Simulated Passenger Journeys

Train carriage respirable dust exposures

London Underground network

Safety, Health and Environment

MAYOR OF LONDON

TRANSPORT FOR LONDON
EVERY JOURNEY MATTERS

Executive Summary

Simulated passenger journeys were undertaken on the London Underground network in December 2018 to assess the potential respirable particulate exposures of the travelling public and provide better information to members of the public on their actual exposure to particulates (dust) along the London Underground network. Aspects of this work have been undertaken previously in occupational exposure studies. This work has now been separated out as a standalone report to enhance clarity for members of the public and other parties who have an interest in this information.

Respirable and inhalable dusts are currently assessed against the respective Workplace Exposure Limits (WEL's) of 4 mg/m3 and 10 mg/m3 averaged over an 8-hour reference period (Health and Safety Executive Document EH40/05, 3rd Edition 2018). As these are occupational measures, they are not applicable to members of the public, although they can be used as a guide. Passenger exposures, even assuming a significant correction factor due to the weight of rail particulates, are very unlikely to exceed the exposure limits set out in EH40/2005, or the stricter recommendations made by the Institute of Occupational Medicine (IOM) if applied to members of the public and their typical travel patterns. The IOM target for airborne respirable dust is $<1 mg/m^3$ time weighted averaged over 8 hours.

The measurement work was undertaken using a TSI Dust Trak photo optical meter fitted with a respirable fraction impactor head to measure particulates along each underground section of line throughout the network.

The highest average reading was on the eastbound Central line, with an average of $0.534mg/m^3$ between White City and Stratford. Other deep Tube lines showed levels in the region of 0.3mg-$0.5mg/m^3$. Much lower levels were measured on the sub surface lines, typically below $0.1 mg/m^3$ for the length of the journeys.

Appendices attached at the end of this report show the real time measurement of particulate levels from start to finish point. Many of the graphs on the deep Tube show particulate levels accumulating in the direction of travel of the trains. This is a feature of the piston effect of trains pushing dust along the tunnels.

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1.0 Introduction

Transport for London (TfL) periodically monitor airborne particulate matter that staff are exposed to in the London Underground network. This monitoring involves measuring the gravimetric weight of particulates by their aerodynamic diameter, as well as their actual content by substance. These are then compared against regulatory standards set out in the Health and Safety Executives publication, Workplace Exposure Limits – EH40/2005 (HSE 2005). Data from this monitoring can be viewed at the TfL Website https://tfl.gov.uk/corporate/publications-and-reports/environment-reports.

Two groups with similar exposure to particulates are considered in this monitoring. These are train operators (drivers) and station staff. Neither of these groups are a particularly good proxy for the exposures experienced by the travelling public, therefore this further analytical exercise has been undertaken.

TfL do not routinely monitor gaseous pollutants in the London Underground as the network does not produce any as it is an electrified system. Levels of pollutants such as Nitrogen Dioxide will be from traffic sources and enter the system with intake air. Some work was undertaken in 2018 in stations to measure gaseous pollutants from traffic sources and these were found to be much lower than the corresponding roadside figures in each area the monitoring was undertaken. Air pollution data for London from traffic sources is available on the London Air Quality Website http://www.londonair.org.uk/LondonAir/Default.aspx

The purpose of measuring particulate exposure on simulated passenger journeys is to try and get a representative figure of what travellers are exposed to on typical trips across London using the London Underground network. Particulate exposures for the travelling public are quite different from those experienced by staff. Train operators are in an enclosed cabin with air filtration. In contrast underground trains in the deep Tube network have windows which expose passengers directly to air in the tunnels. Station staff spend some time on platforms during their shifts which also includes time spent in the gate line areas where air quality parameters are comparable to those measured on the surface. TfL have identified the main sources of Tube dust which are as follows:

- Wheel-rail interface
- Brake blocks

- Carbon brushes on motors
- Fibres from customers
- Engineering works
- Welding and cutting

2.0 Regulatory direction and other guidance

Health and Safety regulations concerning hazardous substances primarily apply to employees, although they can be used as a guide to public exposures. The regulations relevant to airborne particulates are the Control of Substances Hazardous to Health Regulations 2002 (HSE 2002). Regulatory guidance issued under these regulations includes the publication, Workplace Exposure Limits – EH40/2005. These set limits for airborne exposure to particulates as follows:

Inhalable particulates (PM 100) 10mg/m3 (8 hour time weighted average)

Respirable particulates (PM 4.3) 4mg/m3 (8 hour time weighted average)

Environmental particulate parameters such as PM 2.5 and PM 10 are not routinely used in occupational health and safety practice in the UK although they maybe referenced in research work. PM 2.5 is a respirable particulate fraction but not the fraction size which is routinely measured for occupational health and safety work because it can't be directly compared against the regulatory standards.

Measurements of such particulates are time averaged over the equivalent of a work shift which is taken as 8 hours. There are no formal short-term exposure limits (STEL) however HSE guidance states that in the absence of a formal STEL than the 8 hour time weighted average exposure standard can be multiplied by 3 to give an informal STEL (HSE 2005)

The IOM have previously issued guidance on the exposure to inhalable and respirable particulates in workplace environments (BOHS 2012) which is much stricter than the regulatory limits. TfL have adopted this guidance as an internal target through their Air Quality Group. The IOM guidance is as follows:

Inhalable particulates exposure limit: **5mg/m3 (8 hour time weighted average)**

Respirable particulate exposure limit: **1mg/m3 (8 hour time weighted average)**

Rail tunnel particulates are rich in metals as track, wheel and brake wear are significant sources of particulates. This dust is primarily Iron Oxide but also contains some Chromium, Nickel, Copper, Zinc, Manganese and other metals that are used in the alloying process to create high tensile steels. Levels vary but typically the weight of metal in the particulates can contribute between 30 and 70 per cent of the entire weight of the particles. The particulates are very heavy compared to typical ambient particulates measured on the surface which are composed of a mix of lighter mineral particulates, organic matter and products of combustion.

The sample reading results in this project are not directly comparable to workplace exposure limits as they are not work shift equivalent measurements. However, the regulatory limits and IOM guidance provide a useful reference point to compare the measurements and offer guidance to members of the public and staff alike.

3.0 Particulate Sampling Methodologies: Photo Optical Meters and Filter Train Samples

TfL operate several photo-optical particulate monitors which can be used to measure particulates in a range of different environments. The use of photo optical meters has some advantages and disadvantages compared to the other main methodology used to monitor particulates, which is the collection of particulates on a specific filter plate through a size selective filter head.

Photo optical meters allow the user to measure dust concentrations in mg/m^3 in real time and show how this has varied over the measurement period. In contrast collection of particulates on a filter plate will simply give an average particulate concentration over the time period of measurement. However, as the particulate has been physically collected on the filter plate it can be analysed for content. One other disadvantage of photo optical meters is that they are calibrated using a particulate such as Arizona road dust which has a

uniform density of 1.3mg/cm^3. The meter will therefore not accurately measure particulates with significantly different densities. Where particulates with a known significant density difference are being measured the meter in its standard setting will either consistently under measure or over measure the gravimetric weight of particulates in the air sample.

4.0 Methodology

The objective of the monitoring was to measure respirable fraction particulate levels in passenger carriages on typical commuter journeys on the London Underground network.

The measurements took place using TSI Dust Trak II photo optical meters and a 4.0µm size selective impactor head. To simulate passenger journeys, a TfL member of staff travelled within the passenger section of the train on all lines. The monitoring was focused on the common commuting routes that the travelling public take, including the deep tube areas which are known to be the dustiest areas of the network. Examples are Seven Sisters – Brixton (Victoria Line), Earls Court – Wood Green (Piccadilly line) and Finchley Central – Morden (Northern Line). The 4.0 µm impactor head measures dust at a slightly different size from the UK definition of respirable dust which is 4.30 µm however the small difference is not considered to be material to the results collected.

4.1 Equipment

Equipment Type	Model	Serial Number	Calibration Date
Meter	TSi Dust Trak II	6532-1732173511	13.09.2018
Filter Head	4.0µm impactor	N/A	N/A
Flow Rate Meter	TSI 4140 F	4140 1813 003	27.03.2018

TSI Dustrak II

https://www.tsi.com/products/aerosol-and-dust-monitors/dust-monitors/dusttrak-ii-aerosol-monitor-8532/

Particulate Meter Settings

Meter Setting flow rate	3 Litres per minute
User Calibration	Factory setting (Arizona Road Dust – 1.3mg/m^3)
Run Mode	Manual
Zero Calibration	Meter – Zero filter
Correction factors	Unknown

5.0 Results

The monitored levels of respirable dust that passengers were exposed to during this exercise are given in Appendices 1 to 23.

The results from the simulated passenger journey monitoring exercise showed that the levels of respirable dust were below the HSE workplace exposure limit (EH40/50) – 4 mg/m3 over 8-hour TWA, throughout all lines. The results showed:

Highest average reading

The respirable dust exposure level recorded for the Central Line travelling from White City to Stratford on 3rd December 2019 was 0.534mg/m3.

Lowest average reading

The respirable dust exposure level recorded for the Circle Line travelling from Edgeware Road to Hammersmith on 12th December 2019 was 0.020mg/m3.

The dust exposure levels recorded on the sub-surface lines were typically below 0.1mg/m3, and other lines (including deep tube lines, which are known to be the dustiest areas of the network) showed dust exposure levels in the region of 0.3mg/m3 to 0.5mg/m3.

6.0 Discussion

The results from the particulate monitoring give a perspective on concentrations across the network. In general, the deep Tube has higher levels than the sub surface lines. Readings were taken in both directions for the stations sampled on every line. The eastbound Hammersmith & City Line showed levels comparable with the deep Tube lines at 0.378mg/m^3. This may be an anomaly, as the westbound Hammersmith & City Line taken on the same day showed levels more typical of a sub-surface line at 0.069mg/m^3.

The lines with the highest particulate levels were the Central line with levels at 0.534mg/m^3 (eastbound) and 0.378mg/m^3 (westbound), and Victoria line with levels at 0.464mg/m^3 (southbound) and 0.369mg/m^3 (northbound). The remaining deep Tube lines showed levels between 0.230mg/m^3 and 0.400mg/m^3.

Sub surface lines showed much lower levels of particulate with levels typically below 0.1mg/m^3. One anomaly was the eastbound Hammersmith and City line which showed levels of 0.378mg/m^3 which contrasted with the same route in a westbound direction of 0.069mg/m^3.

Many of the graphs shown in the appendices show particulate levels increasing in the direction of travel on the rail line. The deep Tube lines are small one way 'Tubes' and this demonstrates the piston effect that is often referred to where trains shunt the dust along the line. This is particularly noticeable in the Brixton to Seven Sisters (appendix 4) and Stratford to West Hampstead (appendix 5) measurements.

The results are all significantly below the regulatory HSE limits. The highest reading of 0.534mg/m^3 is several times less than the regulatory limit of 4mg/m^3. In addition, we aim to keep respirable dust levels below 1mg/m3 (8-hour time weighted average) as per the IOM recommendations.

7.0 Significance

All readings taken during this exercise indicate that people travelling on the London Underground network are not exposed to dust levels that exceed the workplace exposure limits set by the HSE and IOM.

TfL have a programme to identify the sources of dust, what they contain and how they can be controlled. This will be achieved through collaboration with Kings College London, who have been given access to a static monitoring location on the deep tube. Their analysis of the tube dust at that location will help to determine the exact shape, size and makeup of the particulates, which will help to inform actions to reduce underground dust levels in the future.

7.1 Control Measures

Prevention

TfL has a cleaning programme which ensures that dust and particles are kept to an absolute minimum. TfL is further investigating innovations from subways across the world, such as Seoul, where air purifiers are used and Barcelona, where selective control of the ventilation fans was found to improve air quality. In addition, TfL is carrying out reactive cleaning activities on stations found to have the highest dust levels.

Capture of dust at source

- TfL has invested in local exhaust ventilation equipment to capture particulates produced by work such as welding and flame cutting of tracks and other signalling systems

Cleaning

- Cleaning is the main approach to removing dust once it has been released within the network. TfL has a programme of cleaning trains, tunnels and stations to collect dust that has accumulated in the system.

Ventilation

- Ventilation systems help clear a proportion of the dust generated within the network as well as removing heat and gaseous pollutants. TfL Engineers monitor the status of ventilation units across the network to ensure ventilation is working in accordance with its specification.

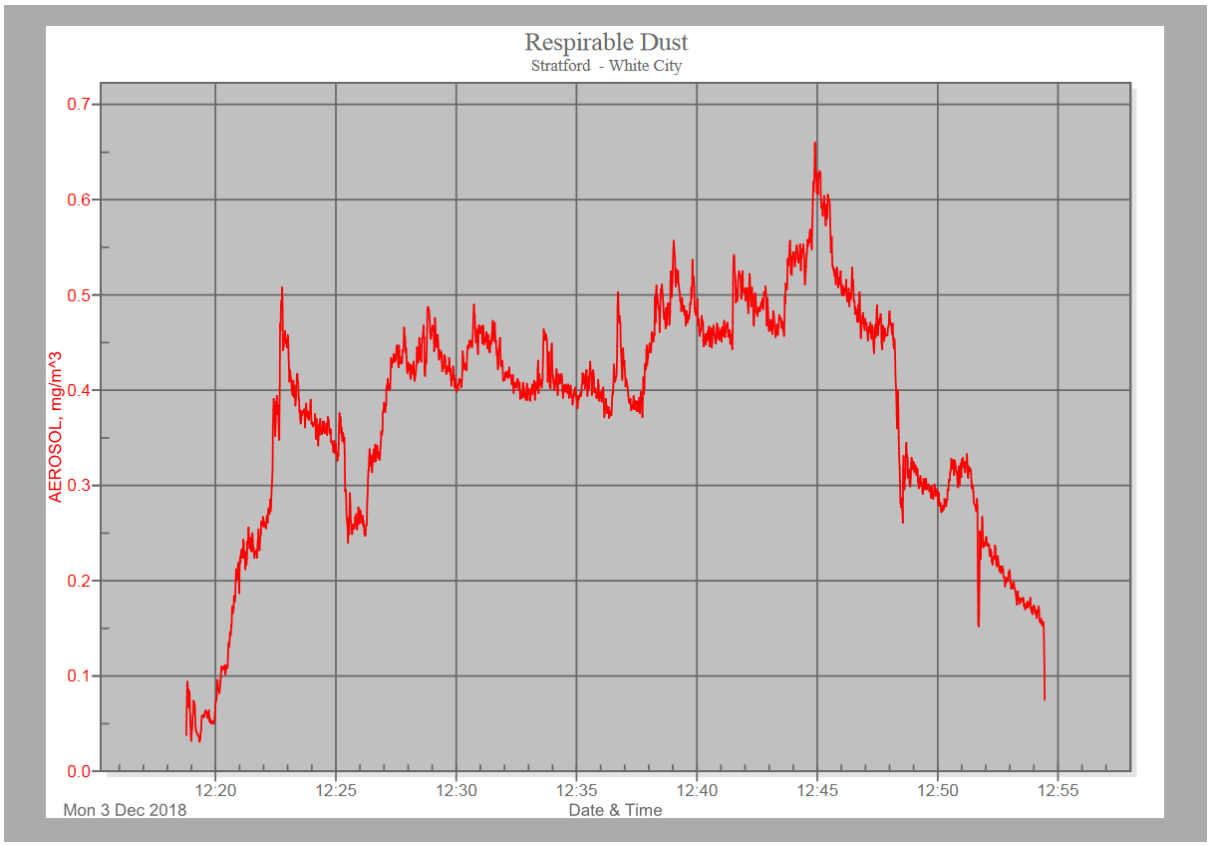
9.0 Conclusion

The monitoring of particulate levels across the London Underground Network has shown that levels do not exceed the regulatory limits set by the Health and Safety Executive under the EH40/2005 document.

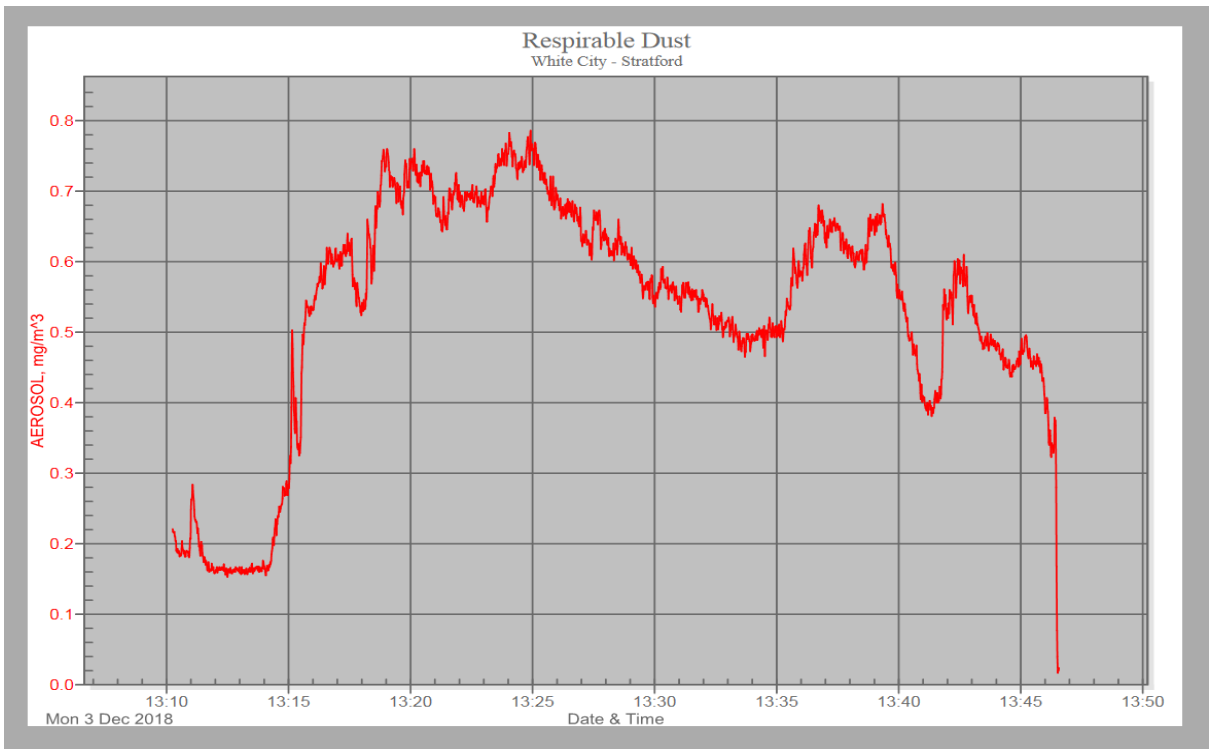
The monitoring of particulate levels when compared against the stricter IOM recommendations is unlikely to breach the recommendations made by the Institute.

Appendices

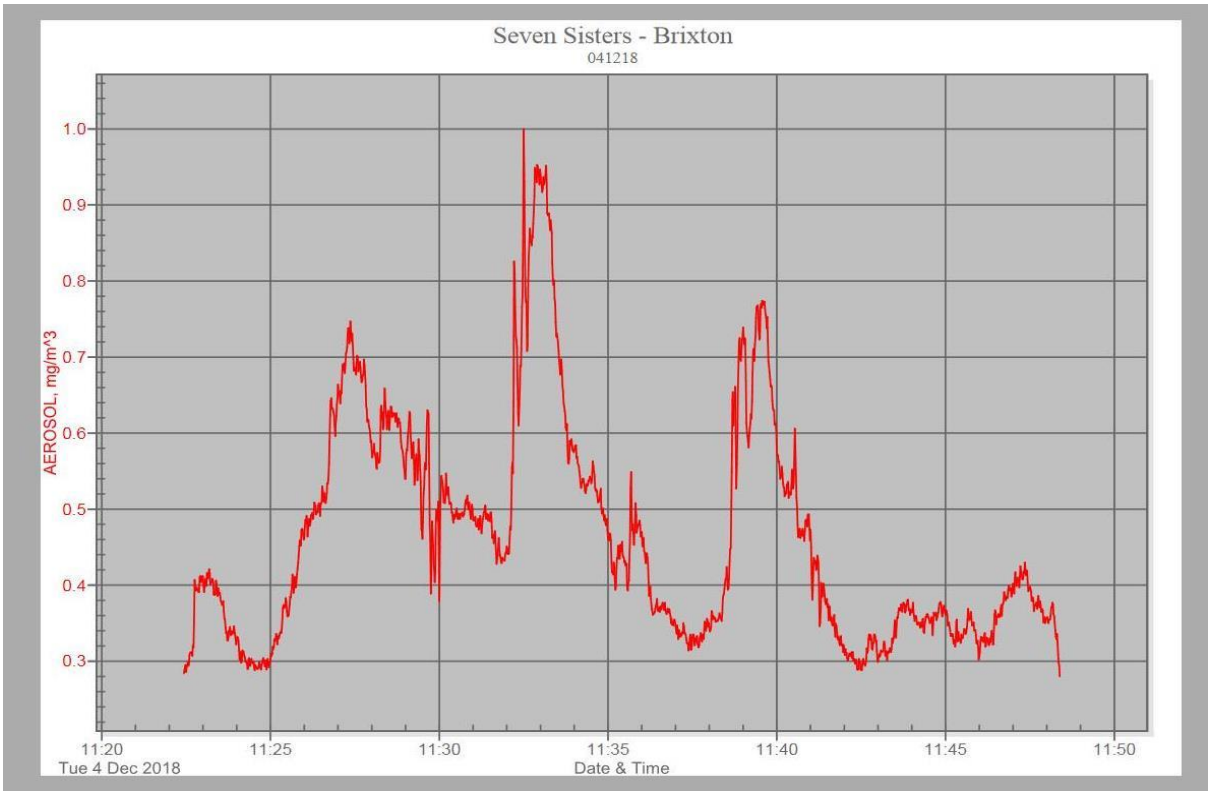
Appendix 1: Central Line, Stratford – White City



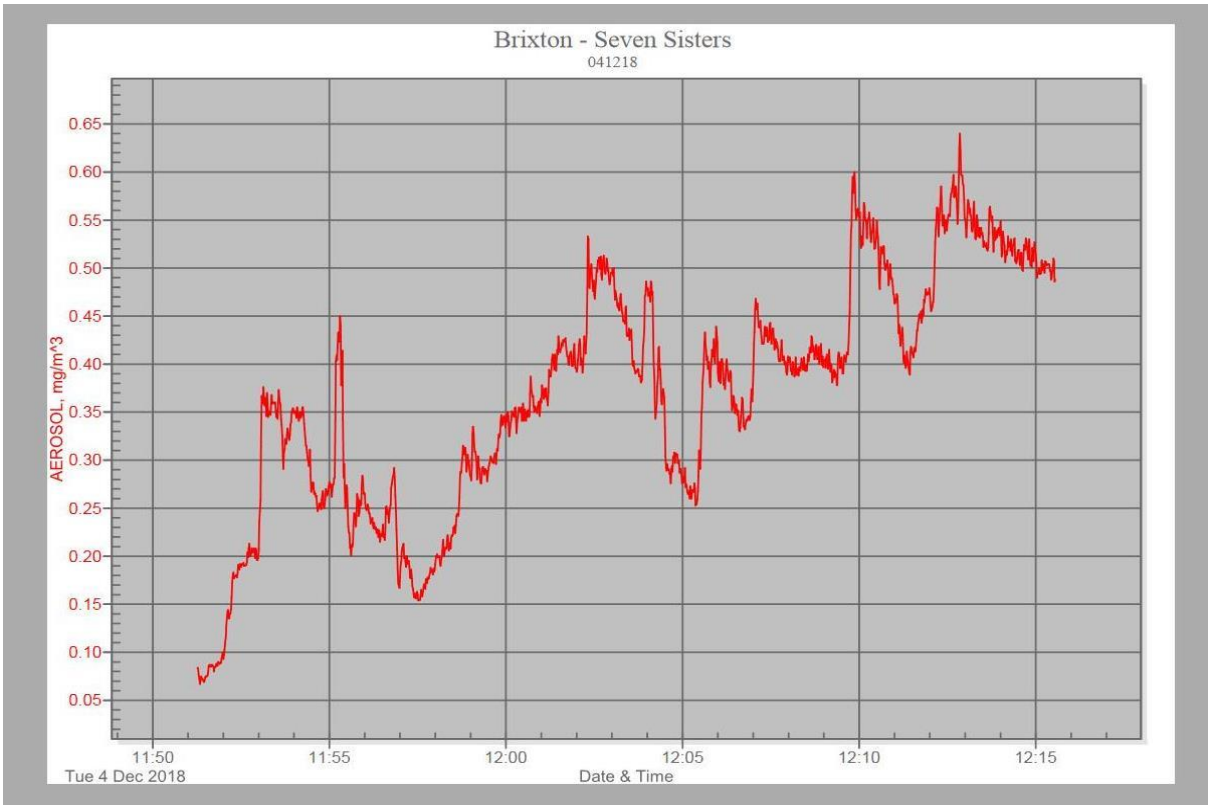
Appendix 2: Central Line, White City - Stratford



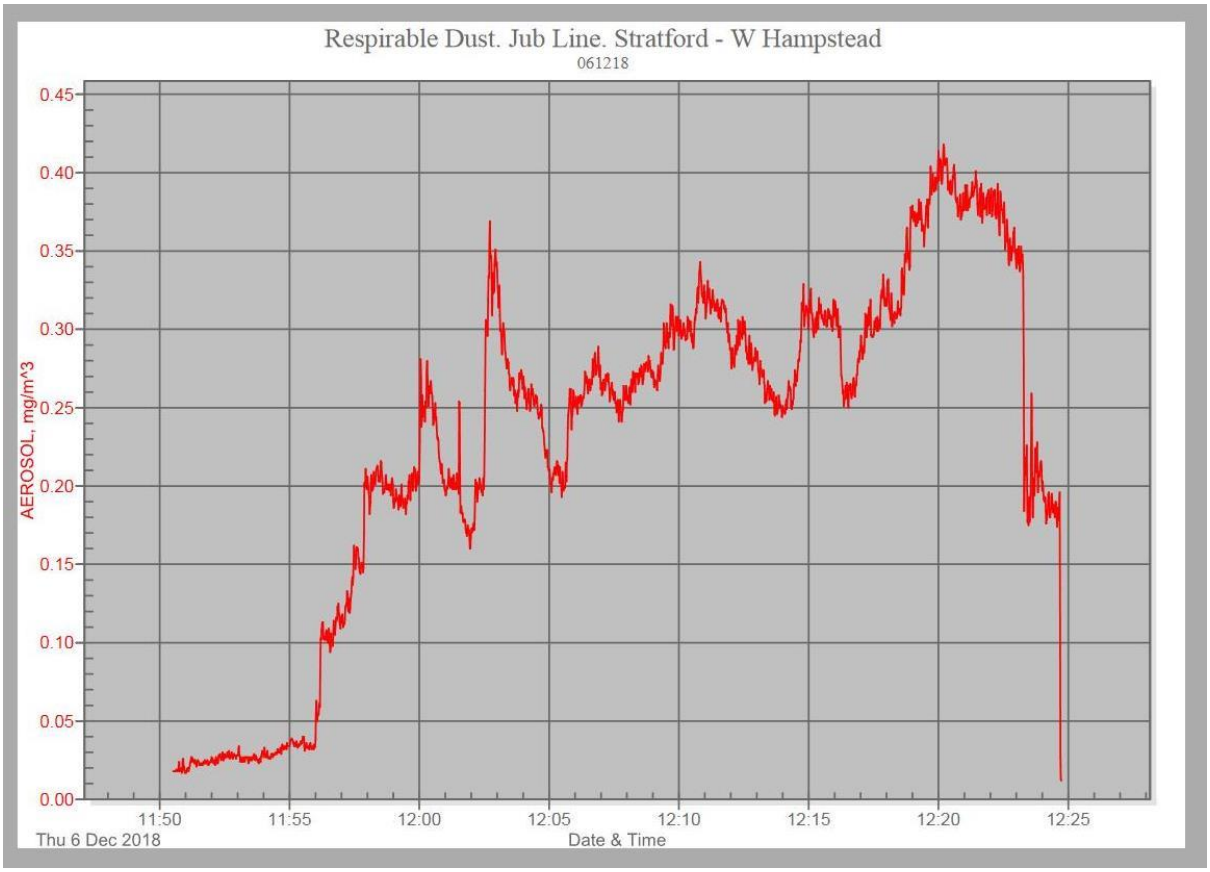
Appendix 3: Victoria Line, Seven Sisters - Brixton



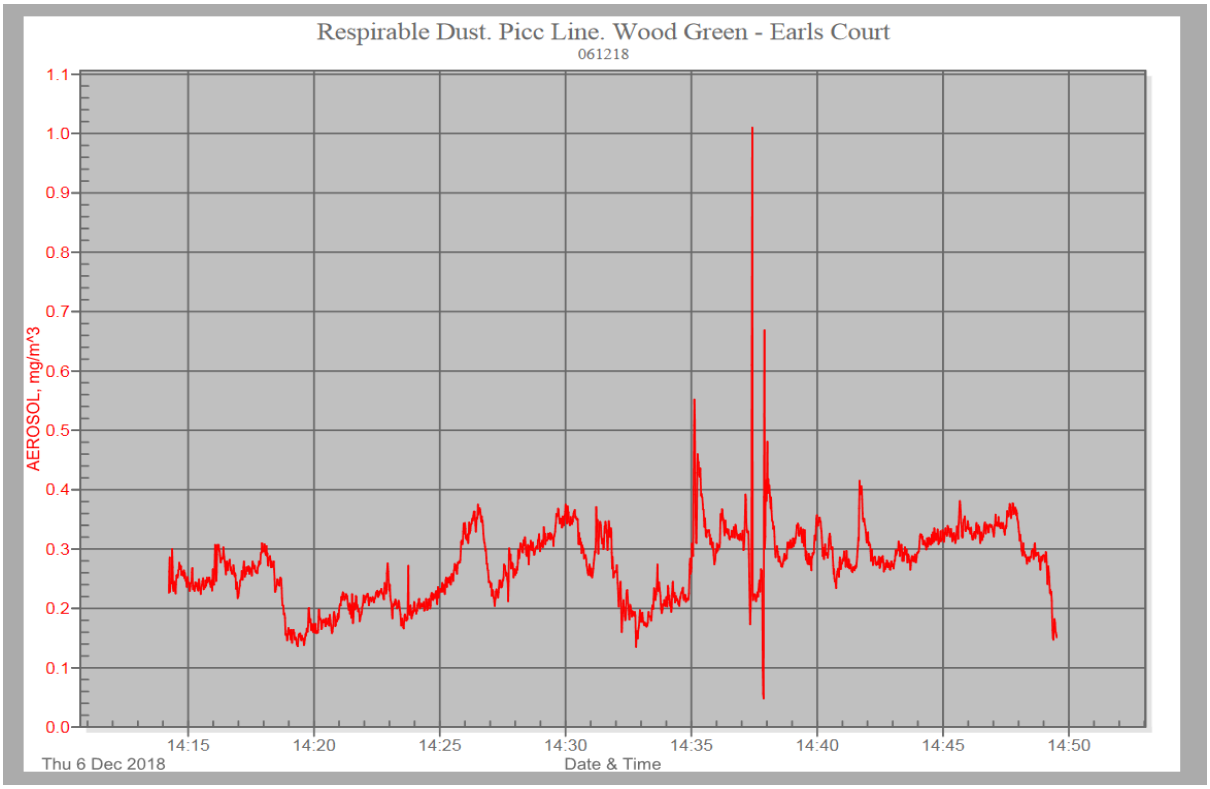
Appendix 4: Victoria Line, Brixton – Seven Sisters



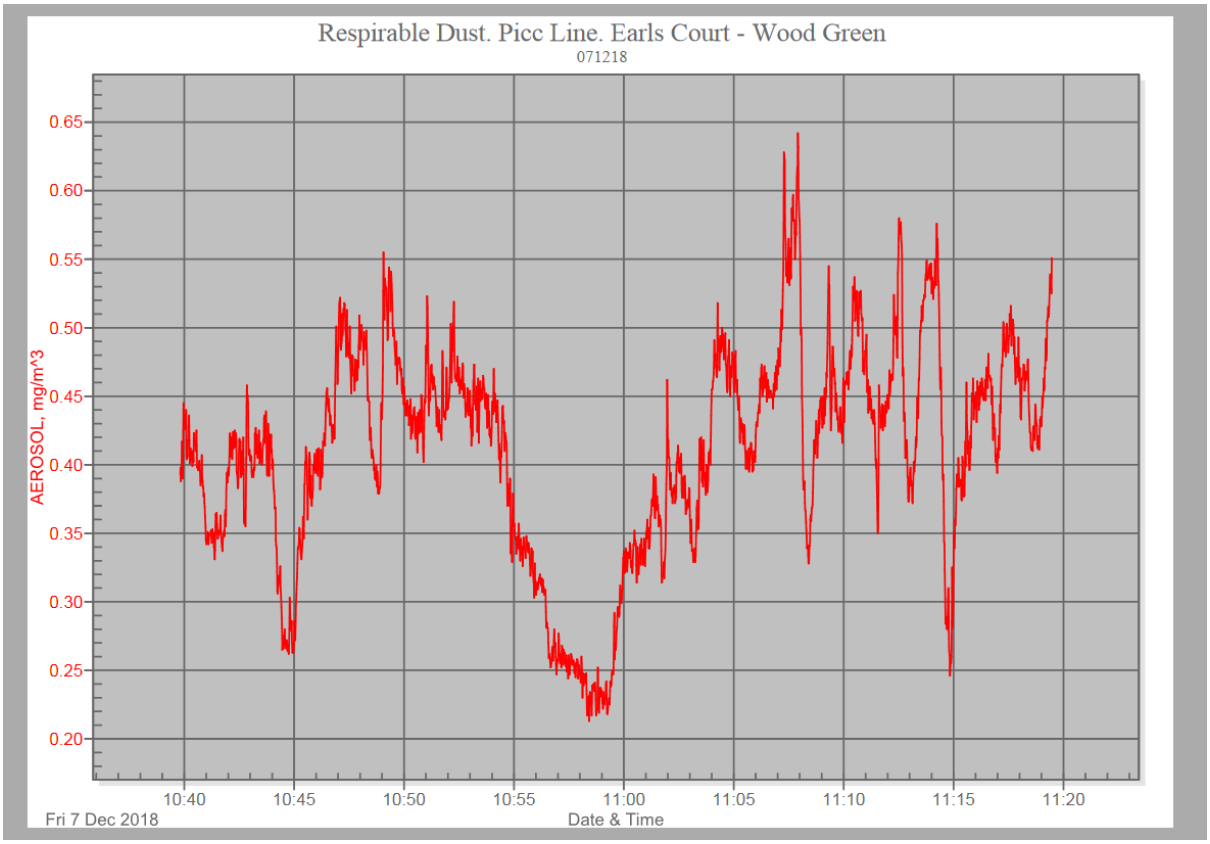
Appendix 5: Jubilee Line, Stratford – West Hampstead



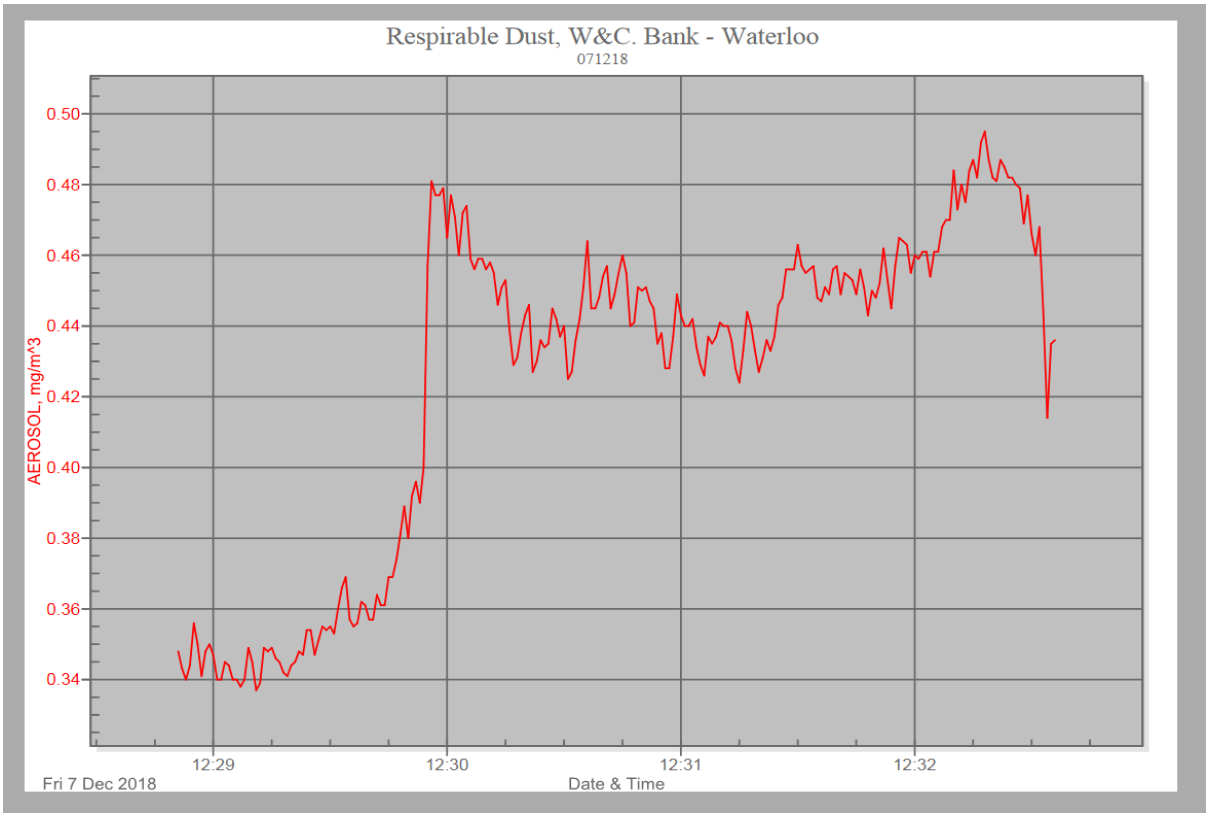
Appendix 6: Piccadilly Line, Wood Green – Earls Court



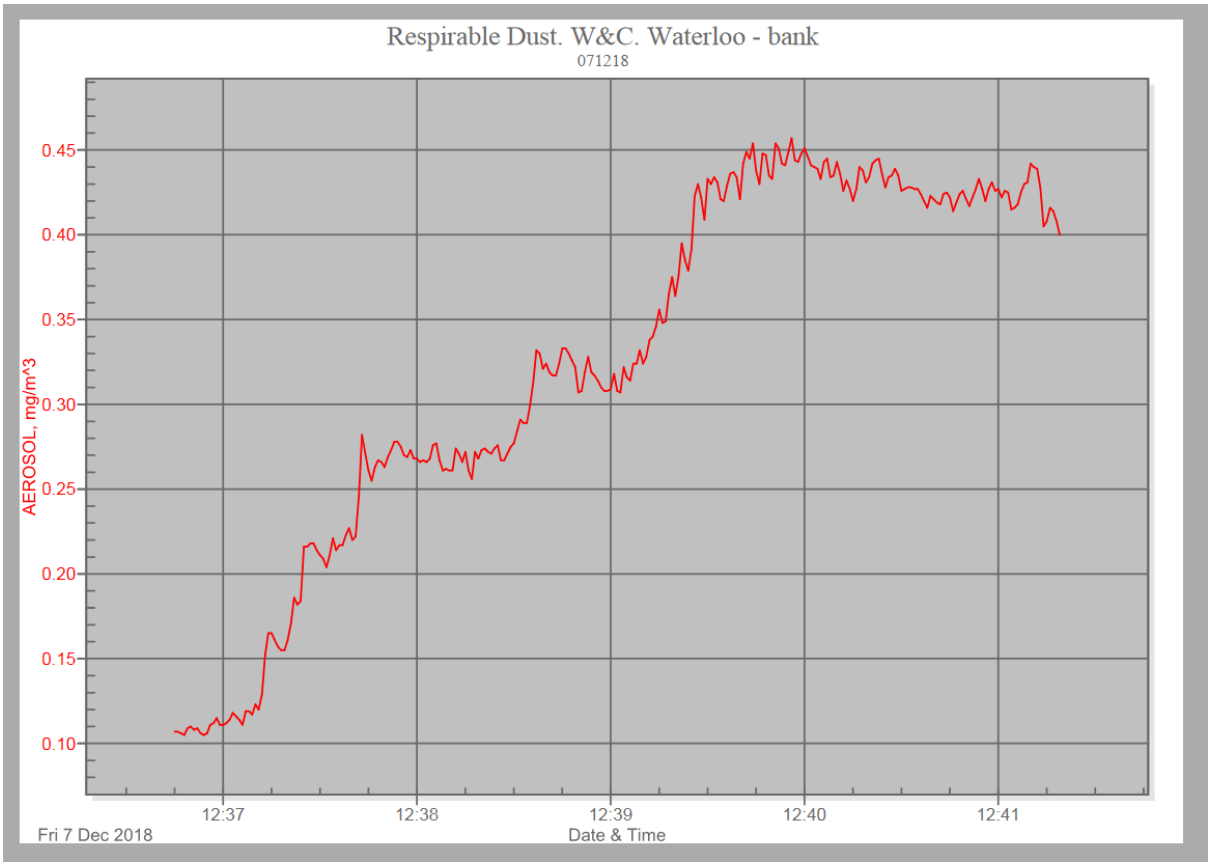
Appendix 7: Piccadilly Line, Earls Court – Wood Green



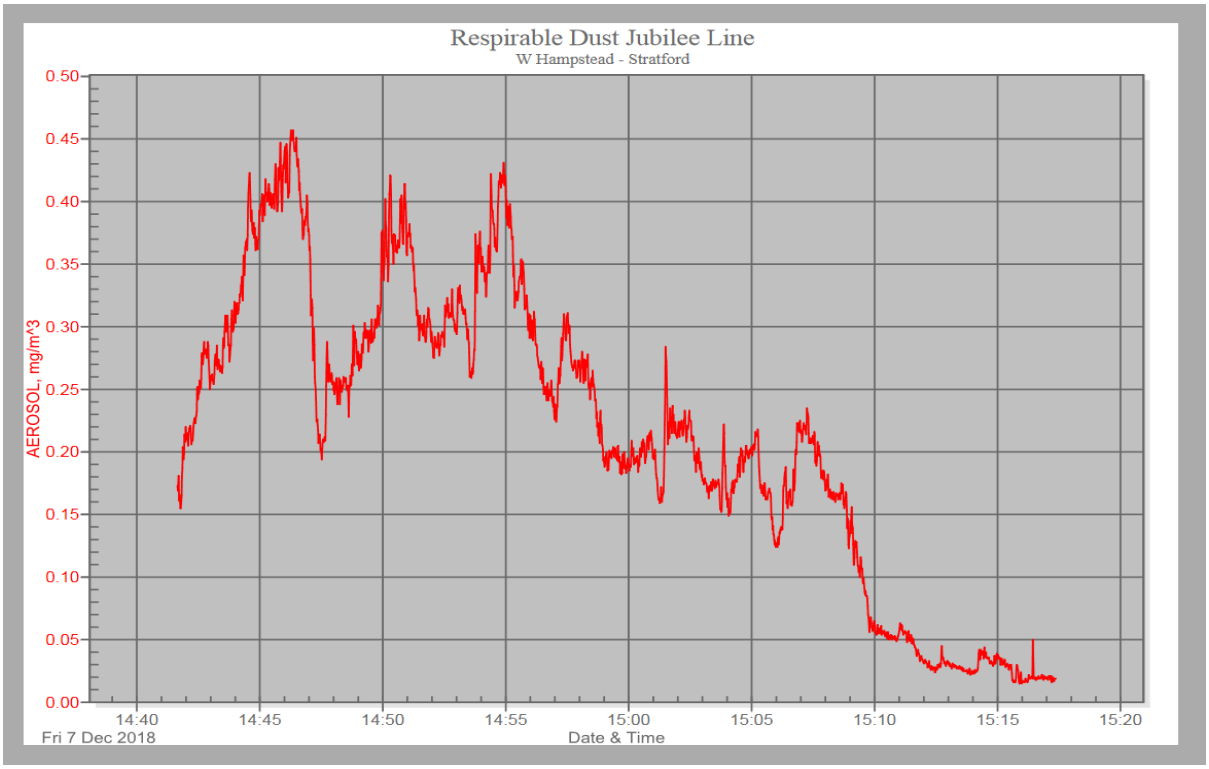
Appendix 8: Waterloo & City Line, Bank - Waterloo



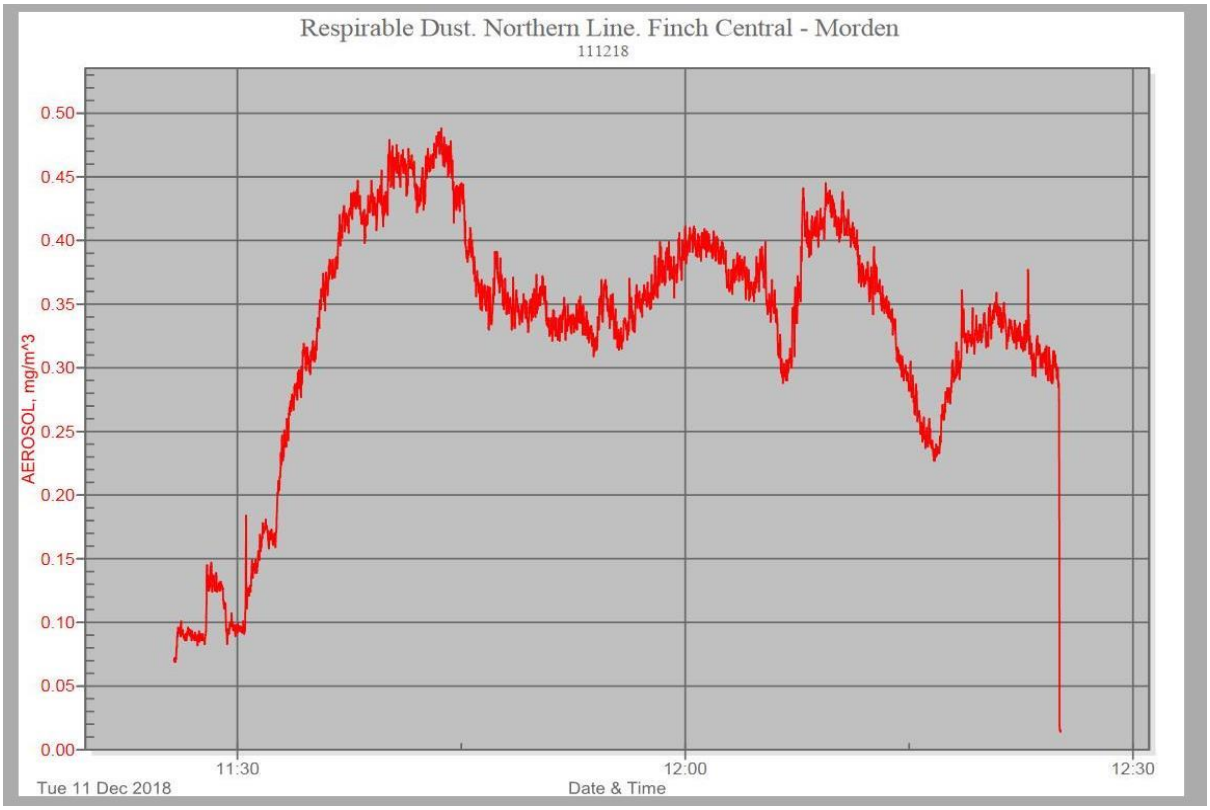
Appendix 9: Waterloo & City Line, Waterloo - Bank



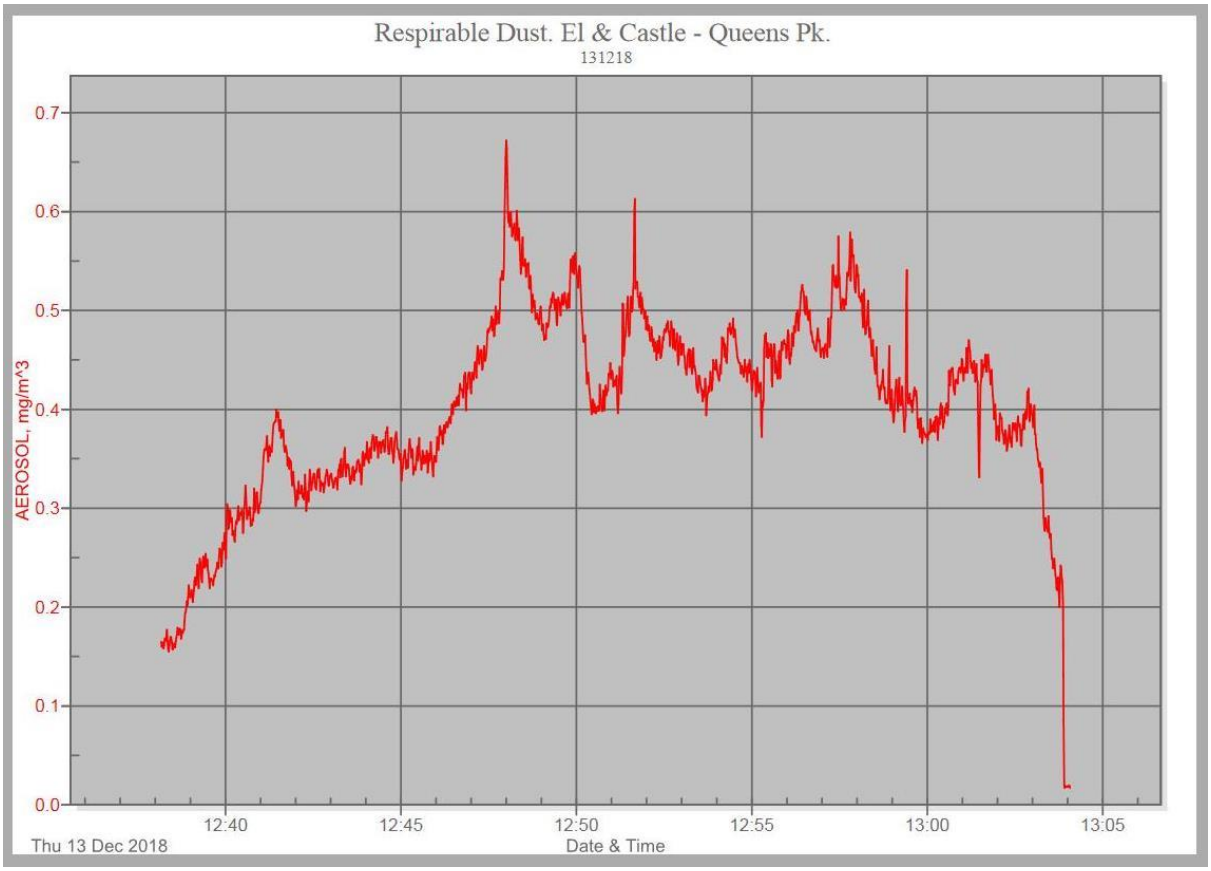
Appendix 10: Jubilee Line, West Hampstead - Stratford



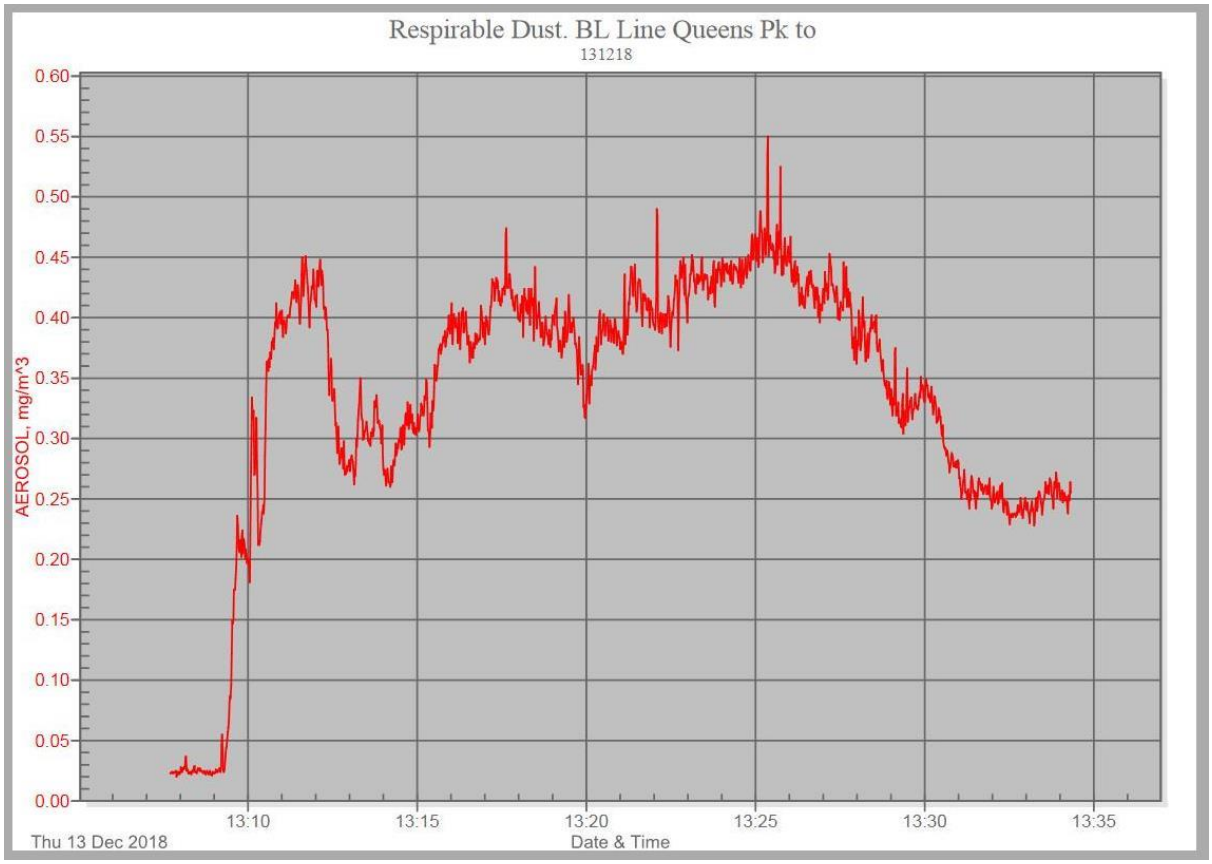
Appendix 11: Northern Line, Finchley Central - Morden



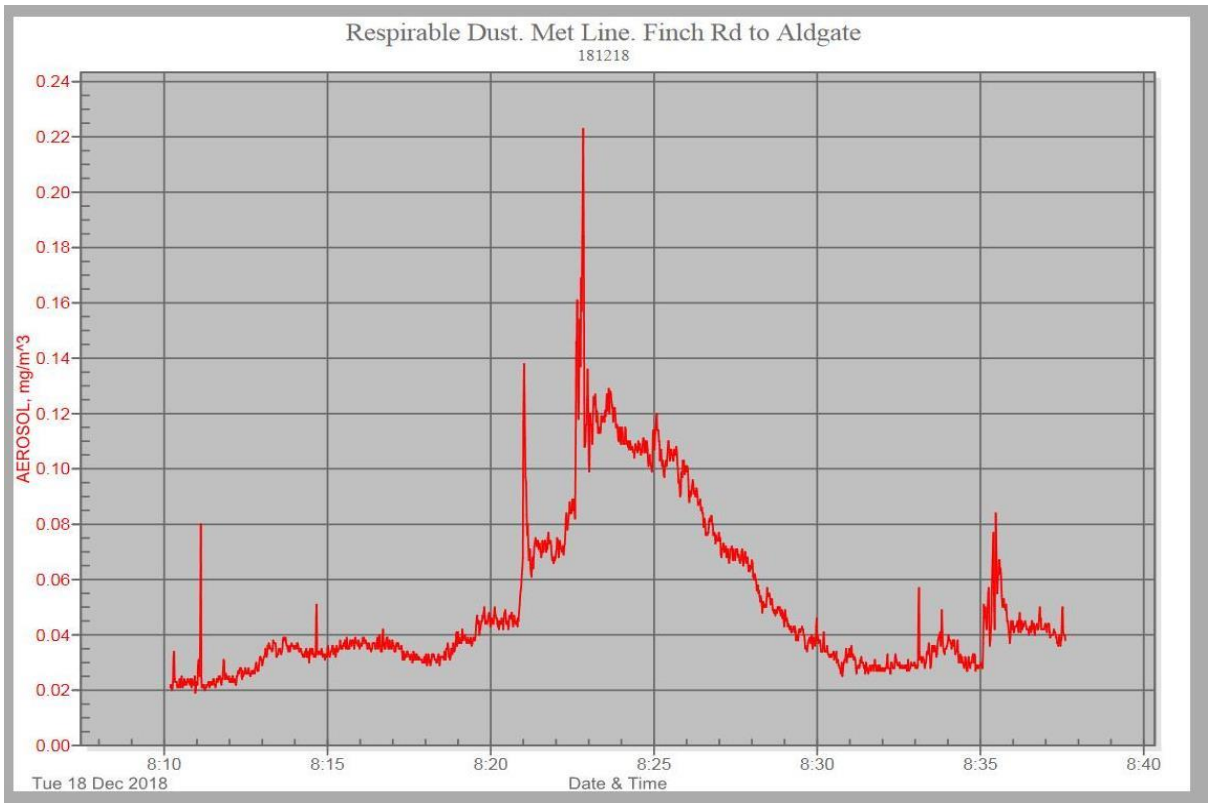
Appendix 12: Bakerloo Line, Elephant & Castle – Queens Park



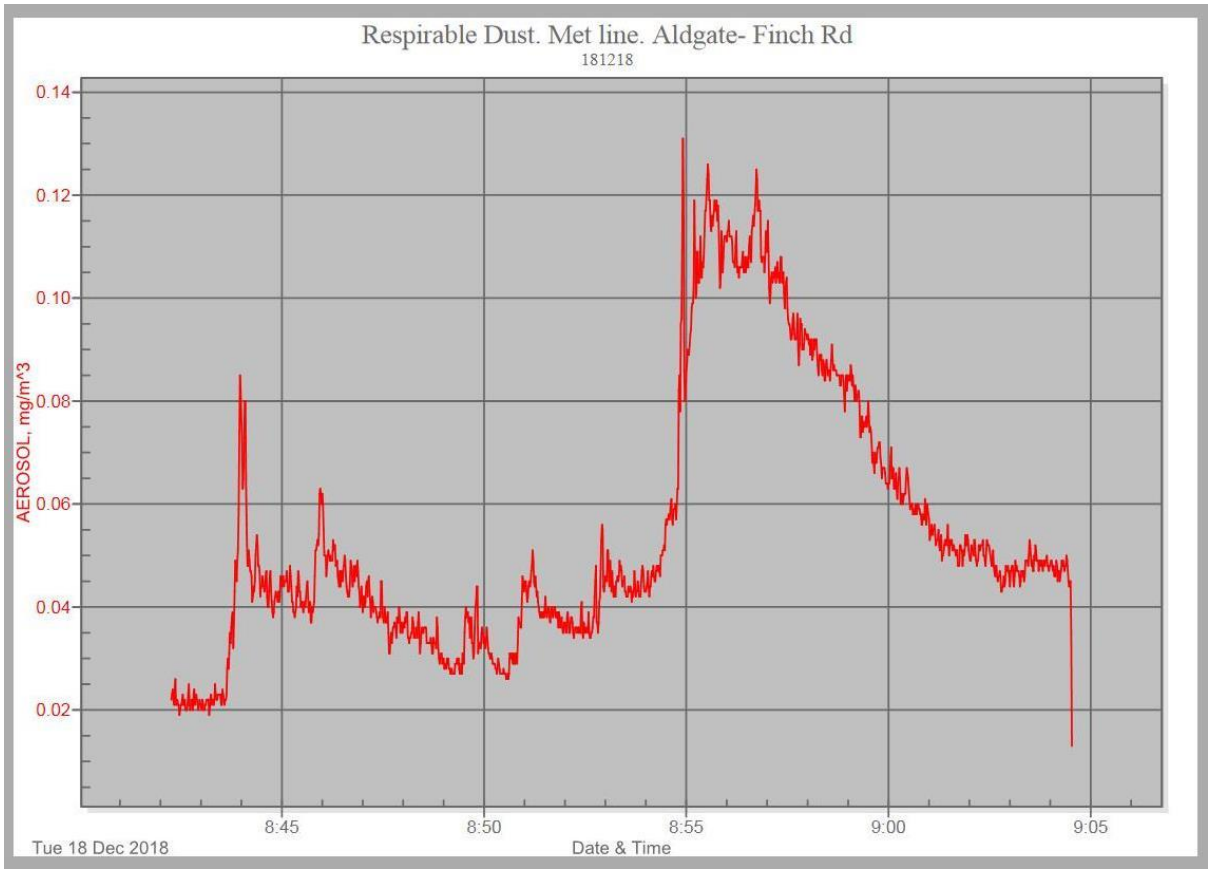
Appendix 13: Bakerloo Line, Queens Park – Elephant & Castle



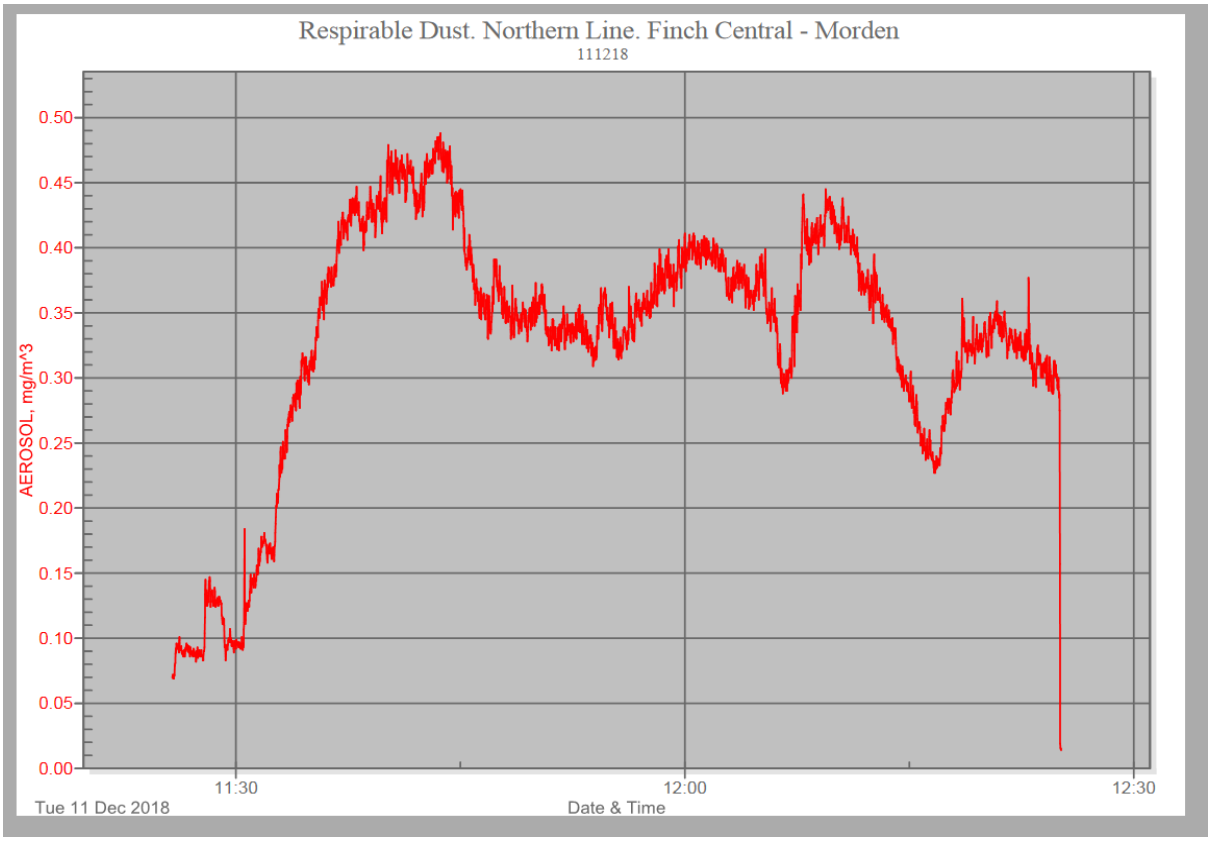
Appendix 14: Metropolitan Line, Finchley Road - Aldgate



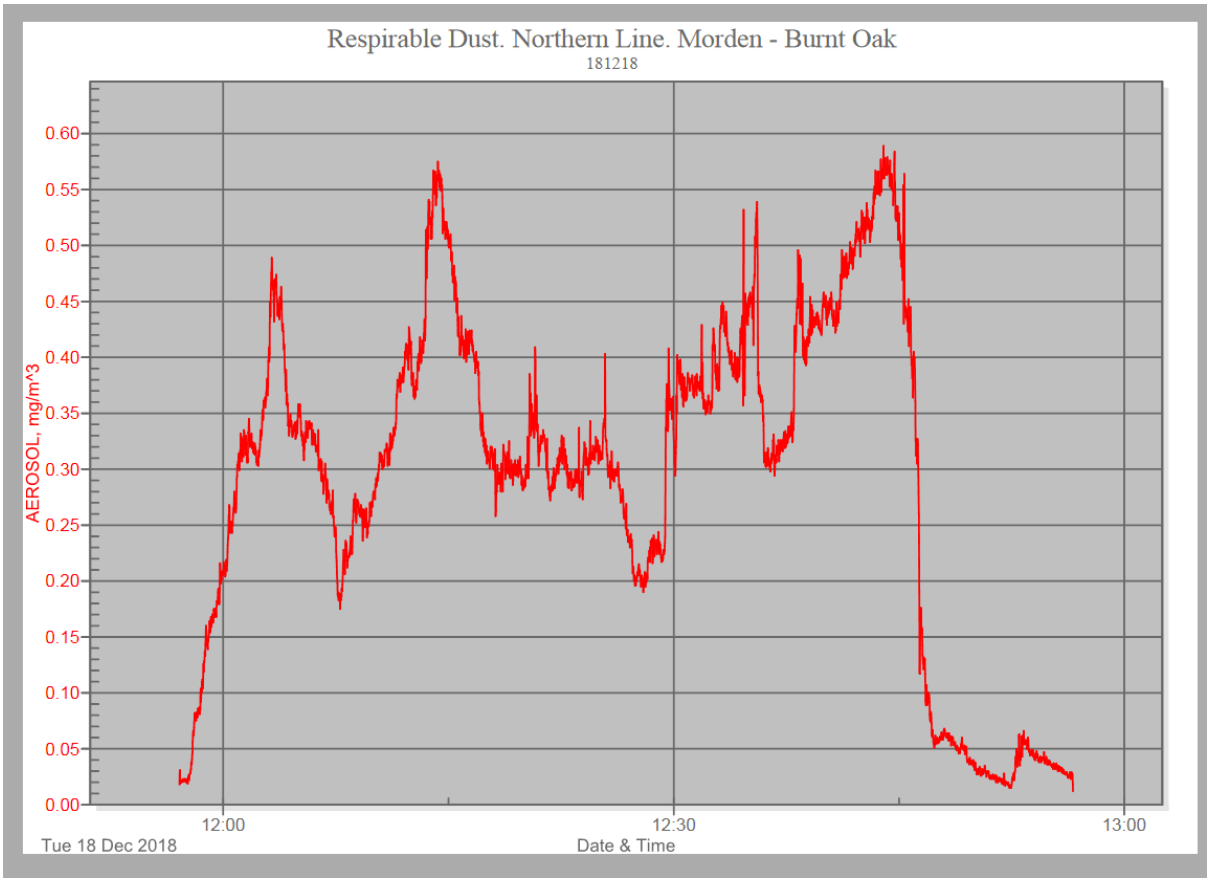
Appendix 15: Metropolitan Line, Aldgate – Finchley Road



Appendix 16: Northern Line, Finchley Central – Morden

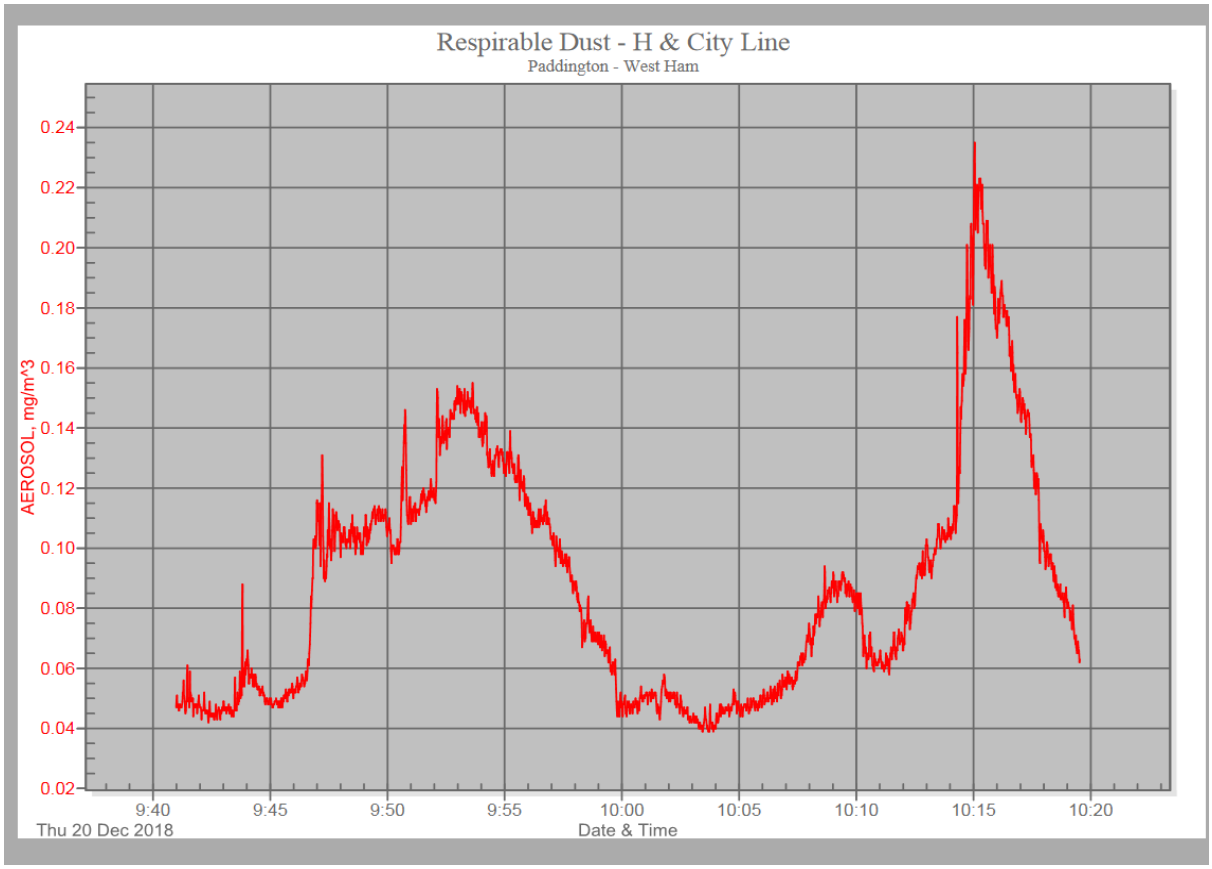


Appendix 17: Northern Line, Morden – Burnt Oak

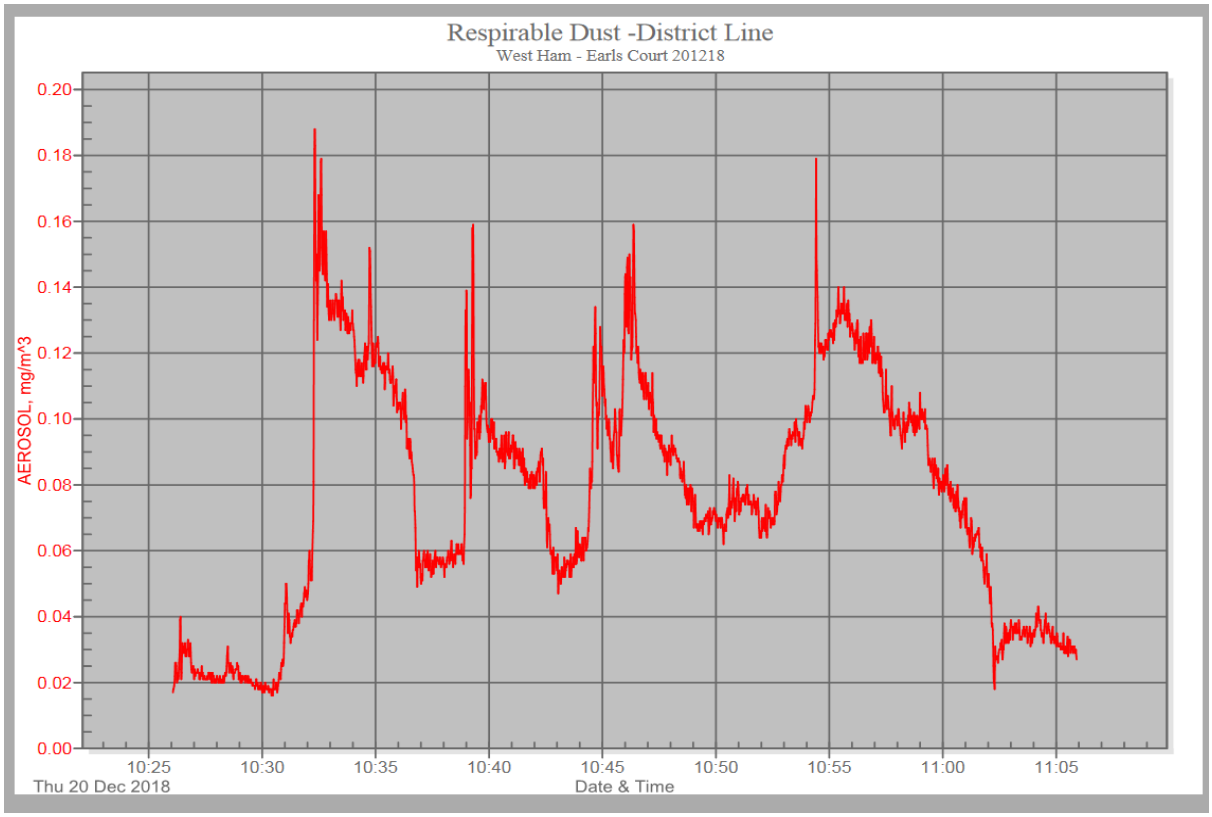


Appendix 18: Burnt Oak – Morden. Graph Not Available.

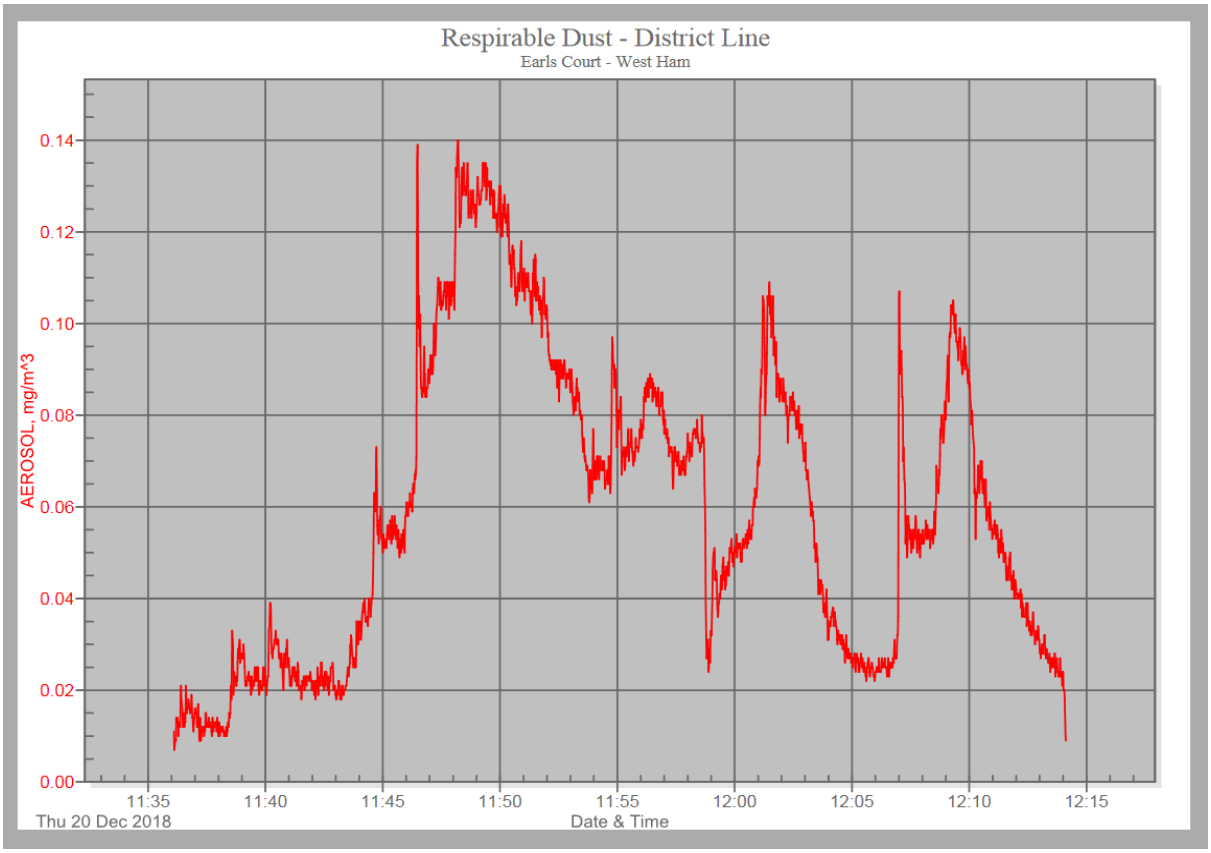
Appendix 19. Hammersmith and City Line, Paddington –West Ham



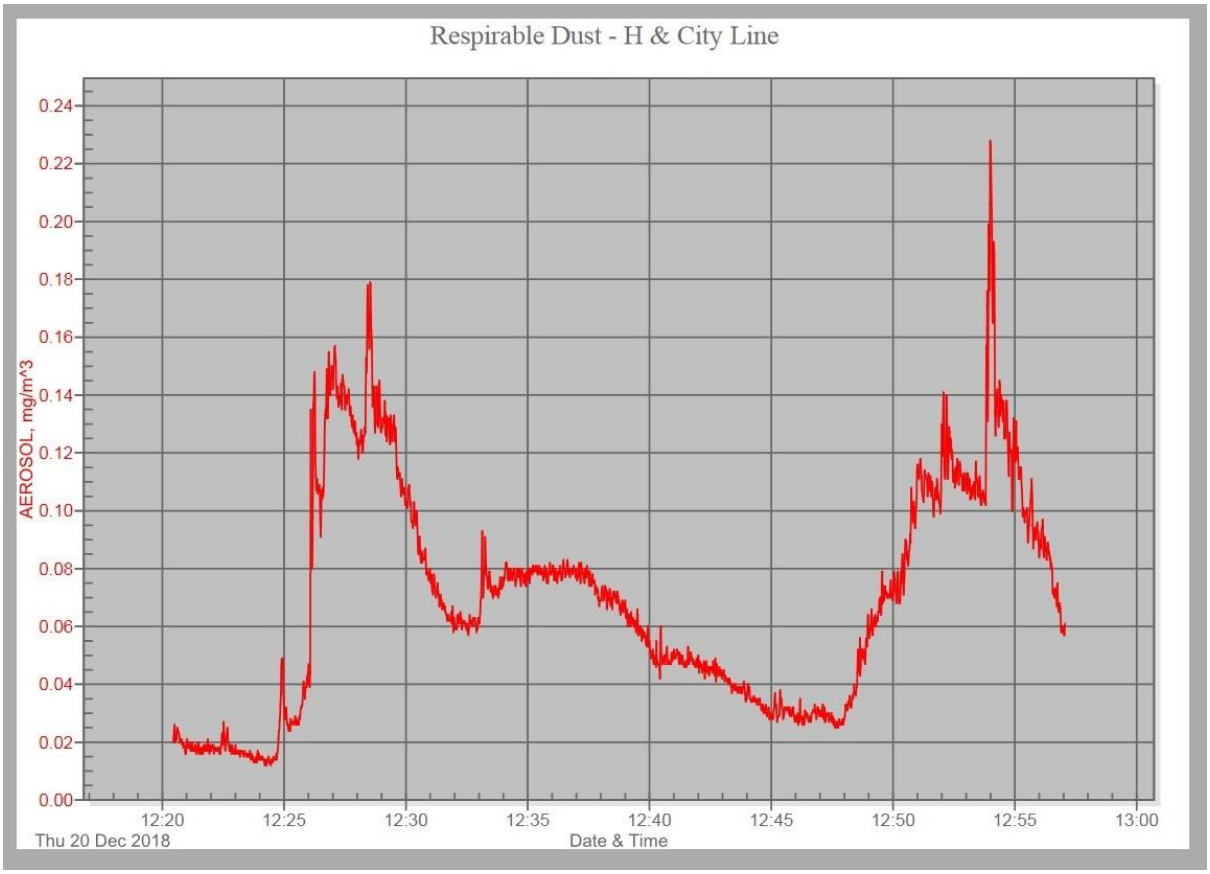
Appendix 20. District Line - West Ham – Earls Court



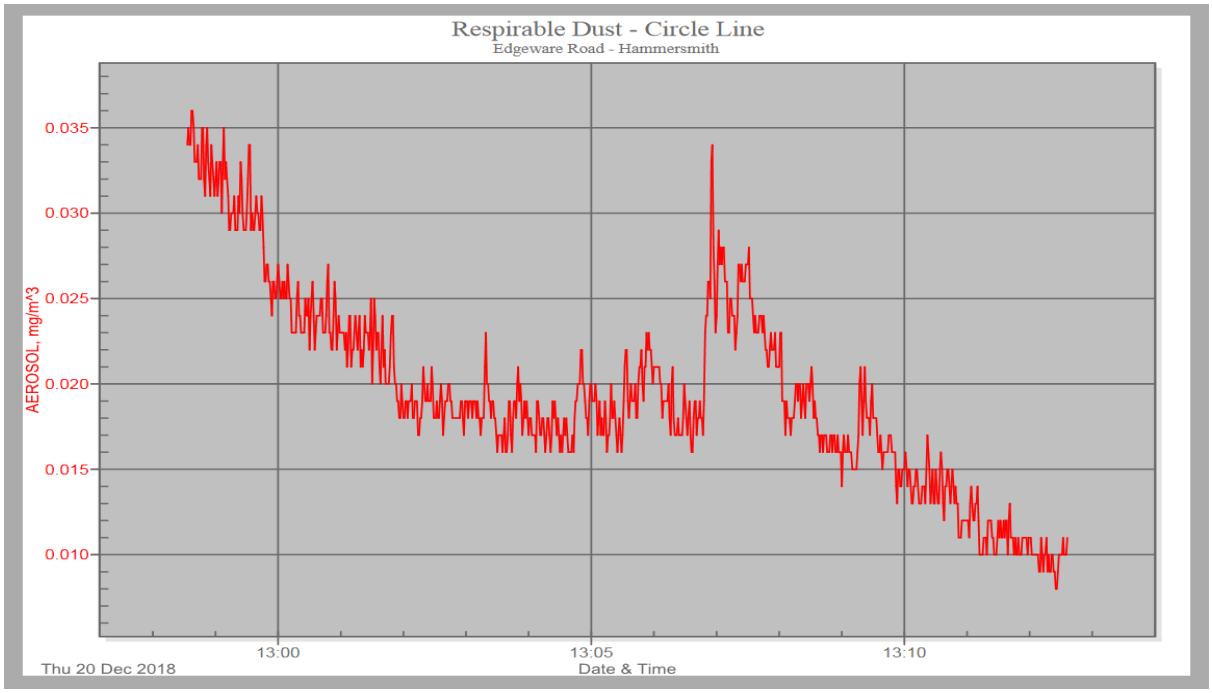
Appendix 21: District Line, Earls Court – West Ham



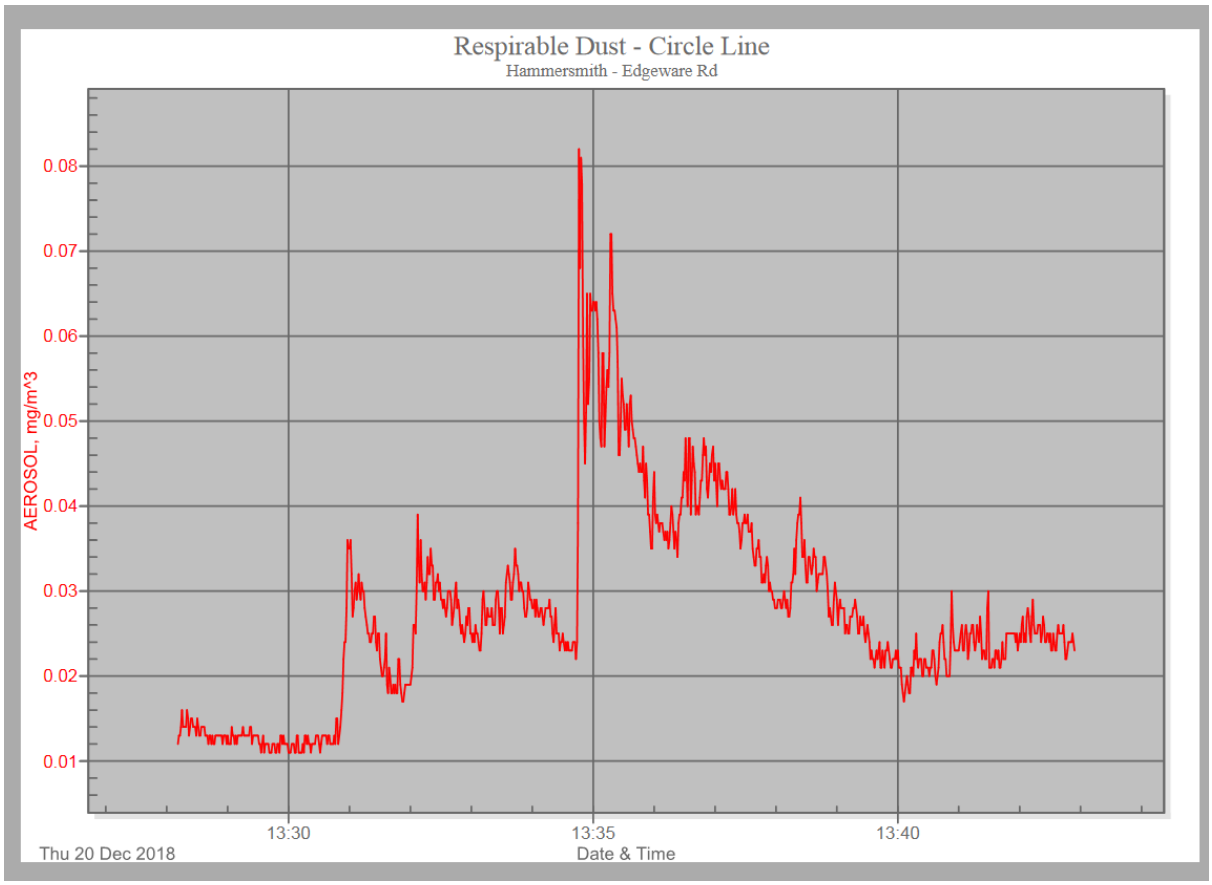
Appendix 22. Hammersmith & City Line, West Ham - Paddington



Appendix 23. Circle Line, Edgware Road - Hammersmith



Appendix 24: Circle Line, Hammersmith – Edgware Road



Appendix 25: Sampling Programme

Sample	Line	Start Location	Stop Location	Date
1	Central	Stratford	White City	03.12.18
2	Central	White City	Stratford	03.12.18
3	Victoria	Seven Sisters	Brixton	04.12.18
4	Victoria	Brixton	Seven Sisters	04.12.18
5	Jubilee	Stratford	West Hampstead	06.12.18
6	Piccadilly	Wood green	Earls Court	06.12.18
7	Piccadilly	Earls Court	Wood green	07.12.18
8	Waterloo & City	Bank	Waterloo	07.12.18
9	Waterloo & City	Waterloo	Bank	07.12.18
10	Jubilee	West Hampstead	Stratford	07.12.18
11	Northern	Finchley Central	Morden	11.12.18
12	Bakerloo	Elephant & Castle	Queens park	13.12.18
13	Bakerloo	Queens Park	Elephant & Castle	13.12.18
14	Metropolitan	Finchley Road	Aldgate	18.12.18
15	Metropolitan	Aldgate	Finchley Road	18.12.18
16	Northern	Finchley Central	Morden	18.12.18
17	Northern	Morden	Burnt Oak	18.12.18
18	Northern	Burnt Oak	Morden	18.12.18
19	H & City	Paddington	West Ham	20.12.18
20	District	West Ham	Earls Court	20.12.18

21	District	Earls Court	West Ham	20.12.18
22	H & City	West Ham	Paddington	20.12.18
23	Circle	Edgware Rd	Hammersmith	20.12.18
24	Circle	Hammersmith	Edgware Road	20.12.18

Appendix 26: Results Summary

Sample (see appendices for graphs)	Date	Start Time	Stop Time	**Average Conc (mg/m^3)**	Min Conc (mg/m^3)	Max Conc (mg/m^3)	Flow Rate Cal (lpm)	Filter head	Zero Cal before use	Sampler
1	03.12.18	12.18	12.54	**0.378**	0.028	0.660	3.0	PM 4	Yes	NJW
2	03.12.18	13.10	13.47	**0.534**	0.017	0.786	3.0	PM 4	Yes	NJW
3	04.12.18	11.22	11.48	**0.464**	0.280	1.00	3.01	PM 4	Yes	AL
4	04.12.18	11.51	12.15	**0.369**	0.067	0.640	3.01	PM 4	Yes	AL
5	06.12.18	11.50	12.25	**0.230**	0.012	0.418	3.00	PM 4	Yes	CM
6	06.12.18	14.14	14.49	**0.272**	0.048	1.01	3.00	PM 4	Yes	CM
7	07.12.18	10.40	11.19	**0.410**	0.213	0.642	3.01	PM4	Yes	CM
8	07.12.18	12.28	12.32	**0.425**	0.337	0.495	3.01	PM4	Yes	CM
9	07.12.18	12.36	12.40	**0.324**	0.105	0.457	3.00	PM4	Yes	CM
10	07.12.18	14.42	15.17	**0.213**	0.015	0.457	3.01	PM4	Yes	AL
11	11.12.18	11.25	12.26	**0.331**	0.014	0.488	3.01	PM4	Yes	AL
12	13.12.18	12.38	13.04	**0.401**	0.017	0.672	3.00	PM4	Yes	CM
13	13.12.18	13.08	13.34	**0.337**	0.020	0.550	3.00	PM4	Yes	CM
14	18.12.18	08.10	08.37	**0.051**	0.019	0.223	3.01	PM4	Yes	CM

15	18.12.18	08.42	09.04	**0.055**	0.013	0.131	3.01	PM4	Yes	CM
16	18.12.18	09.50	10.47	**0.305**	0.012	0.498	3.01	PM4	Yes	CM
17	18.12.18	11.57	12.57	**0.294**	0.012	0.589	3.01	PM4	Yes	CM
18	18.12.18	13.08	14.14	**0.303**	0.008	0.772	3.01	PM4	Yes	CM
19	20.12.18	09.41	10.19	**0.378**	0.031	0.660	3.00	PM4	Yes	CM
20	20.12.18	10.26	11.05	**0.077**	0.016	0.118	3.00	PM4	Yes	CM
21	20.12.18	11.36	12.14	**0.059**	0.007	0.140	3.01	PM4	Yes	CM
22	20.12.18	12.20	12.57	**0.069**	0.012	0.228	3.01	PM4	Yes	CM
23	20.12.18	12.58	13.12	**0.020**	0.008	0.036	3.01	PM4	Yes	CM
24	20.12.18	13.28	13.42	**0.028**	0.011	0.082	3.00			CM

References

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