Measurement at 375nm is interpreted as Ultraviolet Particulate Matter ('UVPM') indicative of wood smoke, tobacco and or biomass burning. Measurements at 625nm, 528nm and 470nm wavelengths provide additional information about the aerosol which can be used for source apportionment and other atmospheric investigations. The MA300 includes hardware and firmware that implement the patented Dual Spot Loading Compensation method (Drinovec et al 2016) which reduces measurement post-processing. For this pilot study the MA300 was set to continuously sample at a sample flow rate of 150ml/min and to record an average black carbon concentration every 30 seconds.

The micro aethalometer has access to the Global Positioning System (GPS) with a built-in antenna. The GPS is used for precise, automatic time synchronization and for location tracking. However, during this pilot study GPS location data from the micro-aethalometer was very often inaccurate and at times not recorded. Due to COVID restrictions equipment could not be returned to our laboratories after each walk. The GPS problems were therefore only realised after walks had been completed and data from the instrument was downloaded. Highly accurate location data from the walker's mobile phone was available for all the walks and this was used in conjunction with time stamped data from the micro-aethalometer to accurately street map BC measurement data from the walks. Although ultimately successful, this method was a time-consuming process that added significantly to the data processing and analysis.

Z-Score

Although raw data output from the micro-aethalometer gives an overview of actual black carbon (BC) measurements along the walking route, a method is required, to standardise data so that readings on different walk days, obtained during different weather conditions can be directly compared. Z-Scores were used to standardise measurements across different days and different monitoring conditions. Converting data to Z-scores allowed direct comparison of relative BC concentrations from the individual walks and allowed combined mapping of all walks using a standard scale.

The Z-score or standard score is a measure of how many standard deviations above or below the population mean a raw score is. Weather conditions can influence BC concentrations measured during a walk. It is therefore impossible to meaningfully compare, or map BC data taken on different days, when for example, on a relatively calm day we may have BC concentrations on a residential street with fewer solid fuel emissions, similar to or possibly higher than BC concentrations on residential streets with higher solid fuel emissions measured during windy and/or wet weather.

A Z-Score allows comparison of BC concentrations from a walk to a *"normally distributed"* set of measurements. Z-Scores show where a BC measurement is relative to the average BC measurement for each of the individual walks, displaying relative concentrations, so we can identify the high and low BC areas.

The basic Z-Score formula is:

$$\boxed{\mathbf{z = (x - \mu) / \sigma}}$$

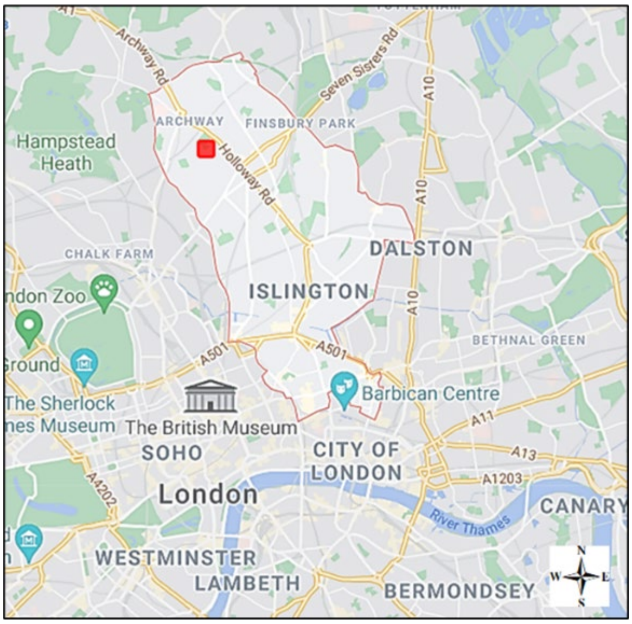
Where x is a 30 second mean BC measurement on a walk, **μ is the mean of all BC measurements on a walk and σ is the standard deviation of all BC measurements on a walk.**

The Z-Score tells us how each measurement on a given walk deviated from the mean for that walk.

The Pilot Study Area

The project focused on a residential area located just south of Archway in the inner London Borough of Islington. Figure 1. shows the location of the pilot study area. It includes Whittington Park and residential streets to the south and east of the park, as well as a couple of residential roads just to the north of the park. This area was selected in discussion with the council based on local knowledge of housing types and analysis of wood burning emission data from the London Atmospheric Emissions Inventory.

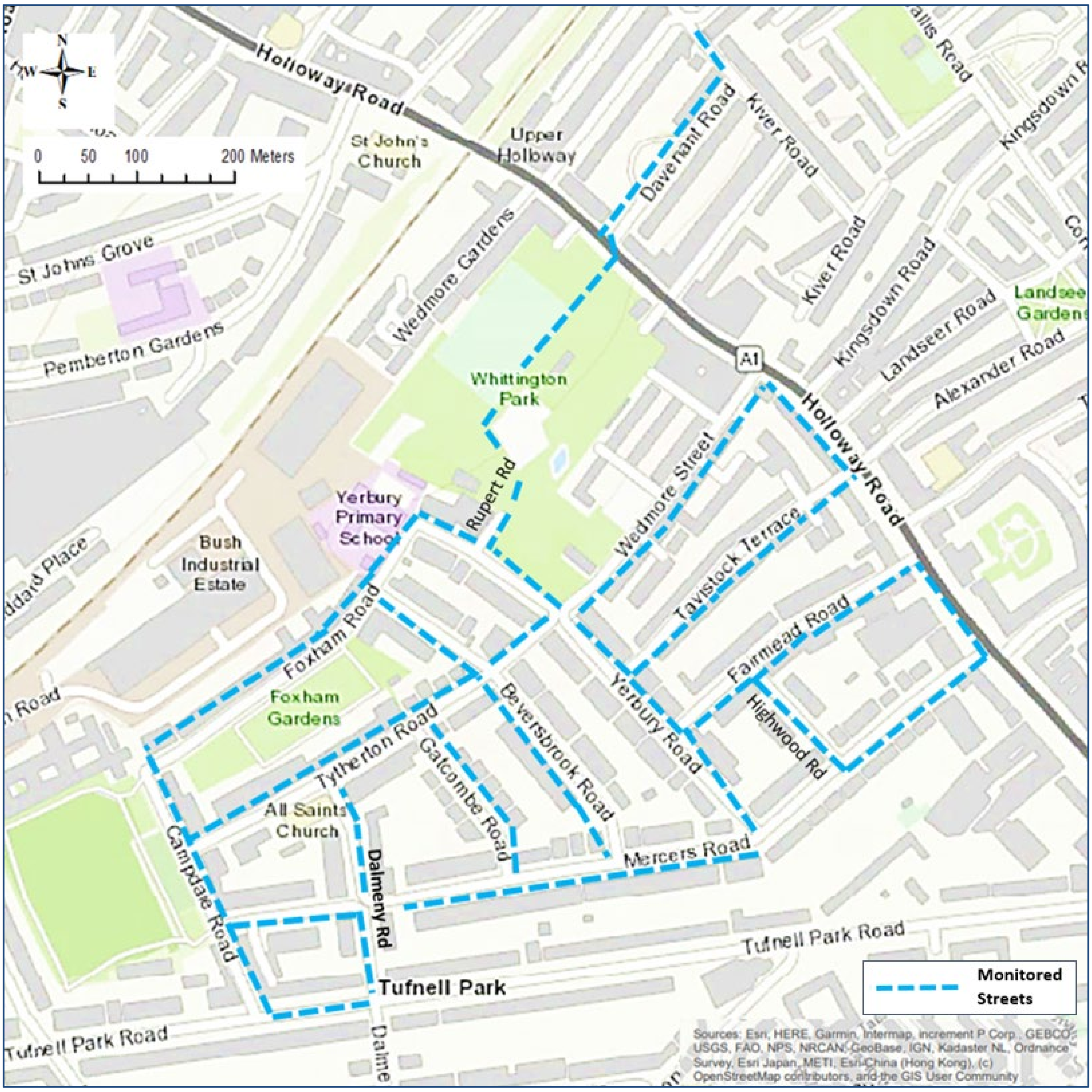
Figure 1. Map of London Borough of Islington with the pilot study area shown as a red square.



Google Maps™ mapping service

A portable micro-aethalometer was carried by a walker through streets in the study area, to measure BC as a tracer for solid fuel burning emissions. Ten walks took place during winter evenings around streets located within the pilot study area. Figure 2. shows the streets walked. Measurements were made with a 30 second averaging time. Walking pace was slower than average, allowing for a good spatial resolution between data points. The walks were tracked by GPS and took place on as much as possible on evenings with poor dispersion and within a peak time window for home solid fuel burning. Monitoring data was downloaded from the micro-aethalometer. Followng analysis and post processing data was mapped using ArcMap to display hotspots for solid fuel burning based on black carbon concentration Z Scores.

Figure 2 Map showing monitored streets in the pilot study area



5. Results

From a total of fourteen completed walks, eight were considered sufficiently similar for inclusion in the pilot study. The eight valid walks were carried out in mid-winter over approximately two months between 14th December 2020 and 11th February 2021. All eight walks were undertaken on separate days between the times of 20:14 and 22:27 GMT and lasted between 55 and 61 minutes. A total of 957 valid 30-second averaged BC measurements were recorded over the eight walks. These measurements were taken across eighteen different roads/pathways.

Weather conditions were compiled from reference to London weather at *timeanddate.com* and *nw3 weather.co.uk*. Summary information for each valid walk is displayed in Table 1. From data in Table 1. we can observe how weather conditions at the time of the walk affected ambient BC concentrations, with higher mean BC concentrations generally observed during colder less windy conditions.

Table 1 Summary of Walks

Walk I.D.	Date	Start	Duration (hh:mm)	BC Data n	BC Data μ ($\mu g/m^3$)	BC Data σ	Weather: Wind Direction & Speed (mph)	Weather: Observe	Weather: Temp °C
1	Mon, 14/12/2020	21:29	00:58	117	0.304	0.318	SSW 8-12	Part Cloudy	9
2	Sun, 20/12/2020	20:38	01:01	125	0.475	0.190	SSW 7	Clear	7
3	Fri, 25/12/2020	20:14	00:55	111	0.845	0.257	WNW 2-5	Part Cloudy	2
4	Fri, 01/01/2021	20:54	01:01	123	0.810	0.406	N 6-10	Low Cloud	4
5	Fri, 08/01/2021	21:04	00:58	118	0.711	0.240	NNE 2-7	Low Cloud	0
6	Sun, 10/01/2021	20:53	00:59	119	1.119	0.316	WNW 5-8	Overcast	3
7	Sun, 17/01/2021	20:47	01:01	123	1.397	0.309	WNW 0-4	Overcast	5
8	Thurs, 11/02/2021	20:24	01:00	121	0.326	0.277	ESE 5-12	Clear	0

Table 2 displays the locations covered by each of the eight valid walks. Locations covered by the eight walks are sorted in decreasing order based on the mean percentage data recorded at each location. Colour scaling wss used to highlight the similarity of data from each of the eighteen locations across all eight valid walks used in the pilot study.

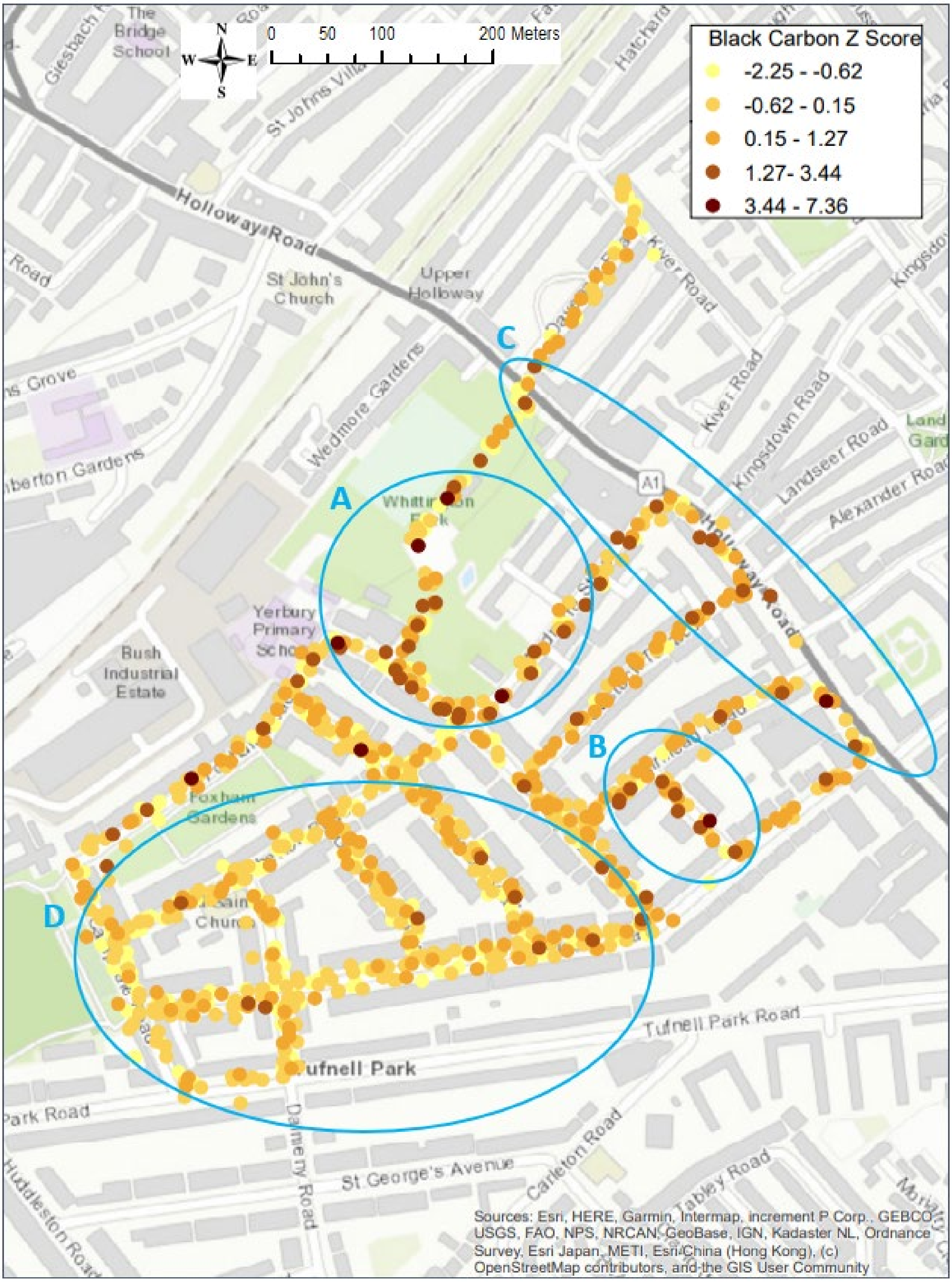
Table 2 Percentage of walk at each location

Location	Walk ID 1	2	3	4	5	6	7	8	x̄
Mercers Rd	11	22	16	17	19	18	18	18	17
Yerbury Rd	14	6	14	11	12	11	11	12	11
Beversbrook Rd	13	10	11	11	10	11	11	12	11
Tytherton Rd	12	10	11	9	8	9	9	8	10
Foxham Rd	5	10	5	6	5	5	5	6	6
Fairmead Rd	6	4	6	6	7	6	5	6	6
Dalmeny Rd	5	6	5	4	5	6	5	5	5
Campdale Rd	4	9	4	7	3	3	4	5	5
Gatcombe Rd	5	5	3	6	5	5	5	5	5
Wedmore St	5	5	5	5	4	3	5	5	5
Tavistock Terrace	4	4	5	4	4	5	4	4	4
Whittington Park	4	1	5	4	4	6	6	4	4
Holloway Rd	4	3	3	4	3	4	4	4	4
Davenant Rd	3	0	3	3	3	3	2	2	2
Highwood Rd	2	3	2	2	2	2	2	2	2
Tufnell Park Rd	1	1	2	2	2	2	2	0	1
Rupert Rd	1	1	2	1	2	1	2	2	1
Kiver Rd	1	1	1	1	2	1	2	1	1

The map displayed in Figure 3. shows relative concentrations of BC measured across locations in the pilot study area. Areas with individual measurements much greater than average BC measurements, (higher Z-Scores), are clearly visible as darker brown colours on the map. Mapping of data allows for a more in-depth analysis of BC levels within the pilot study area, with identification of BC levels on sections of individual streets.

Darker brown coloured markers on the pathway through Whittington Park and streets in the immediate surrounding area, Foxham Rd, Rupert Rd, Yerbury Rd and Wedmore St indicated locations on these streets which had the highest relative BC concentrations. Higher relative BC concentrations as evidenced by clusters of darker spots were also visible in the vicinity of Highwood Rd/Mercers Rd and at locations close to Holloway Rd. By contrast the area in the south west section of the study area had lower relative BC concentrations as shown by lighter coloured spots mostly visible on streets in this section.

Figure 3 Map of black carbon Z-Scores for all eight valid walks in the pilot study area with different zones highlighted.



6. Discussion & Recommendations

A cluster of relatively high black carbon data was observed around the sports pavilion in Whittington Park (Zone A Figure 3.). A photo of the pavilion with smoke from the flue clearly visible and a map showing the location of the pavilion within the park are shown in Figure.4. The photo was taken during daylight, at 15:15 on 10th December 2020, so not during one of the walks which took place at night. However, it clearly particle emissions from the flue and it is likely that similar emissions would also have been present at times when the walks took place. The pavilion contains a 40kW biomass boiler to meet the shower hot water and heating needs of the pavilion's changing rooms. This type of boiler uses thermal stores - large tanks of water - that act as a heat battery by storing hot water from the boiler which is then circulated to the heating system. The biomass boiler is responsible for keeping the thermal store at predefined temperatures. The boiler will switch itself on when the thermal store drops below a certain temperature, then when the thermal store is up to temperature it switches itself off to conserve fuel. Consequently, normal operation of the boiler would most likely give rise to intermittent emissions from the chimney. The fact that multiple walks are carried out on different dates increases the likelihood that an intermittent source will be picked up by monitoring.

Figure 4 Photo & Location of Sports Pavilion in Whittington Park.

The cluster of relatively higher black carbon measurements from Whittington Park, Foxham Rd, Rupert Rd, Yerbury Rd and Wedmore St are located close to the sports pavilion, and it must be considered likely that the emissions from the biomass boiler are responsible, wholly or in part for these higher BC measurements in the pavilion's locality. The maintenance history and emissions from the biomass boiler should be investigated to confirm the source and that the boiler is being operated and maintained in the correct manner.

Another cluster of darker spots (Zone B Figure 3.) was observed from the junction of Mercers Rd along Highwood Rd. It is thought that solid fuel burning at residential premises in this area was responsible for these higher BC measurements. The walker noted the smell of smoke on more than one occasion when in the area.

Darker spots were also noted (Zone C Figure 3.) along Holloway Rd and close to its junction with Whittington Park, Wedmore St, Tavistock Terrace, Fairmead Rd and Mercers Rd. It's possible that BC from vehicle emissions on the higher trafficked Holloway Rd were responsible for these elevated BC measurements.

There was no obvious reason for some higher black carbon data and darker spots further along Foxham Rd towards Campdale Rd. It's possible the sports pavilion may also be responsible or some activity within Rush Industrial Estate, just to the east of Foxham Rd. Further investigation would be required to determine the source as nothing obvious was noted from the walks.

Lighter coloured spots were most in evidence in the south-west section (Zone D Figure 3.) of the pilot study area. There were no obvious emission sources noted in this area during the walks

Organic components of woodsmoke particles absorb light at 370 nm more effectively than 880 nm. This enhanced absorption at 370nm can serve as an indicator of woodburning particles. For four of the eight valid pilot study walks, Ultraviolet Particulate Matter (UVPM) measurements at 370nm were recorded in addition to Infra-Red Black Carbon (IRBC) measurements at 880nm. The difference between these two measurements was calculated and plotted for the four walks. However, this data did not map as expected to the wood burning area in the vicinity of the biomass boiler at the sports pavilion. The UVPM micro-aethalometer measurements led us to consider whether they did genuinely reflect properties of Particulate Matter (PM) in the area. There was an interesting UV question to be answered for these walks, but we were unable to from data collected. Why did we not see the UVPM data expected? One possibility is that the micro-aethalometer used did not provide accurate UVPM measurements. Further study outside the scope of this pilot project would be required to definitively answer this question.

This was a pilot study and as such lessons were learned for future projects.

- Measurement data from the micro-aethalometer at the beginning of each walk was often unstable and affected by a step change obvious in the data when the monitoring environment changed from inside to outside. This resulted in measured data having to be eliminated at the beginning of each walk before data processing was undertaken. To get the best data from the micro-aethalometer for a sampling campaign it is recommended by the manufacturer that the instrument warm up for approximately 30 minutes so that it can equilibrate. We have found during this pilot study that it also needs to equilibrate in the environment in which it will be monitoring.

- In addition to reliable simultaneous UVPM measurements, simultaneous PM2.5 measurements, on all walks would increase our understanding of emissions from solid fuel burning especially with respect to wood burning.

- Notes taken by walkers detailing smells of solid fuel burning, any visible smoke from chimneys encountered at different locations on a walk and weather conditions during a walk, would add to the overall picture painted by the measurement data and ultimately help identify hot spots and even help to identify a possible source of pollution.

- We saw from summary walk data that the BC signal overall was generally stronger on colder evenings with lighter wind activity. In future efforts should be made as much as is possible, to carry out walks on dry evenings with light wind activity and less dispersion. This approach would involve a higher degree of planning and flexibility for undertaking walks.

- For the pilot study identical walks were required to provide Z-Score BC data that could be compared and mapped using a standard scale for each individual walk. Although all walks were not identical, walks were only selected with a similar street footprint. For future projects a route should be identified, with detailed instructions provided for walking the route, with a start and end point clearly identified so as streets are walked in the same order for each individual sampling walk. This would ensure identical sets of data can be used to build up a 'Hot Spot' map.

- Based on results from this pilot solid fuel burning project and a previous Marylebone LEN vehicle emission project, ten replicate walks should be the aim for data capture to make up a 'Hot Spot' map in any future study.

- COVID restrictions meant that it was not possible to return the instrument to the laboratory during the study however it is recommended that data from each walk should be downloaded and the walk verified soon after it is completed.

7. Conclusion

The aim of this pilot project was to map hotspots of outdoor air pollution from solid fuel burning on residential streets in Islington, specifically, are there hotspots and can we measure them?

Using BC as a tracer for solid fuel burning emissions and using standardized BC Z-Scores to layer data from different monitoring walks, we found clear hotspots along residential streets. We identified the possible sources of pollution responsible, so providing a focus for further investigations and interventions.

Attempts to map hotspots using UVPM as a tracer for woodsmoke emissions using the Z-score method were unsuccessful. Although wood burning was detected, clear hotspots did not map as expected. Possible explanations for failure to map UVPM hotspots in this pilot study were too little data or inaccurate data from the monitoring equipment.

Overall, we identified a number of improvements that could be made to the monitoring procedure for any future project work to ensure better-quality data.

Hotspots identified could be mapped to any nuisance complaints to the local authority and to housing type to function as a predictor of solid fuel burning problems in other areas.

8. Funding

This project was part-funded by a Defra air quality grant to Islington Council.

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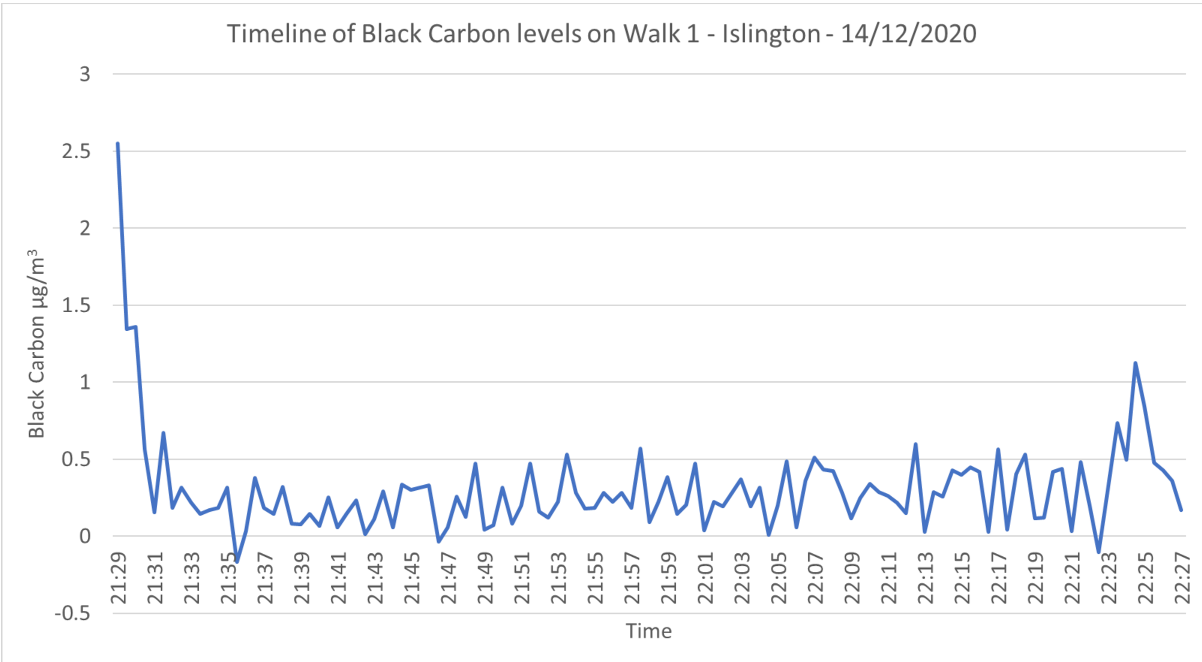
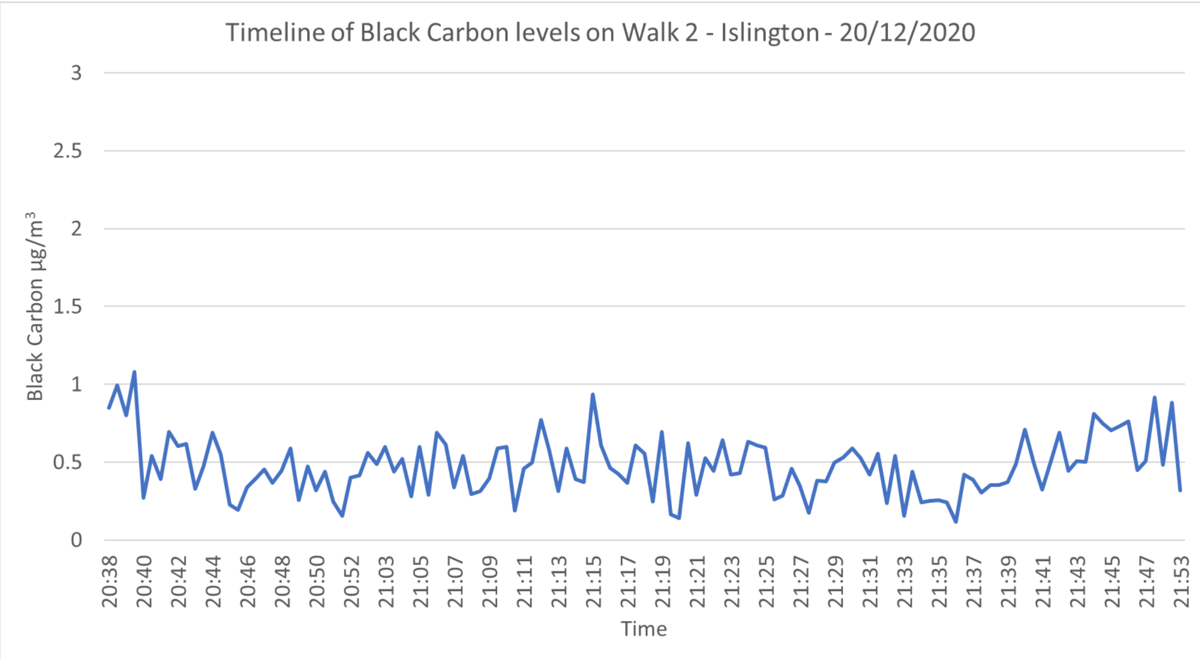
10. Appendix – time series BC concentrations from each walk

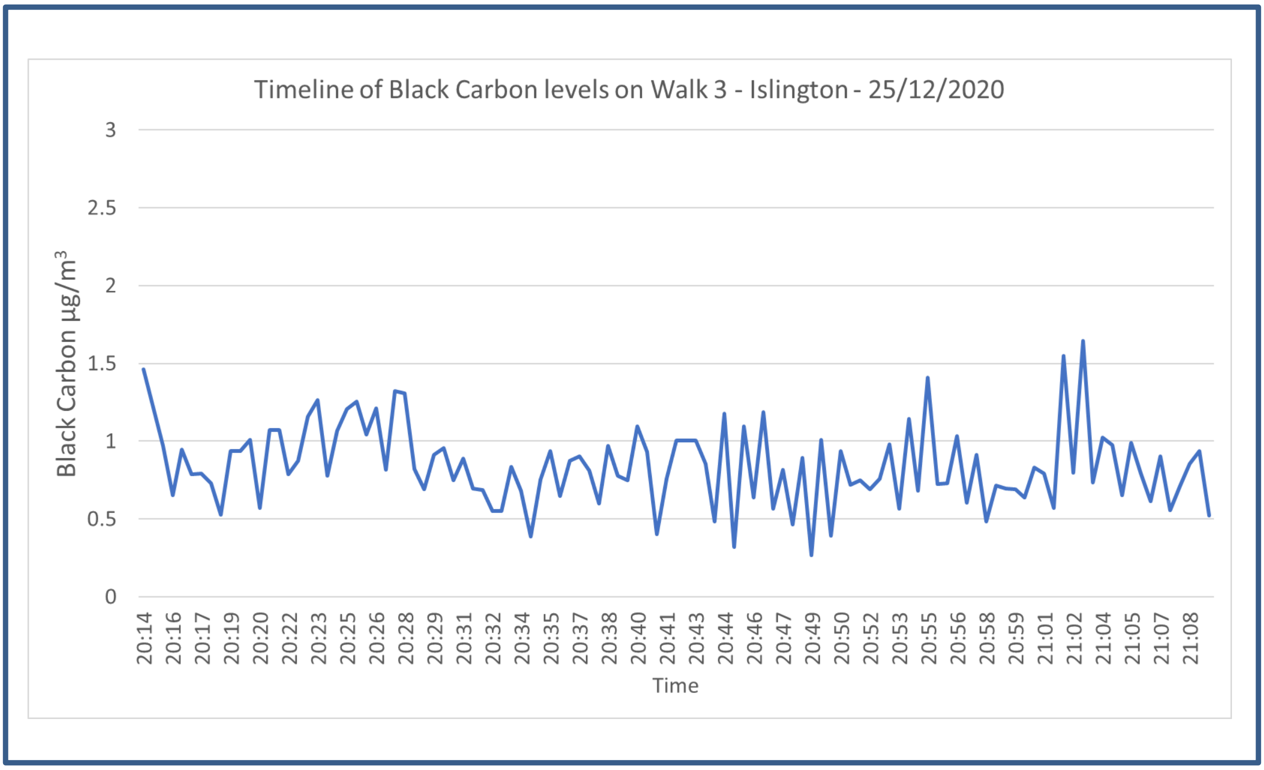
Location :	Islington – Walk 1
Date/Time:	14/12/2020 21:29, Duration 0:58
Weather:	9ºC, SSW 8 mph, 12 mph gust, partly cloudy.
Measurement:	MA300, 30s @150ml



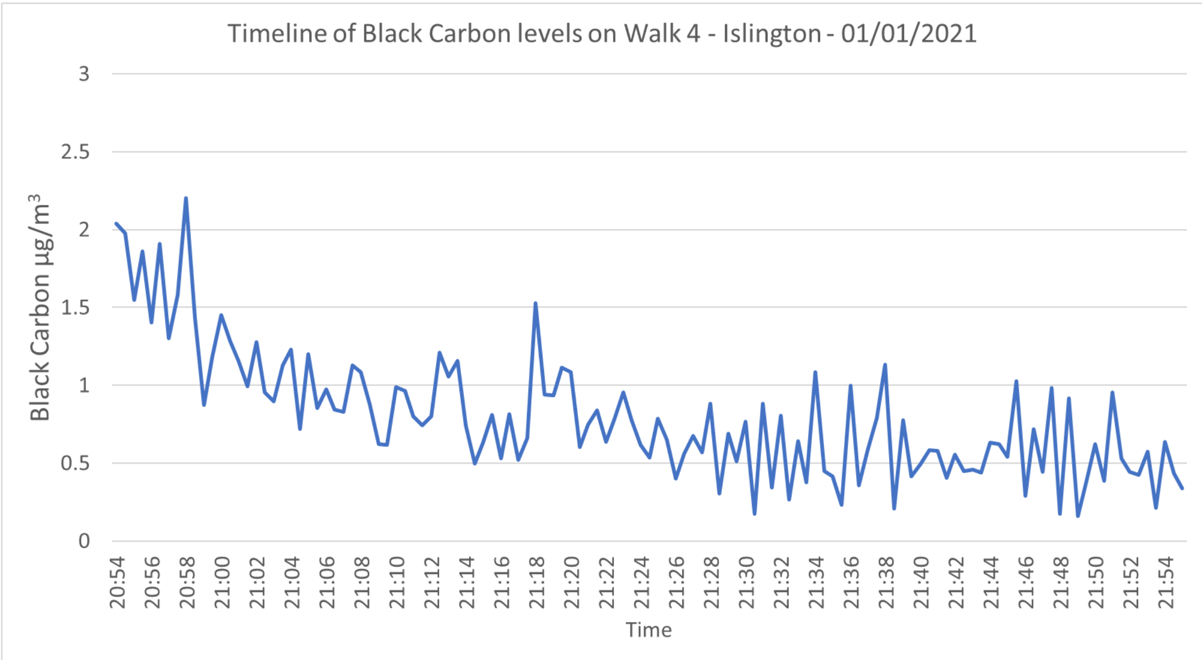
Location :	Islington – Walk 2
Date/Time:	20/12/2020 20:38, Duration 1:01
Weather:	7°C, SSW 7 mph, 0 mph gust, clear.
Measurement:	MA300, 30s @150ml



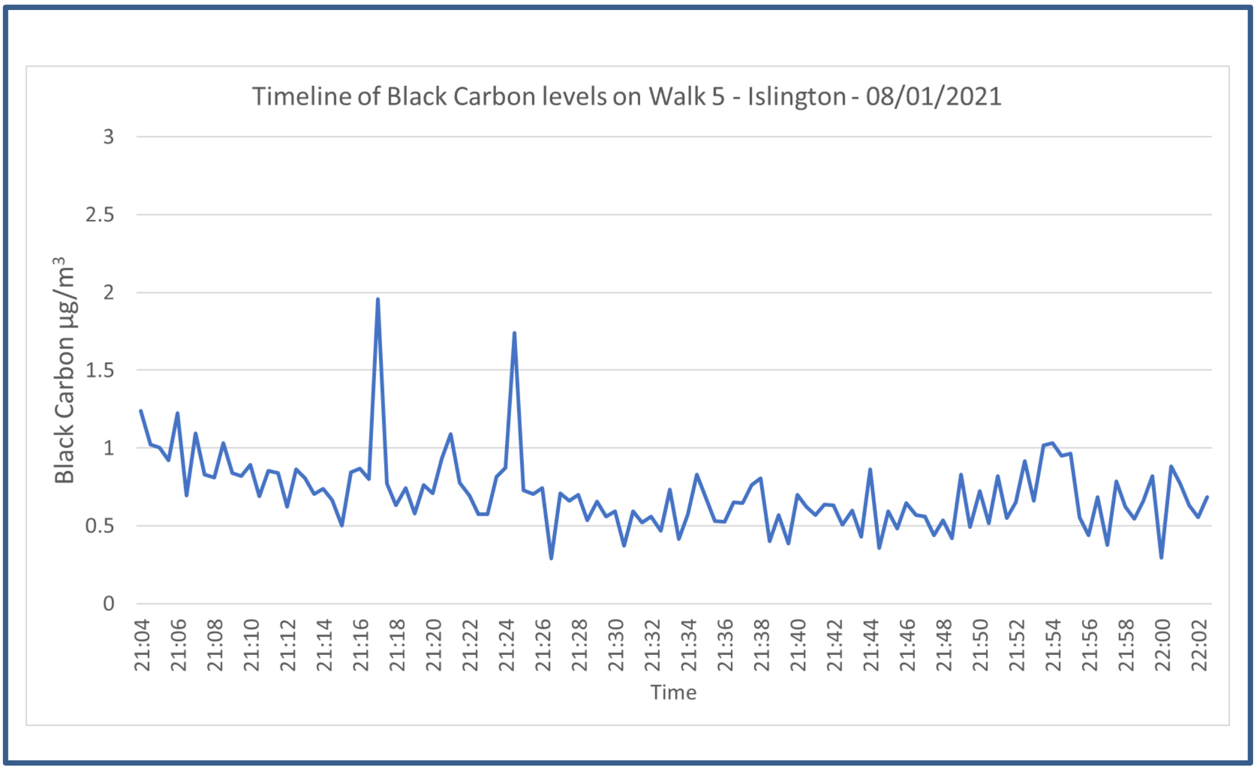
Location :	Islington – Walk 3
Date/Time:	25/12/2020 20:14, Duration 0:55
Weather:	2^{o}C, WNW 2-5 mph, 0 mph gust, passing clouds.
Measurement:	MA300, 30s @150ml



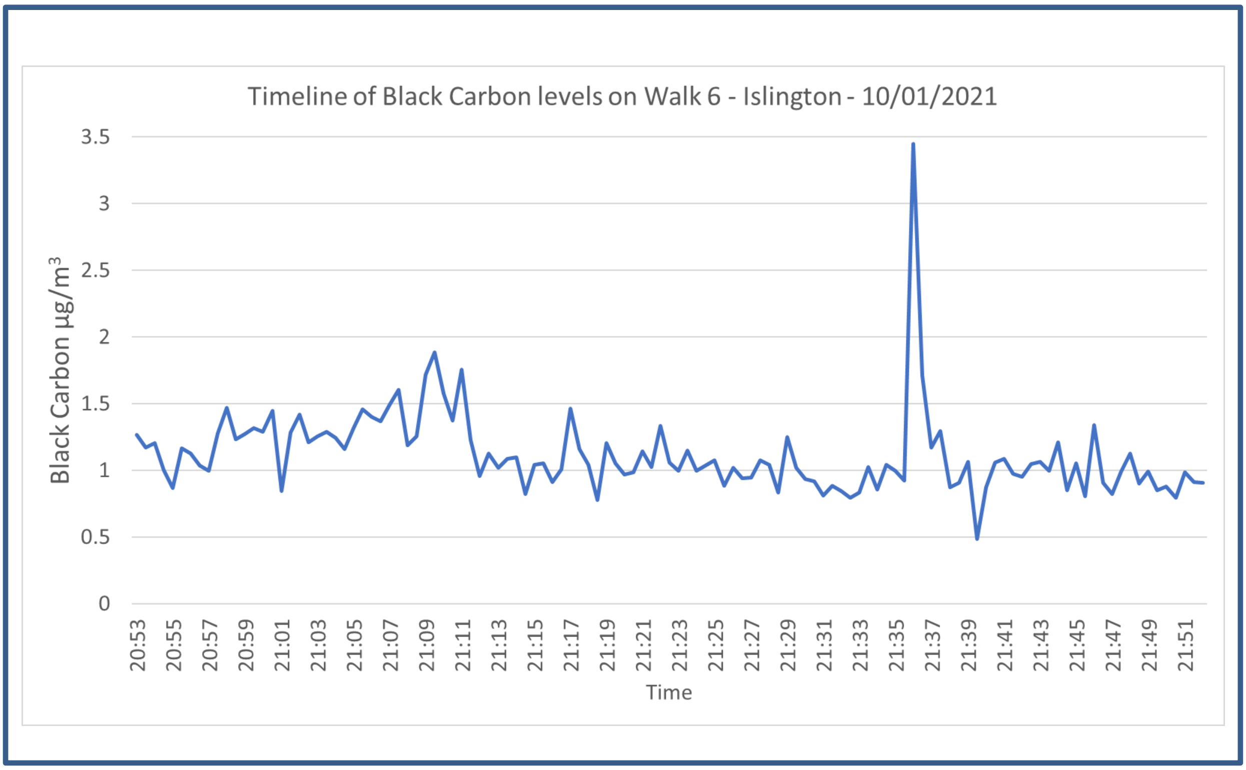
Location :	Islington – Walk 4
Date/Time:	01/01/2021 20:54, Duration 1:01
Weather:	4°C, N 6 mph, 10 mph gust, low clouds.
Measurement:	MA300, 30s @150ml



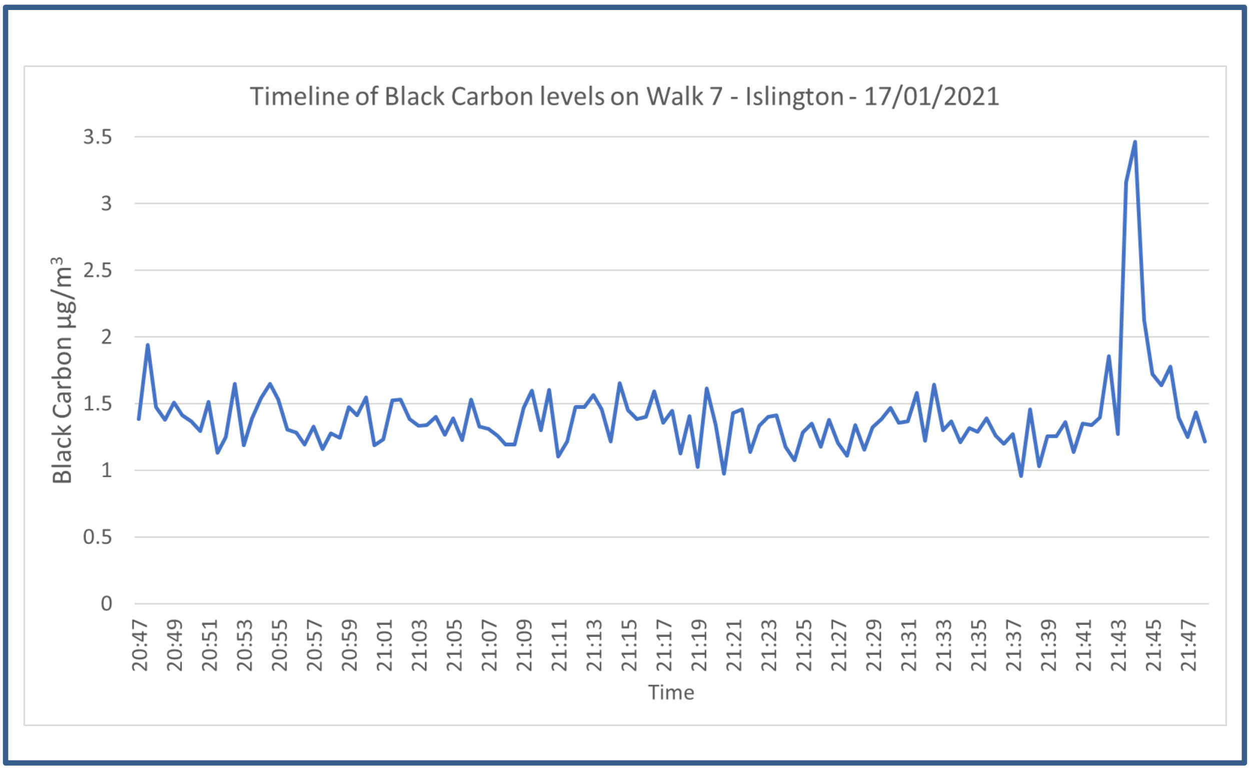
Location:	Islington – Walk 5
Date/Time:	08/01/2021 21:04, Duration 0:58
Weather:	0ºC, NNE 3 mph, 7 mph gust, Low Clouds
Measurement:	MA300, 30s @150ml



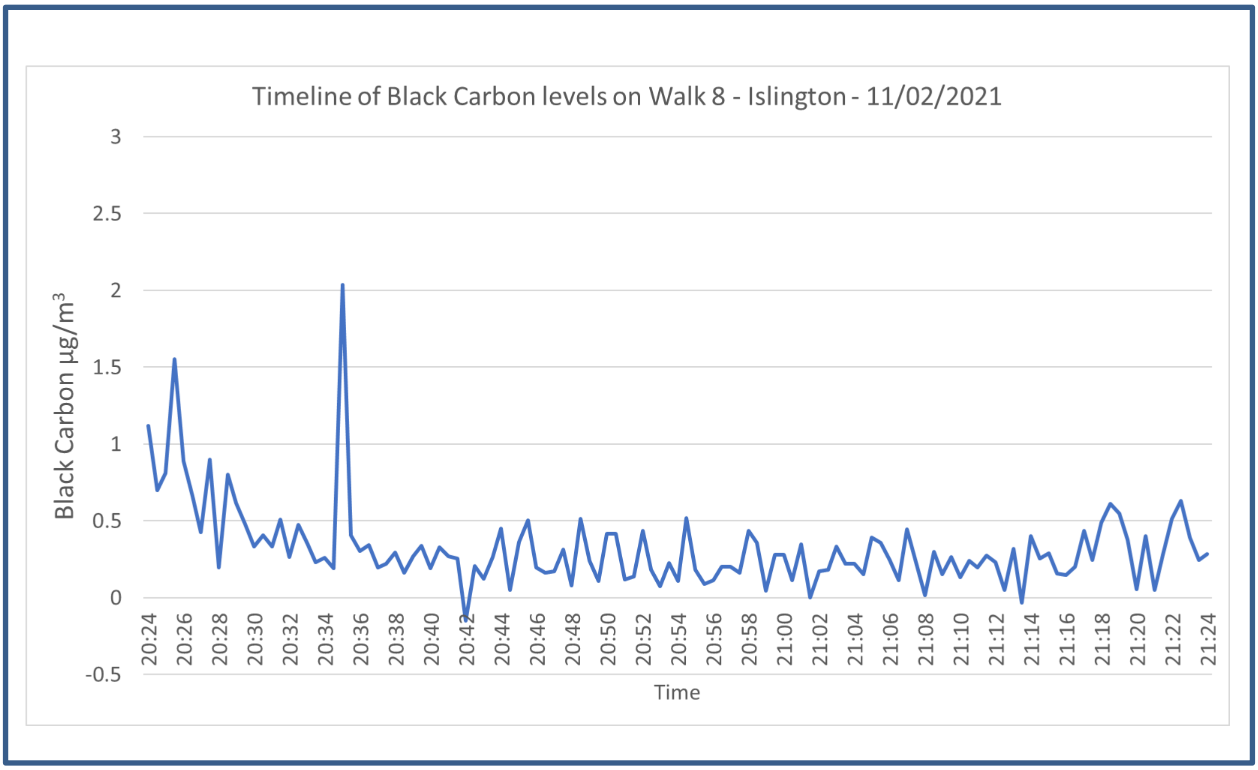
Location:	Islington – Walk 6
Date/Time:	10/01/2021 20:53, Duration 0:59
Weather:	3ºC, WNW 0-5 mph, 8 mph gust, Overcast.
Measurement:	MA300, 30s @150ml



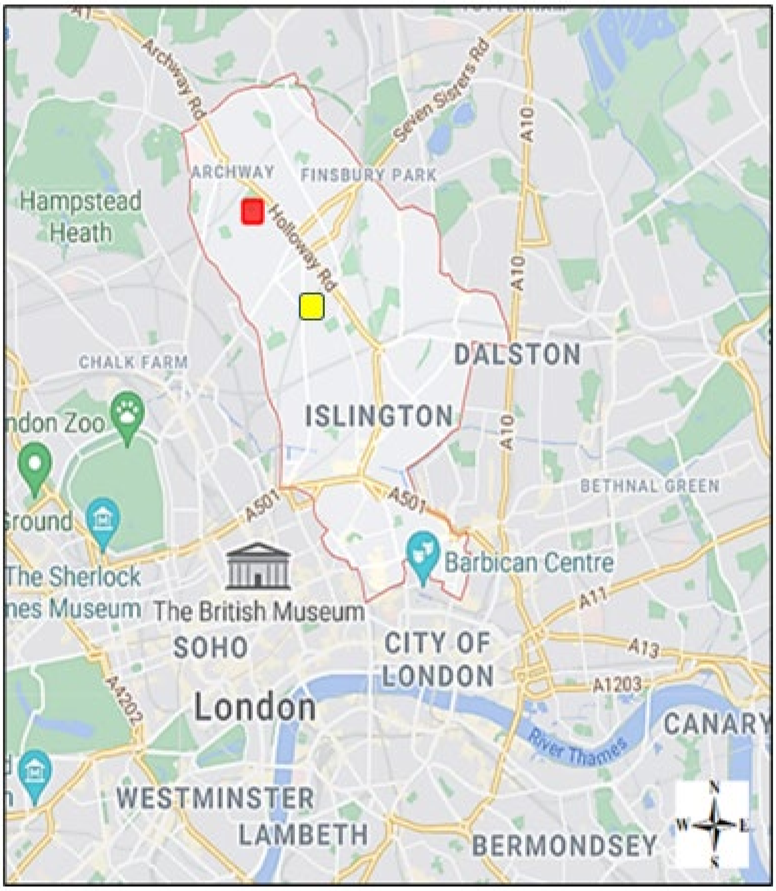
Location:	Islington - Walk 7
Date/Time:	17/01/2021 20:47, Duration 1:01
Weather:	5^{o}C, WNW 0-4 mph, overcast.
Measurement:	MA300, 30s @150ml



Location:	Islington – Walk 8
Date/Time:	11/02/2021 20:24, Duration 1:00
Weather:	0ºC, ESE 5 mph, 12mph gust, clear.
Measurement:	MA300, 30s @150ml



Two Walks (South)

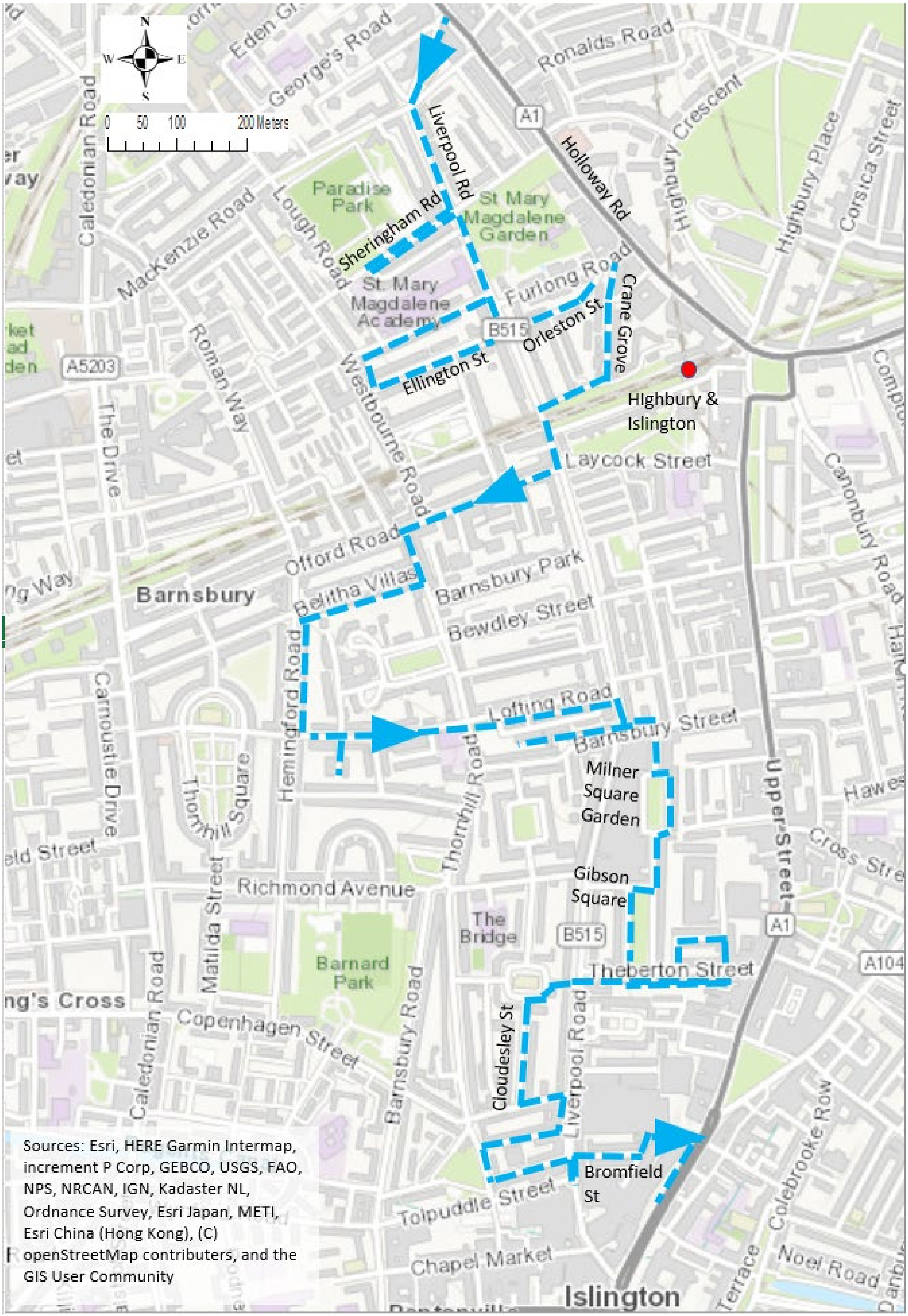


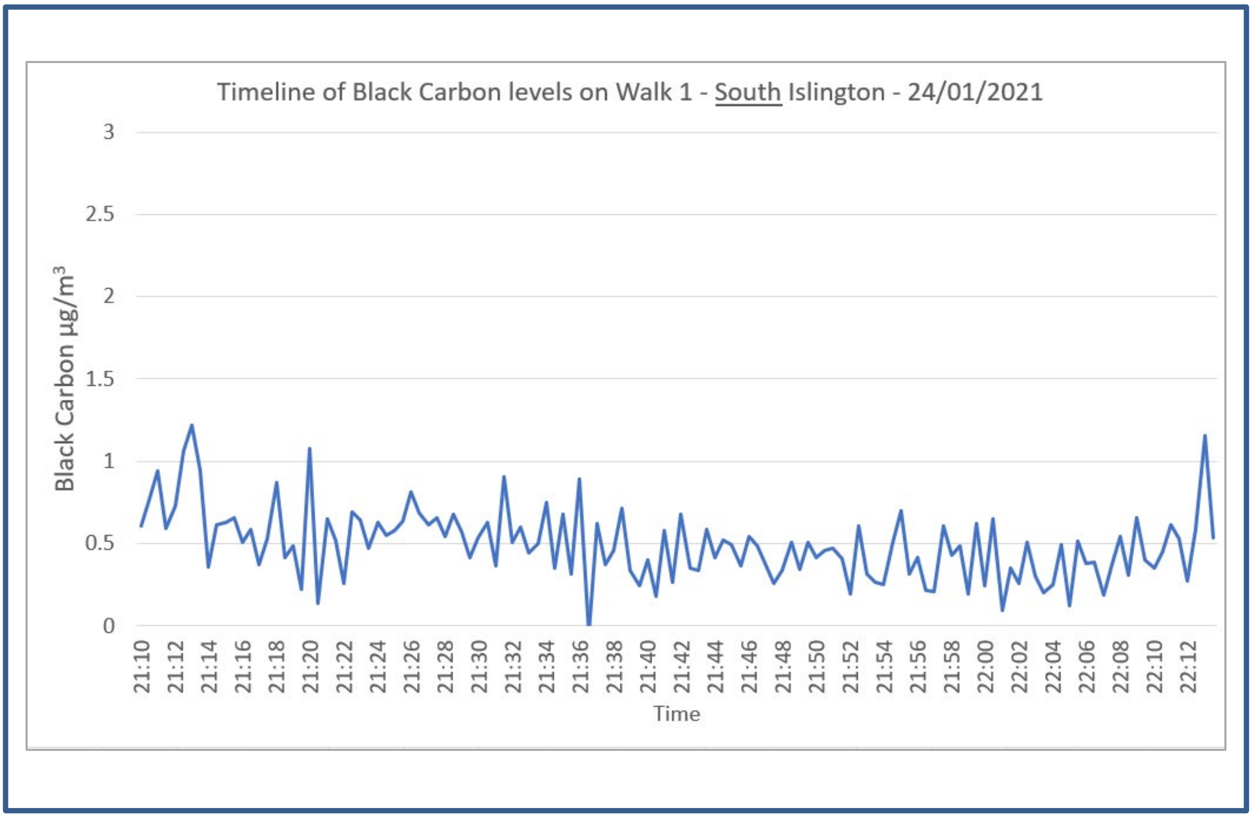
Google Maps™ mapping service

Pilot Study Area

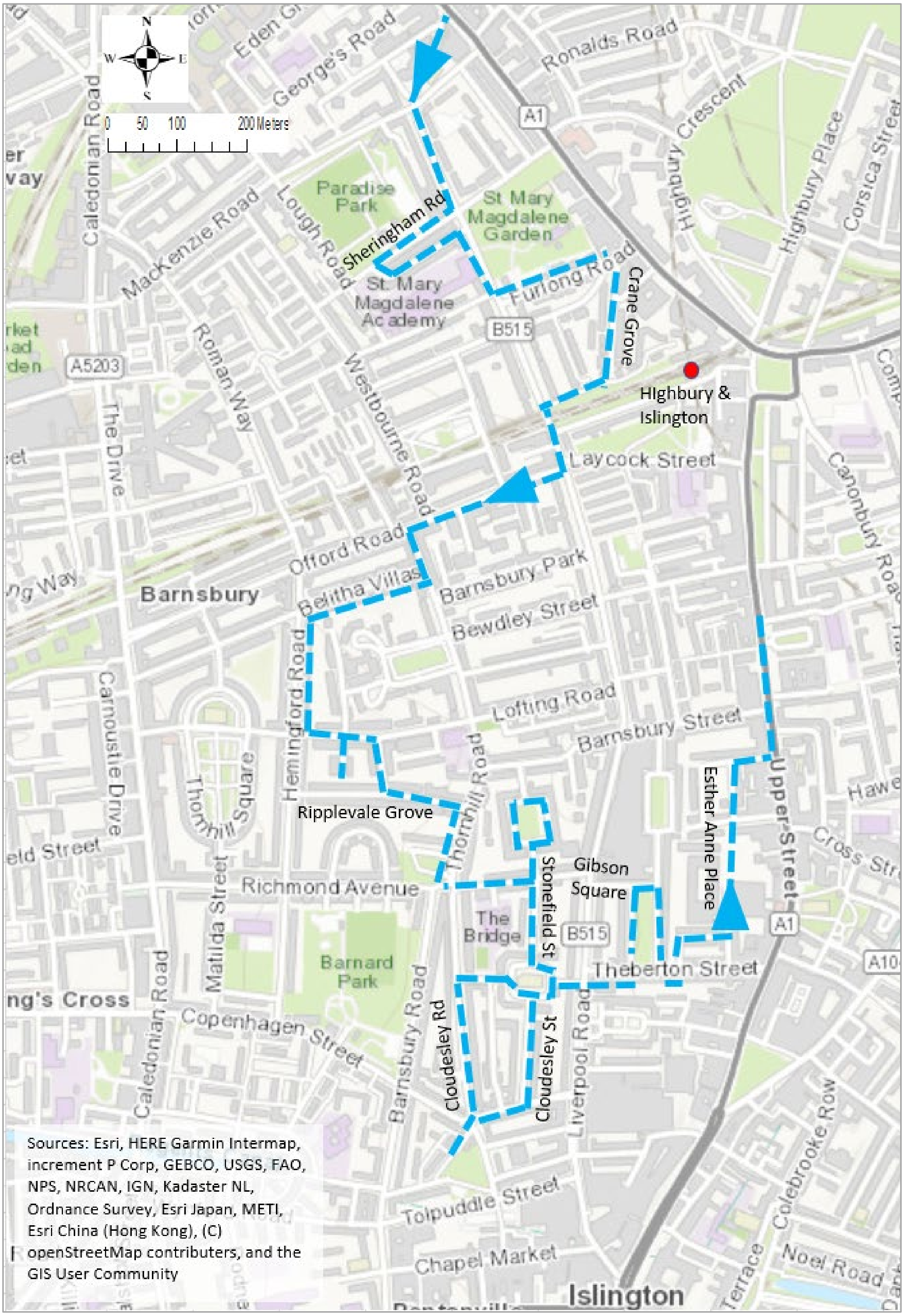
Two Walks (South)

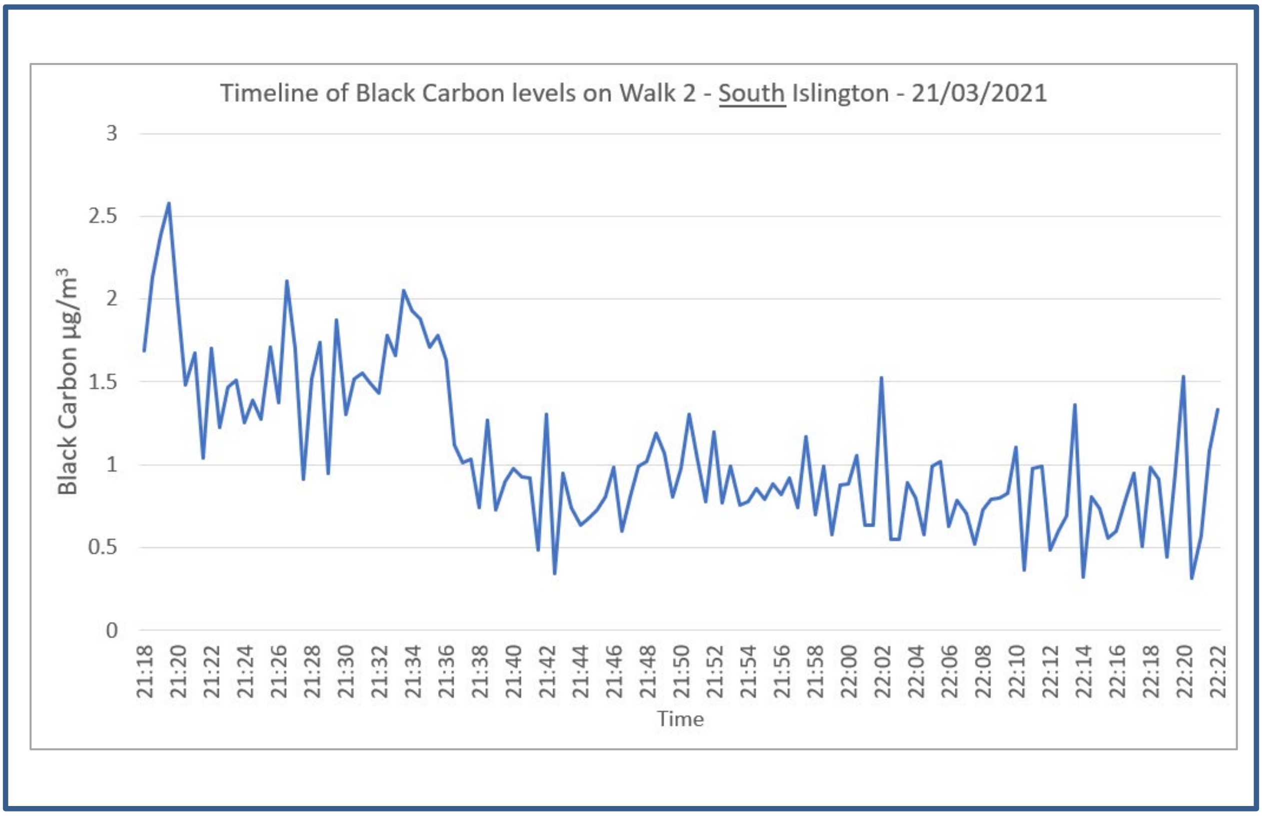
Walk- 1 South 24/01/2021




Timeline of Black Carbon levels on Walk 1 - South Islington - 24/01/2021
Black Carbon µg/m³
3
2.5
2
1.5
1
0.5
0
21:10
21:12
21:14
21:16
21:18
21:20
21:22
21:24
21:26
21:28
21:30
21:32
21:34
21:36
21:38
21:40
21:42
21:44
21:46
21:48
21:50
21:52
21:54
21:56
21:58
22:00
22:02
22:04
22:06
22:08
22:10
22:12
Time

<u>Walk- 2 South 21/03/2021</u>





Timeline of Black Carbon levels on Walk 2 - South Islington - 21/03/2021
Black Carbon µg/m³
3
2.5
2
1.5
1
0.5
0
21:18
21:20
21:22
21:24
21:26
21:28
21:30
21:32
21:34
21:36
21:38
21:40
21:42
21:44
21:46
21:48
21:50
21:52
21:54
21:56
21:58
22:00
22:02
22:04
22:06
22:08
22:10
22:12
22:14
22:16
22:18
22:20
22:22
Time

Imperial College London

Projects

Contact us:

Dr Gary Fuller, Environmental Research Group
Email: gary.fuller@imperial.ac.uk

Natasha Ahuja, Project Manager.
Email: n.ahuja@imperial.ac.uk

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