



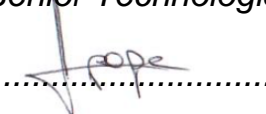
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**AIRBORNE DUST MONITORING DURING TRAIN OPERATOR
WORKING SHIFTS ON LONDON UNDERGROUND - ES12102**

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REPORT REVISION	ISSUE DATE	REVISION DETAILS
INITIAL	10 TH SEPTEMBER 2021	DRAFT FOR COMMENT
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Executive Summary

Dust monitoring was undertaken across eight London Underground (LU) railway lines and over the course of three journeys on each chosen line. The monitoring was undertaken between April and July 2021.

The results for the respirable dust fractions were compared against the Work Exposure Limits as given within Health and Safety document EH40/2005, 4th Edition 2020. All the results were below the 4 mg/m³ 8-hr time-weighted average concentration for respirable dust, and below the 10 mg/m³ 8-hr time-weighted average concentration for inhalable dust.

The subsequent further analysis for of the respirable samples for crystalline silica were also below the WEL of 0.1 mg/m³ 8-hr time-weighted average concentration.

The results from the monitoring programme showed that the levels of inhalable and respirable dust were below the HSE workplace exposure limits (EH40/50) of 10 mg/m³ and 4 mg/m³ over 8-hour TWA, throughout all the lines and during all the shifts.

The majority of the results obtained for the airborne dust concentrations in the inhalable, PM₁₀, respirable and PM_{2.5} were noted to differ from the expected general trend where the dust concentrations would decrease as the size fraction decreases. This is likely due to differences in the required sampling methodology, and variations within a statistical data set.

The metal content within the inhalable dust fraction analysed for Chromium and Hexavalent Chromium showed very low concentrations, below their relevant assigned WELs.

1. Introduction

1.1. At the request of Mr Nick Wilson, Occupational Hygienist – Transport for London, a dust monitoring programme was to be undertaken at twenty-four selected platforms and ticket halls across London Underground (LU) stations, and train operator monitoring within the cabs of eight London Underground train lines.

1.2. The scheduled dust monitoring sessions was to be undertaken in accordance with the scope specification document ES12102, version v3, 09.01.2020. 'London Underground Network: Occupational Exposures to dust monitoring and survey.' As follows:

- *To undertake monitoring in line with MDHS14/4 and HSG173, with exposure results being compared to those detailed within HSE document EH40, issue 4, Jan 2020, where applicable.*
- *To establish the work shift exposures to respirable dust for train operators for each underground line*
- *To establish the work shift exposures to respirable crystalline silica for train operators for each underground line*
- *To establish the work shift exposures to respirable dust for station staff across a sample of 24 stations*
- *To measure respirable dust levels at the platforms and gatelines of the sample group of stations*
- *To replicate each static station measurement and personal samples on train operators in PM 2.5 and PM 10 aerodynamic diameter fraction sizes*
- *To analyse 24 samples in inhalable fraction from the sample group of stations for their metallic content.*
- *To measure in real time (can use photo optical measurement device) the dust levels along each line in Respirable, PM 10 and PM 2.5 fractions.*
- *To produce a final report detailing the findings, broadly following the British occupational Hygiene Societies guidance on report writing.*

Undertake a programme of workplace sampling at London Underground Stations and in trains in accordance with the Health and Safety Executives (HSE) guidance on gravimetric sampling (MHDS 14/4).

1.2.1 Undertake Work shift exposure monitoring for the train operators (drivers) on the following lines

- *Victoria*
- *Piccadilly*
- *Central*
- *Northern*
- *Jubilee*
- *Bakerloo*
- *Circle*
- *District*

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The sampling for each line will involve at least 3 entire line runs (end to end) and will monitor the following:

- *Respirable Dust*
- *PM 2.5*
- *PM 10*
- *Respirable Crystalline Silica (to be analysed by the Institute of Occupational Medicine)*

1.2.2 Undertake real time monitoring of dust levels in train operators cabins. This work can be undertaken using photo optical equipment. The calibration test particulate density must be stated in the report and whether or not the results were corrected to take account of the high density of rail dusts.

1.2.3 Undertake static and personal monitoring at 12 London Underground stations

The Stations will include the following group. The number of anticipated sample points including one personal sample per station are detailed in brackets below:

Aldgate East (4)

Baker Street (8)

Elephant & Castle (7)

Euston Square (5)

Hampstead (4)

Kings Cross (11)

Oxford Circus (8)

Paddington (6)

Piccadilly Circus (6)

Tottenham Court Road (6)

Vauxhall (4)

Waterloo (8)

1.2.4 Undertake static and personal monitoring at an additional twelve stations from across the network. These will be selected by London Underground Management and Trade Unions for monitoring. It is anticipated all or most of these stations will be within the curtilage of the North and South Circular road system

The quote should assume:

- *74 Static sampling points to measure respirable, PM 2.5, PM 10 dust fractions*
- *12 Personal samples measuring respirable dust*
- *12 sample points on the deep tube (where applicable) to measure Inhalable dust and to analyse those for metal content (see section 3.1.5)*

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- *At least one personal sample in respirable fraction shall be taken at each station. The similarly exposed group of staff from which to sample are the Customer Service Assistants at each station*

1.2.5 Additionally a single inhalable sample will be taken at each station from a Platform on the deep tube lines. This sample will then be submitted for content analysis for comparison against the exposure limits published in the HSE document EH40/2005.

The sample will be analysed for the following substances:

- *Iron (in oxide form)*
- *Manganese*
- *Copper*
- *Zinc*
- *Chromium (all species)*
- *Chromium VI*
- *Nickel*
- *Arsenic*
- *Aluminium*

- 1.3. The station monitoring was undertaken in October and November 2020 and is reported in the 4-RAIL report reference 4RS-APO-202073-R685426.
- 1.4. This report cover the train operator's work shift exposure assessments which were undertaken between 21st April 2021 and 8th July 2021.
- 1.5. In line with the provided scope document, dust monitoring was carried out during three shifts on each of the right railway lines. Dust monitoring comprised of air sampling for respirable dust and inhalable dust as well as PM_{2.5} and PM₁₀ aerodynamic diameter fraction sizes. Additionally, a GRIMM laser scatter static dust monitor was employed to undertake measurements during tunnel section train journeys on the third shift scheduled for each London Underground tube line. The respirable dust fraction was further analysed for crystalline silica.
- 1.6. Due to an oversight during the station monitoring where the inhalable samples were not analysed for Chromium and Chromium VI, an additional inhalable sample was added to this monitoring to allow for this analysis to take place.

2. Technical Background

2.1. Airborne Dust in Occupational Health

2.1.1. The health effects from the inhalation of airborne dust are dependent upon the size, shape and composition of the particulates. In occupational health, airborne dust is classified as three fractions - inhalable, thoracic or respirable. Summary as follows:

- The inhalable fraction of dust is defined as particulates that can be inhaled and deposited throughout the respiratory tract, i.e. from the nasal to the alveolar region in the lungs, diameter size measuring up to 100µm.
- Thoracic dust is the fraction of inhaled airborne material penetrating beyond the larynx.

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- Respirable dust is the fraction of dust that are small enough to penetrate the deep lung, typically less than 4-5µm diameter size, and largely deposit in the alveolar region where gas exchange takes place.
- 2.1.2. The COSHH definition of a substance hazardous to health includes dust of any kind when present in air equal or greater than 10 mg/m³ 8-hr time-weighted average (TWA) for inhalable dust and 4 mg/m³ 8-hour TWA for respirable dust. A short-term 15-minute TWA exposure limits do not currently exist for airborne dust, but usually the short-term exposure limits are taken to be 3 times the long-term exposure limits.
- 2.1.3. Substances in Health and Safety Executive Document EH40/2005, 4th Edition 2020 Workplace Exposure Limits use the inhalable and respirable dust fractions.
- 2.1.4. Many metals have WELs in EH40/2005, 4th Edition 2020 as they can pose additional health risks. Therefore, the metal content in the inhalable dust samples are determined by laboratory analysis. Inhalable dust samples were taken during one selected train operator's shift on each of the eight tube lines monitored and the samples were then analysed for Chromium and Hexavalent Chromium, as these analytes were omitted due to oversight during dust monitoring exercise undertaken at selected London Underground stations.
- 2.1.5. The Workplace Exposure Limits for Chromium and Hexavalent Chromium are listed within table below (Table 1):

SUBSTANCE	LONG - TERM EXPOSURE LIMIT OF (8-HOUR TIME WEIGHTED AVERAGE) / MG.M ⁻³
Chromium	0.5
Chromium VI, compounds (as Cr)	0.01 0.025 (process generated)

Table 1. Workplace Exposure Limits from HSE EH40/05, 4th Edition, January 2020.

2.2. Particulate Matter

- 2.2.1. Particulate Matter (PM) is a mixture of micrometre sized solid and liquid particulates of various sizes and chemical composition. It is recognised as pollutant with an impact on human health.
- 2.2.2. There are two fractions of particular health interest due to their sizes. These dust fractions are defined by their diameters, with aerosol particulates having a diameter of less than 10µm, known as PM₁₀ and aerosol particulates with a diameter of less than 2.5µm, known as PM_{2.5}. Due to their size differences, PM₁₀ is known as the coarse fraction and PM_{2.5} is known as the fine fraction. While particulate matter is known to cause adverse effects to human health, they are not assessed using Workplace Exposure Limits.
- 2.2.3. Sources of PM vary based on location, with the source of PM in urban environments mainly from road traffic. Within the railway environment the particulate matter mainly originates from the train wheel and rail interface, braking activity, but may also be from cementitious sources. Studies to determine concentrations and compositions of the PM_{2.5} and PM₁₀ within the underground environment have noted that iron oxide is the most predominant at 47% of the overall composition (J.D. Smith et al., 2020).

3. Method

- 3.1. Airborne dust concentrations were monitored in accordance with 4-RAIL Services limited, UKAS accredited laboratory number 1931, in-house test procedure 4R-E206 Method for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols. On site monitoring and procedures are based on guidance given in Health & Safety Executive Document MDHS 14/4.
- 3.2. Sampling was carried out using pumps with different sampling heads to collect the different fractions of dust needed, as follows:
 - 3.2.1. PM_{2.5} – sampled using SKC Personal Environmental Monitor (PEM) PM_{2.5} impactor heads with glass fibre filters
 - 3.2.2. PM₁₀ – sampled using SKC Personal Environmental Monitor (PEM) PM_{2.5} impactor heads with glass fibre filters
 - 3.2.3. Respirable dust – sampled using cyclone heads with polyvinyl chloride (PVC) filters
 - 3.2.4. Inhalable dust – sampled using IOM Inhalable heads with PVC filters.
- 3.3. Examples of the PM_{2.5}, PM₁₀, IOM inhalable and respirable cyclone dust heads and air samplers used in this exercise are shown in Appendix 3.
- 3.4. The Train Operators monitoring was undertaken over three shifts on each of the nine London Underground tube lines. As well as personal dust exposure measurements, a GRIMM laser scatter static dust monitor was also used during one of the shifts to take continuous measurements of different size particles by the physical principle of orthogonal light scattering. For the current monitoring programme, the particles' diameter sizes chosen for measurement were PM 10 µm, 2.5 µm and 1 µm
- 3.5. The train operators duties and times, details of situations encountered during sampling are given in the table of results.
- 3.6. The inhalable samples were analysed for metal content by UKAS accredited laboratory, Institute of Occupational Medicine (IOM), accreditation no. 0374.

4. Analysis

- 4.1. The samples taken on site were returned to the laboratory where gravimetric analysis was undertaken in accordance with MDHS 14/4 & 4-RAIL Services in-house test procedure 4R-E206.
- 4.2. Following gravimetric analysis of the inhalable dust samples, the filters were submitted together with the site blanks to the Institute of Occupational Medicine (IOM) for quantitative analysis of metals. The respirable samples were also submitted for further analysis for crystalline silica by IOM.
- 4.3. The GRIMM laser scatter meter is factory calibrated to a synthetic dust comprising monodisperse 1µm latex and micro Dolomit DR80 polydisperse powder (0.2 – 80 µm).

5. Results & Discussion

The airborne respirable dust, inhalable dust, PM_{2.5} and PM₁₀ results for the train operator monitoring programme are shown in Appendix 1 - Tables 2 to 9.

The quantitative respirable crystalline silica results are given in Appendix 1, Table 10.

The quantitative metal concentrations for the inhalable samples are given in Appendix 1, Table 11.

- 5.1. The results from the monitoring programme showed that the levels of inhalable and respirable dust were below the HSE workplace exposure limits (EH40/50) of 10 mg/m³ and 4 mg/m³ over 8-hour TWA, throughout all the lines and during all the shifts. Details for each line monitored for dust concentrations within a train operator cab during his/her duty are given as follows:

- Victoria Line

The respirable dust exposure levels for the Victoria Line measured on the shifts of 21st, 22nd and 23rd April 2021 showed low dust concentrations varying between 0.22 and 0.43 mg/m³. The inhalable dust exposure level measured during shift of 22nd April 2021 showed a satisfactory dust concentration of 0.47 mg/m³.

- Bakerloo Line

The respirable dust exposure levels for the Bakerloo Line measured on the shifts of 28th, 29th and 30th April 2021 showed low dust concentrations varying between 0.30 and 0.44 mg/m³. The inhalable dust exposure level measured during shift of 29th April 2021 showed a satisfactory dust concentration of 0.53 mg/m³.

- Central Line

The respirable dust exposure levels for the Central Line measured on the shifts of 12th, 13th and 14th May 2021 showed low dust concentrations varying between 0.18 and 0.27 mg/m³. The inhalable dust exposure level measured during shift of 13th May 2021 showed a satisfactory dust concentration of 0.09 mg/m³. However, this result is considered to be anomalous, due to the value being significantly lower than the remainder of the dust fractions.

- Northern Line

The respirable dust exposure levels for the Northern Line measured on the shifts of 19th, 20th and 21st May 2021 showed low dust concentrations varying between 0.34 and 0.40 mg/m³. The inhalable dust exposure level measured during shift of 20th May 2021 showed a satisfactory dust concentration of 0.47 mg/m³.

- Hammersmith & City Line

The respirable dust exposure levels for the Hammersmith & City Line, measured on the shifts of 26th, 27th and 28th May 2021, showed dust concentrations varying between 0.04 and 0.058 mg/m³. The inhalable dust exposure level measured during shift of 27th May 2021 showed a satisfactory dust concentration of 0.06 mg/m³.

- District Line

The respirable dust exposure levels for the District Line measured on the shifts 9th, 10th and 11th June 2021, showed low dust concentrations varying between 0.03 and 0.05 mg/m³. The inhalable dust exposure level measured during shift of 10th June 2021 showed a satisfactory dust concentration of 0.04 mg/m³.

- **Piccadilly Line**

The respirable dust exposure levels for the Piccadilly Line measured on the shifts 30th June, 1st and 2nd July 2021 showed dust concentrations varying between 0.24 and 0.28 mg/m³. The inhalable dust exposure level measured during shift of 1st July 2021 showed a satisfactory dust concentration of 0.36 mg/m³.

- **Jubilee Line**

The respirable dust exposure levels for the Jubilee Line measured on the shifts 6th, 7th and 8th July 2021 showed dust concentrations varying between 0.12 and 0.14 mg/m³. The inhalable dust exposure level measured during shift of 7th July 2021 showed a satisfactory dust concentration of 0.14 mg/m³.

5.1.2 The measurements for various dust size particulate matter (PM₁₀, PM_{2.5} and PM₁), have been recorded using a scatter laser (GRIMM monitor) and the results are shown in graphs Figures 1 to 8, within Appendix 2. The highest peak observed, was during tunnel section journey between Arnos Grove and Barons Court on Piccadilly line.

5.2. **Particulate Matter – PM_{2.5} and PM₁₀**

The findings were assessed by comparing the various dust fractions concentrations during each tube line monitored. A general particulate size distribution would be classified as follows: the inhalable fraction of dust to include all particulates with size diameters of up to 100 µm, the respirable fraction to include all particulates with an average aerodynamic diameter of up to 4-5 µm, PM₁₀ to include all particulates with diameters of up to 10 µm and the PM_{2.5} to include all particulates with a diameter of up to 2.5 µm.

Therefore, a typical particle size distribution trend for the dust concentrations obtained from this current monitoring exercise would show the highest concentration for the inhalable fraction, followed by PM₁₀ concentrations, then respirable fraction and finally PM_{2.5} concentration. The findings of this trend and any deviations are detailed below for each tube line and summarised in the conclusion.

5.2.1. **Victoria Line**

The results for particulate matter were between 0.09 and 0.33 mg/m³ for PM_{2.5} and between 0.20 and 0.36 mg/m³ for PM₁₀.

The particulate size collection trend did not apply during 22nd April 2021 shift, duty 833. The PM₁₀ concentration was less than the respirable fraction and PM_{2.5} due to damaged filter.

5.2.2. **Bakerloo Line**

The results for particulate matter were between 0.19 and 0.34 mg/m³ for PM_{2.5} and between 0.54 and 0.69 mg/m³ for PM₁₀.

The particulate size collection trend generally applied during 29th April 2021 shift, duty 125. It was noted that the inhalable dust fraction concentration was slightly lower than the PM₁₀ concentration.

5.2.3. Central Line

The results for particulate matter were between 0.16 and 0.33 mg/m³ for PM_{2.5} and between 0.33 and 4.59 mg/m³ for PM₁₀.

The particulate size collection trend did not apply during 13th May 2021 shift, duty 824. There were significant deviations from the trend where PM₁₀ concentration was significantly greater than the concentrations for the respirable dust and PM_{2.5} fractions.

5.2.4. Northern Line

The results for particulate matter were between 0.04 and 0.38 mg/m³ for PM_{2.5} and between 0.09 and 1.00 mg/m³ for PM₁₀.

The particulate size collection trend did not apply during 20th May 2021 shift, duty 662. There was a slight deviation, where the PM₁₀ concentration was significantly higher than the concentration of the inhalable dust fraction.

5.2.5. Hammersmith & City Line

The results for particulate matter were between 0.05 and 0.17 mg/m³ for PM_{2.5} and between 0.56 and 1.05 mg/m³ for PM₁₀.

The particulate size collection trend did not apply during 27th May 2021 shift, duty 037. There was significant deviation between the concentration for the particulate matter fraction PM₁₀ and the concentrations for the inhalable, respirable and PM_{2.5} dust fraction sizes.

5.2.6. District Line

The results for particulate matter were between 0.03 and 0.14 mg/m³ for PM_{2.5} and between 0.26 and 0.48 mg/m³ for PM₁₀.

The particulate size collection trend did not apply during 10th June 2021 shift, duty 530. There was a slight deviation where the concentration for the particulate matter fraction PM₁₀ was greater than the concentration for the inhalable dust.

5.2.7. Piccadilly Line

The results for particulate matter were between 0.11 and 3.08 mg/m³ for PM_{2.5} and between 0.26 and 4.17 mg/m³ for PM₁₀.

The particulate size collection trend generally applied during 1st July 2021 shift, duty 427. There was significant deviation for the particulate matter fraction PM_{2.5} concentration, which was found significantly greater than the respirable, inhalable and PM₁₀ dust fraction concentrations.

5.2.8. Jubilee Line

The results for particulate matter were between 0.05 and 0.38 mg/m³ for PM_{2.5} and between 0.25 and 0.79 mg/m³ for PM₁₀.

The particulate size collection trend generally applied during 7th July 2021 shift, duty 672. There was a slight deviation where the concentration for the particulate matter fraction PM₁₀ was greater than the concentration for the inhalable dust

5.3. Inhalable dust fraction and metal content

The results for the inhalable dust fraction showed concentrations varying from 0.45 mg/m³ for the sample collected from District line train operator during duty 530, to 0.47 mg/m³ for the samples collected from Victoria and Northern line train operators during duties 838 and 662.

The particle size collection trend where inhalable dust would be greater than particulate matter PM₁₀ applied only for samples collected from Victoria and Piccadilly lines train operators during duties 838 and 427.

There was a significant deviation observed for the dust concentrations between the inhalable dust and the particulate matter PM₁₀ of 2.02 mg/m³ for the sample collected from Central line train operator during duty 824. This could be likely due to variations during sampling.

The results for all the personal samples collected during this exercise showed that the metal content concentrations were all generally low, below the applicable Workplace Exposure Limits (WELs):

- **Chromium** – all results were found below 0.001 mg/m³, below the WEL of 0.5 mg/m³;
- **Hexavalent Chromium** – all results were found below 0.001 mg/m³, below the WEL of 0.01 mg/m³.

5.4. Respirable Crystalline Silica Analysis

All of the respirable sample taken were further analysed for crystalline silica, and all were found to be below the WEL of 0.1 mg/m³.

6. Conclusions

- 6.1. The levels of airborne respirable dust during personal monitoring undertaken on train operators during their duties on the following tube lines: Victoria, Bakerloo, Central, Northern, Hammersmith & City, District, Piccadilly and Jubilee lines, were all below the WEL of 4 mg/m³ for respirable dust (long-term 8 hour time weighted average).
- 6.2. The respirable dust concentrations calculated following personal sampling on train operators during their shifts found that the highest value was for the samples collected from the train operators on the second shifts of Victoria Line and Northern Line. The lowest dust levels were for the samples collected from the train operators of sub-surface lines: District and Hammersmith & City Lines.
- 6.3. The results obtained from gravimetric analysis of particulate matter PM_{2.5} samples showed concentrations between 0.04 mg/m³ for the sample collected from Northern line train operator during duty 662 and 3.08 mg/m³ for the sample collected from Piccadilly line train operator during duty 415.
- 6.4. The results obtained from gravimetric analysis of particulate matter PM₁₀ samples showed concentrations varying between 0.20 mg/m³ for the sample collected from Victoria line train operator during duty 839 and 4.17 mg/m³ for the sample collected from Piccadilly line train operator during duty 415.
- 6.5. The results from the monitoring programme showed that the levels of inhalable dust were below the HSE workplace exposure limits (EH40/50) of 10 mg/m³ over 8-hour TWA, throughout all the lines and during all the shifts.
- 6.6. The results of the metal content of the inhalable dust concentrations were satisfactory, well below the assigned WELs for Chromium and Hexavalent Chromium.
- 6.7. Overall, the collective dust monitoring data showed the general particle size distribution trend applied to the samples collected during train operator journey on Bakerloo line, and broadly to other lines, although multiple deviations from the expected trend were identified as detailed within section 5. These deviations could be due to a number of factors, such as:
 - Sampling variations and general outliers within a statistical data set;
 - Possible impact of different filter types required to be used within the impactor heads, compared to the cyclone and IOM sampling heads;
- 6.8. Resampling should be considered where abnormal results were present, deviated from an expected data set.

7. References

HSE Document, EH40/2005 Workplace Exposure Limits (Fourth Edition, January 2020);

Control of Substances Hazardous to Health (COSHH) Regulations 2002 (as amended);

Health and Safety at Work Act 1974;

MDHS 14/4 – General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols;

J.D. Smith, B.M. Barratt, G.W. Fuller, F.J. Kelly, M. Loxham, E. Nicolosi, M. Prietsman, A.H. Tremper, D.C. Green (2020) PM_{2.5} on the London Underground.

Previous Trains and Stations monitoring, 4-RAIL Report Reference 4RS-APO-190189-R658226, February 2020.

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Appendix 1: Tables of Results

Table 2. Dust concentrations within train cabins during Train Operators duties - Victoria Line

FILTER NUMBER*	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/479	RD	LU TO – Duty 844 (AC1692188)	21/04/21	18:00	19:15	19:51	22:29	2.2	512.6	0.43	Train 266: BRX - WAL Train 224: WAL - BRX Train 222: BRX - WAL Train 242: WAL - BRX Train 236: BRX - WAL Train 214: WAL - BRX.
202073/481	PM2.5	4RS Analyst						2.0	466	0.18	
202073/482	PM10							2.0	466	0.27*	

*Note: Damaged filter during handling may have caused mass loss. Therefore, possibility of lower concentration.

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
202073/480	ID	LU TO – Duty 838 (AC1692188)	22/04/21	16:25	20:27	2.0	484	0.47	Train 275: BRX - WAL Train 213: WAL – BRX Train 222: BRX - WAL Train 242: WAL - BRX Train 223 (Shuttle): BRX - NPD - SVS - NPD.
202073/476	RD					2.2	532.4	0.22	
202073/477	PM2.5	4RS Analyst				2.0	484	0.33	
202073/478	PM10					2.0	484	0.20	

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Table 2. Dust concentrations within train cabins during Train Operators duties - Victoria Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/483	RD	LU TO – Duty 833 (AC1692188)	23/04/21	15:19	18:22	19:37	22:00	2.2	717.2	0.28	Train 215: BRX - WAL Train 211: WAL - BRX Train 2xx: BRX – WAL* Train 2xx: WAL – BRX* Train222: BRX - WAL Train 214: WAL - BRX. Train 276: BRX - WAL Train 270: WAL - BRX. Train 226: BRX - SVS.
202073/484	PM2.5	4RS Analyst						2.0	652	0.09	
202073/485	PM10							2.0	652	0.36	

*Note: Train numbers were not provided due to oversight during sampling.

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Table 3. Dust concentrations within train cabins during Train Operators duties - Bakerloo Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/486	RD	LU TO – Duty 122	28/04/21	09:11	10:41	13:05	16:49	2.2	690.8	0.44	Train 206: QPK N - ELE Train 225: ELE - QPK SG Train 225: QPK SG - ELE cancelled Train 213: QPK SG - ELE Train 226: ELE - SPD stabling road 43 Train 245: ELE - QPK N - ELE Train 204: ELE - QPK N.
202073/487	PM2.5	4RS Analyst						2.0	629.55	0.24	
202073/488	PM10							2.0	628	0.69	

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/489	RD	LU TO – Duty 125	29/04/21	10:39	14:06	15:20	15:54	2.2	530.2	0.30	Train 245: QPK N - HAW Train 245: HAW - ELE Train 225: ELE - SPK N Train 225: SPK S - ELE Train 203: ELE - QPK N Train operator would continue to HAW (approx. 20 mins) in open section.
202073/490	ID	4RS Analyst						2.0	482	0.53	
202073/491	PM2.5							2.0	481.1	0.19	
202073/492	PM10	2.0						481.1	0.54		

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 3. Dust concentrations within train cabins during Train Operators duties - Bakerloo Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
202073/493	RD	LU TO – Duty 125	30/04/21	10:43	14:04	2.2	442.2	0.31	Train 245: QPK N - HAW Train 245: HAW - ELE Train 225: ELE - SPK N Train 225: SPK S - ELE Train operator would have meal relief between 14:05-15:17, then Train 203: ELE - HAW.
202073/494	PM2.5	4RS Analyst				2.0	402	0.34	
202073/495	PM10					2.0	402	0.63	

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 4. Dust concentrations within train cabins during Train Operators duties - Central Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/496	RD	LU TO – Duty 831	12/05/21	15:44	16:57	18:21	21:27	2.2	569.8	0.25	Train 023: White City – North Acton - Hainault Travel to Leytonstone Train 105: Leytonstone - Ealing Broadway - Hainault - White City.
202073/497	PM2.5	4RS Analyst						2.0	518	0.33	
202073/498	PM10							2.0	518	0.33	

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/499	ID	LU TO – Duty 824	13/05/21	14:15	17:42	19:23	21:15	2.0	638	0.09	Train 023: White City - West Ruislip - Epping - West Ruislip Travel to White City Train 120: White City - Hainault - White City.
202073/500	RD							2.2	701.8	0.18	
202073/501	PM2.5	4RS Analyst						2.0	638	0.16	
202073/502	PM10							2.0	638	2.11*	

*Note: Anomalous results obtained for inhalable dust and PM10 dust fraction air samples

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 4. Dust concentrations within train cabins during Train Operators duties - Central Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
202073/503	RD	LU TO – Duty 827	14/05/21	18:34	20:52	2.2	303.6	0.27	Train 005 cancelled. Travel to West Ruislip Train 017: West Ruislip - Epping Train 016: Hainault - White City.
202073/504	PM2.5	4RS Analyst				2.0	276	0.29	
202073/505	PM10					2.0	276	4.59*	

*Note: Anomalous result obtained for the PM10 dust fraction air sample. Low volumes of air samples during this shift were due to train cancellation.

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 5. Dust concentrations within train cabins during Train Operators duties - Northern Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/506	RD	LU TO – Duty 662	19/05/21	14:15	16:36	17:25	21:01	2.2	785.4	0.40	Train 013: Morden - Edgware (via Bank) - Morden (via Bank) Train 060: Morden - Edgware (via Bank) - Kennington (via Charing Cross) - High Barnet (via Charing Cross) - Morden (via Bank). Air samplers switched off at Stockwell station.
202073/507	PM2.5	4RS Analyst						2.0	714	0.04	
202073/508	PM10							2.0	714	0.09*	

*Note: Anomalous result obtained for the PM10 dust fraction air sample.

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/509	ID	LU TO – Duty 662	20/05/21	14:16	16:37	17:25	20:36	2.0	664	0.47	Train 013: Morden - Edgware (via Bank) - Morden (via Bank) Train 060: Morden - Edgware (via Bank) - Kennington (via Charing Cross) - High Barnet (via Charing Cross) - Morden (via Bank). Air samplers switched off at Euston station.
202073/510	RD	4RS Analyst						2.2	730.4	0.38	
202073/511	PM2.5							2.0	664	0.31	
202073/512	PM10	2.0						664	1.00		

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 5. Dust concentrations within train cabins during Train Operators duties - Northern Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/513	RD	LU TO – Duty 661	21/05/21	14:27	17:05	18:27	22:11	2.2	840.4	0.34	Train 145: Morden - High Barnet (via Bank) - Kennington (via Charing Cross) - High Barnet (via Charing Cross) Train 131: High Barnet - Morden (via Bank). Train 023: Morden - Edgware (via Bank) - Morden (via Bank).
202073/514	PM2.5	4RS Analyst						2.0	764	0.30	
202073/515	PM10							2.0	764	0.91	

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 6. Dust concentrations within train cabins during Train Operators duties – Hammersmith & City Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/516	RD	LU TO – Duty 034	26/05/21	16:11	18:51	19:43	22:23	2.2	704	0.04	Train 273: Edgware Road - Barking – Hammersmith - Edgware Road Train 265: Edgware Road - Hammersmith - Barking - Hammersmith.
202073/517	PM2.5	4RS Analyst						2.0	640	0.17	
202073/518	PM10							2.0	640	0.56	

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
202073/519	ID	LU TO – Duty 037	27/05/21	15:58	19:21	2.0	406	0.06	Train 276: Edgware Road - Hammersmith - Barking - Hammersmith - Edgware Road.
202073/520	RD					2.2	446.6	0.07	
202073/521	PM2.5	4RS Analyst				2.0	406	0.13	
202073/522	PM10					2.0	406	1.05*	

*Note: Anomalous result obtained for the PM10 dust fraction air sample.

Table 6. Dust concentrations within train cabins during Train Operators duties – Hammersmith & City Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/523	RD	LU TO – Duty 028	28/05/21	14:09	16:37	17:55	20:15	2.2	633.6	0.05	Train 263: Edgware Road - Hammersmith - Barking - Edgware Road. Train 217 (Circle line): Edgware Road ('Outer Rail') - Edgware Road ('Inner Rail') - Hammersmith.
202073/524	PM2.5	4RS Analyst						2.0	576	0.05	
202073/525	PM10							2.0	576	0.75	

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 7. Dust concentrations within train cabins during Train Operators duties – District Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/526	RD	LU TO – Duty 506	09/06/21	05:43	09:01	10:11	13:04	2.2	816.2	0.05	Train 204: Upminster - Richmond - Upminster. Train 006: Upminster - Richmond - Barking.
202073/527	PM2.5	4RS Analyst						2.0	742	0.14	
202073/528	PM10							2.0	742	0.48	

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/529	ID	LU TO – Duty 530	10/06/21	07:25	10:20	11:23	13:06	2.0	556	0.04	Train 012: Upminster - Wimbledon - Barking. Train 020: Barking - Upminster - Hammersmith.
202073/530	RD	4RS Analyst						2.2	611.6	0.03	
202073/531	PM2.5							2.0	556	0.03*	
202073/532	PM10							2.0	556	0.26	

* Note: The filter was noted damaged during weighing back. As such, the result obtained for the respirable dust fraction is indicative only.

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 7. Dust concentrations within train cabins during Train Operators duties – District Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
202073/533	RD	LU TO – Duty 528	11/06/21	07:07	11:10	2.2	534.6	0.04	Train 060: Upminster - Wimbledon - Barking. Signal failure at Aldgate East caused a 90-minute delay. Train 060 held at Tower Hill. At 11:04 the train is taken out of service.
202073/534	PM2.5	4RS Analyst				2.0	486	0.11	
202073/535	PM10					2.0	486	0.26	

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 8. Dust concentrations within train cabins during Train Operators duties – Piccadilly Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/536	RD	LU TO – Duty 415	30/06/21	08:11	09:14	10:26	12:24	2.2	398.2	0.28*	Train 362: Arnos Grove - Northfields. Train 305: Northfields - Heathrow Terminal 5 - Arnos Grove.
202073/537	PM2.5	4RS Analyst						2.0	362	3.08	
202073/538	PM10							2.0	362	4.17	

*Note: Anomalous result obtained for the respirable dust fraction air sample.

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/539	ID	LU TO – Duty 427	01/07/21	10:16	11:32	12:45	16:05	2.0	552	0.36	Train 221: Arnos Grove - Cockfosters - Acton Town. Train 353: Acton Town - Northfields - Arnos Grove - Northfields - Acton Town.
202073/540	RD	4RS Analyst						2.2	607.2	0.25	
202073/541	PM2.5							2.0	552	0.98*	
202073/542	PM10	2.0						552	0.28		

*Note: Anomalous result obtained for the PM2.5 dust fraction air sample.

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 8. Dust concentrations within train cabins during Train Operators duties – Piccadilly Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/543	RD	LU TO – Duty 416	02/07/21	08:05	11:50	13:06	15:10	2.2	767.8	0.24	Train 334: Cockfosters - Rayners Lane - Wood Green (changed destination) - Acton Town. Train 253: Acton Town – Rayners Lane - Arnos Grove.
202073/544	PM2.5	4RS Analyst						2.0	698	1.09*	
202073/545	PM10							2.0	698	0.78	

*Note: Anomalous result obtained for the PM2.5 dust fraction air sample.

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 9. Dust concentrations within train cabins during Train Operators duties – Jubilee Line

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/546	RD	LU TO – Duty 675	06/07/21	17:35	21:00	22:18	23:22	2.2	591.8	0.12	Train 306: Wembley Park - Stratford. Train 356: Stratford - Stanmore - Stratford. Train 307: Stratford - Willesden Green - Stratford. Air samplers switched off at Green Park station.
202073/547	PM2.5	4RS Analyst						2.0	538	0.38	
202073/548	PM10							2.0	538	0.79	

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/549	ID	LU TO – Duty 672	07/07/21	17:05	18:23	22:05	00:15	2.0	416	0.14	Train 306: Wembley Park - Stanmore - Stratford. Train 320 was cancelled. Train 331: Wembley Park - Stanmore - Stratford. Train 330: Stratford - Wembley Park.
202073/550	RD	4RS Analyst						2.2	457.6	0.12	
202073/551	PM2.5							2.0	416	0.05	
202073/552	PM10							2.0	416	0.25	

Table 9. Dust concentrations within train cabins during Train Operators duties – Jubilee Line (continued)

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	START TIME	BREAKS IN SAMPLING		FINISH TIME	FLOW RATE (l/min)	VOLUME OF AIR (litres)	CALC. DUST CONC ^N (MG/M ³)	ROUTE COVERED
					TIME OFF	TIME ON					
202073/553	RD	LU TO – Duty 678	08/07/21	18:03	19:17	21:18	00:12	2.2	545.6	0.12	Train 340: Wembley Park - Stanmore - West Ham. Train 331: Stratford - Stanmore - Stratford - Wembley Park.
202073/554	PM2.5	4RS Analyst						2.0	496	0.21	
202073/555	PM10							2.0	496	0.32	

AIRBORNE DUST MONITORING DURING TRAIN OPERATOR WORKING SHIFTS ON LONDON UNDERGROUND – ES12102

Table 10. Dust concentrations within train cabins during Train Operators duties – Respirable Silica

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	VOLUME OF AIR (litres)	DUST CONC. (mg/m ³)	QUARTZ (mg/filter)	QUARTZ CONC. (mg/m ³)	QUARTZ CONC. 8-HR TWA (mg/m ³)
202073/476	RD	LU TO – Duty 844	22.04.21	512.6	0.22	< 0.01	< 0.020	< 0.009
202073/479	RD	LU TO – Duty 844	21.04.21	532.4	0.43	< 0.01	< 0.019	< 0.009
202073/483	RD	LU TO – Duty 833	23.04.21	717.2	0.28	< 0.01	0.014	0.009
202073/486	RD	LU TO – Duty 122	28.04.21	690.8	0.44	0.01	< 0.019	<0.009
202073/489	RD	LU TO – Duty 125	29.04.21	530.2	0.30	< 0.01	< 0.019	<0.009
202073/493	RD	LU TO – Duty 125	30.04.21	442.2	0.31	< 0.01	< 0.023	< 0.009
202073/496	RD	LU TO – Duty 831	12.05.21	569.8	0.25	< 0.01	< 0.018	< 0.009
202073/500	RD	LU TO – Duty 824	13.05.21	701.8	0.18	< 0.01	< 0.014	< 0.009
202073/503	RD	LU TO – Duty 827	14.05.21	303.6	0.27	< 0.01	< 0.033	< 0.009
202073/506	RD	LU TO – Duty 662	19.05.21	785.4	0.40	0.01	0.013	0.009
202073/510	RD	LU TO – Duty 662	20.05.21	730.4	0.38	0.01	0.014	0.009
202073/513	RD	LU TO – Duty 661	21.05.21	840.4	0.34	0.01	0.012	0.009

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FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	VOLUME OF AIR (litres)	DUST CONC. (mg/m ³)	QUARTZ (mg/filter)	QUARTZ CONC. (mg/m ³)	QUARTZ CONC. 8-HR TWA (mg/m ³)
202073/516	RD	LU TO – Duty 034	26.05.21	704	0.04	< 0.01	< 0.014	< 0.009
202073/520	RD	LU TO – Duty 037	27.05.21	446.6	0.07	< 0.01	< 0.022	< 0.009
202073/523	RD	LU TO – Duty 028	28.05.21	633.6	0.05	< 0.01	< 0.016	< 0.009
202073/526	RD	LU TO – Duty 506	09.06.21	816.2	0.05	< 0.01	< 0.012	< 0.009
202073/530	RD	LU TO – Duty 508	10.06.21	611.6	0.03	< 0.01	< 0.016	< 0.009
202073/533	RD	LU TO – Duty 528	11.06.21	534.6	0.04	< 0.01	< 0.019	< 0.009
202073/536	RD	LU TO – Duty 415	30.06.21	398.2	0.28	< 0.01	< 0.025	< 0.009
202073/540	RD	LU TO – Duty 427	01.07.21	607.2	0.25	< 0.01	< 0.016	< 0.009
202073/543	RD	LU TO – Duty 416	02.07.21	767.8	0.24	< 0.01	< 0.013	< 0.009
202073/546	RD	LU TO – Duty 675	06.07.21	591.8	0.12	< 0.01	< 0.017	< 0.009
202073/550	RD	LU TO – Duty 672	07.07.21	457.6	0.12	< 0.01	< 0.022	< 0.009
202073/553	RD	LU TO – Duty 678	08.07.21	545.6	0.12	< 0.01	< 0.018	< 0.009

Table 11. Inhalable dust fraction – Chromium and Hexavalent Chromium Quantitative Analysis

FILTER NUMBER	SAMPLE TYPE (RESPIRABLE DUST, RD, INHALABLE DUST, ID)	SAMPLE LOCATION	DATE	VOLUME OF AIR (litres)	DUST CONC. (mg/m ³)	CHROMIUM (MG/FILTER)	CHROMIUM CONC. (mg/m ³)	HEXAVALENT CHROMIUM (MG/FILTER)	HEXAVALENT CHROMIUM CONC. (mg/m ³)
202073/480	ID	LU TO – Duty 838	22.04.21	484	0.47	< 0.6	< 0.001	< 0.25	< 0.001
202073/490	ID	LU TO – Duty 838	29.04.21	482	0.53	< 0.6	< 0.001	< 0.25	< 0.001
202073/499	ID	LU TO – Duty 838	13.05.21	638	0.09	< 0.6	< 0.001	< 0.25	< 0.001
202073/509	ID	LU TO – Duty 838	20.05.21	664	0.47	< 0.6	< 0.001	< 0.25	< 0.001
202073/519	ID	LU TO – Duty 838	27.05.21	406	0.06	< 0.6	< 0.001	< 0.25	< 0.001
202073/529	ID	LU TO – Duty 838	10.06.21	556	0.04	< 0.6	< 0.001	< 0.25	< 0.001
202073/539	ID	LU TO – Duty 838	01.07.21	552	0.36	< 0.6	< 0.001	< 0.25	< 0.001
202073/549	ID	LU TO – Duty 838	07.07.21	416	0.14	< 0.6	< 0.001	< 0.25	< 0.001

Appendix 2: GRIMM Real Time Data Results

Figure 1. GRIMM monitoring data – Victoria Line.

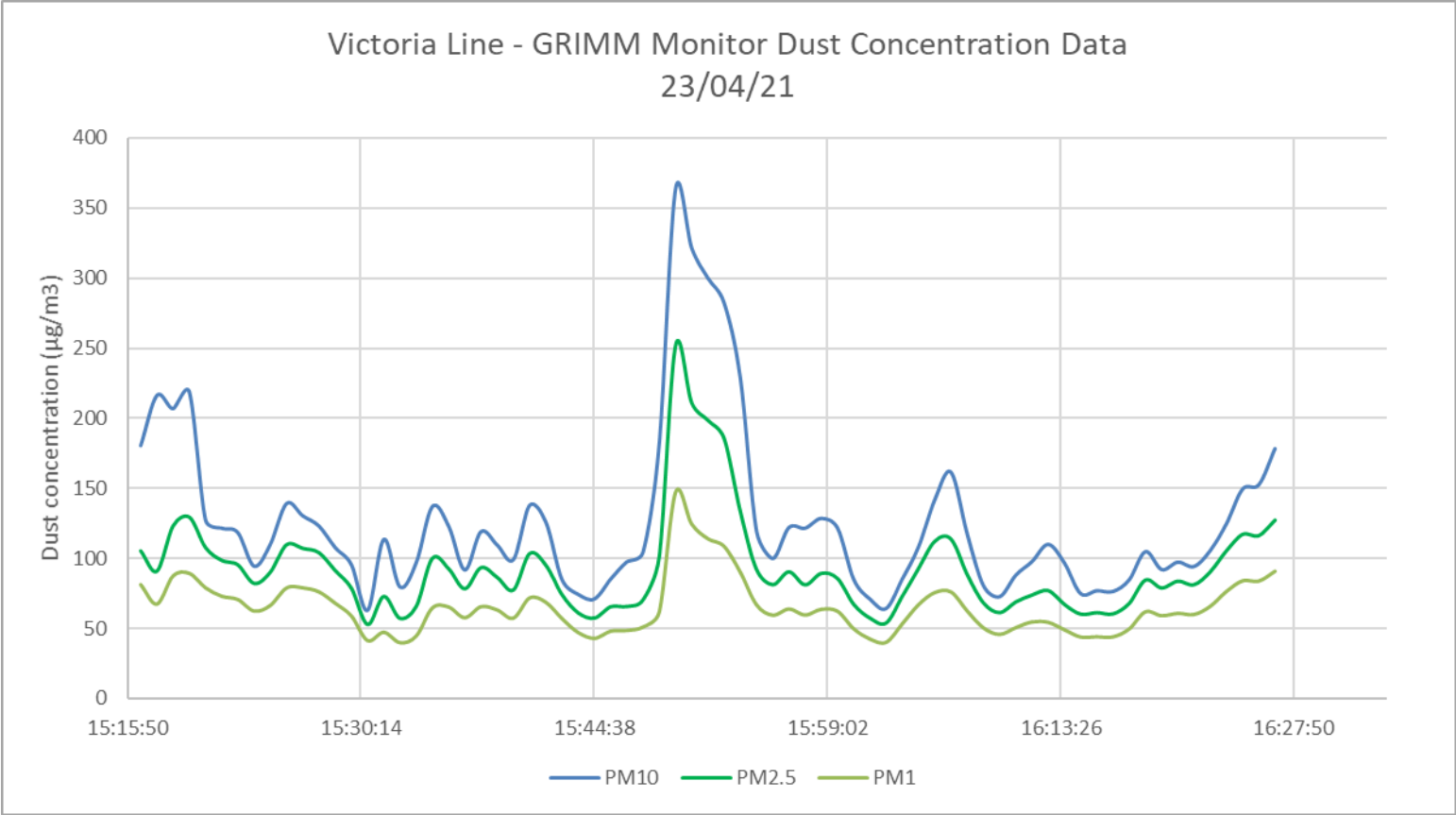


Figure 2. GRIMM monitoring data – Bakerloo Line.

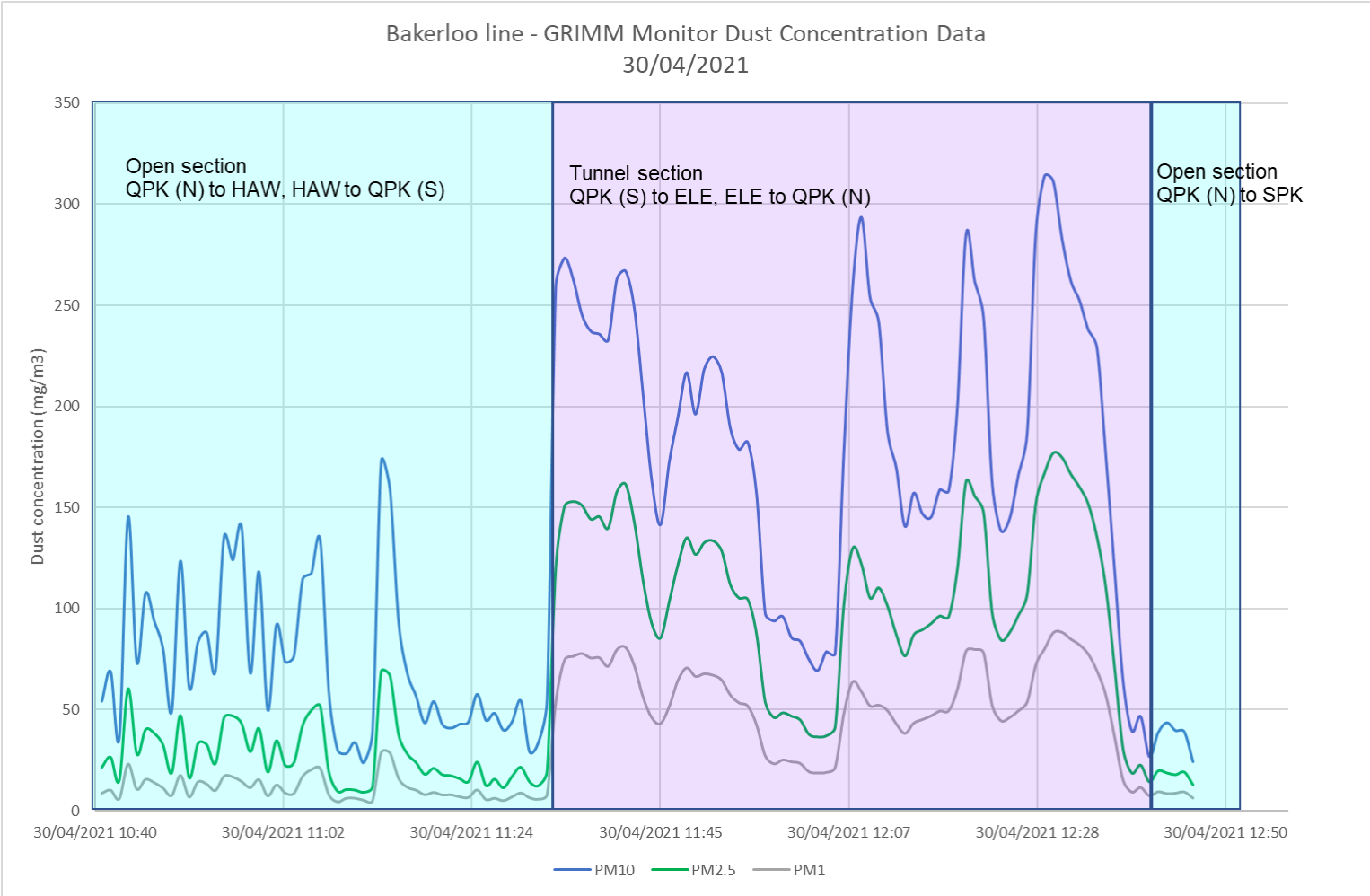


Figure 3. GRIMM monitoring data – Central Line.

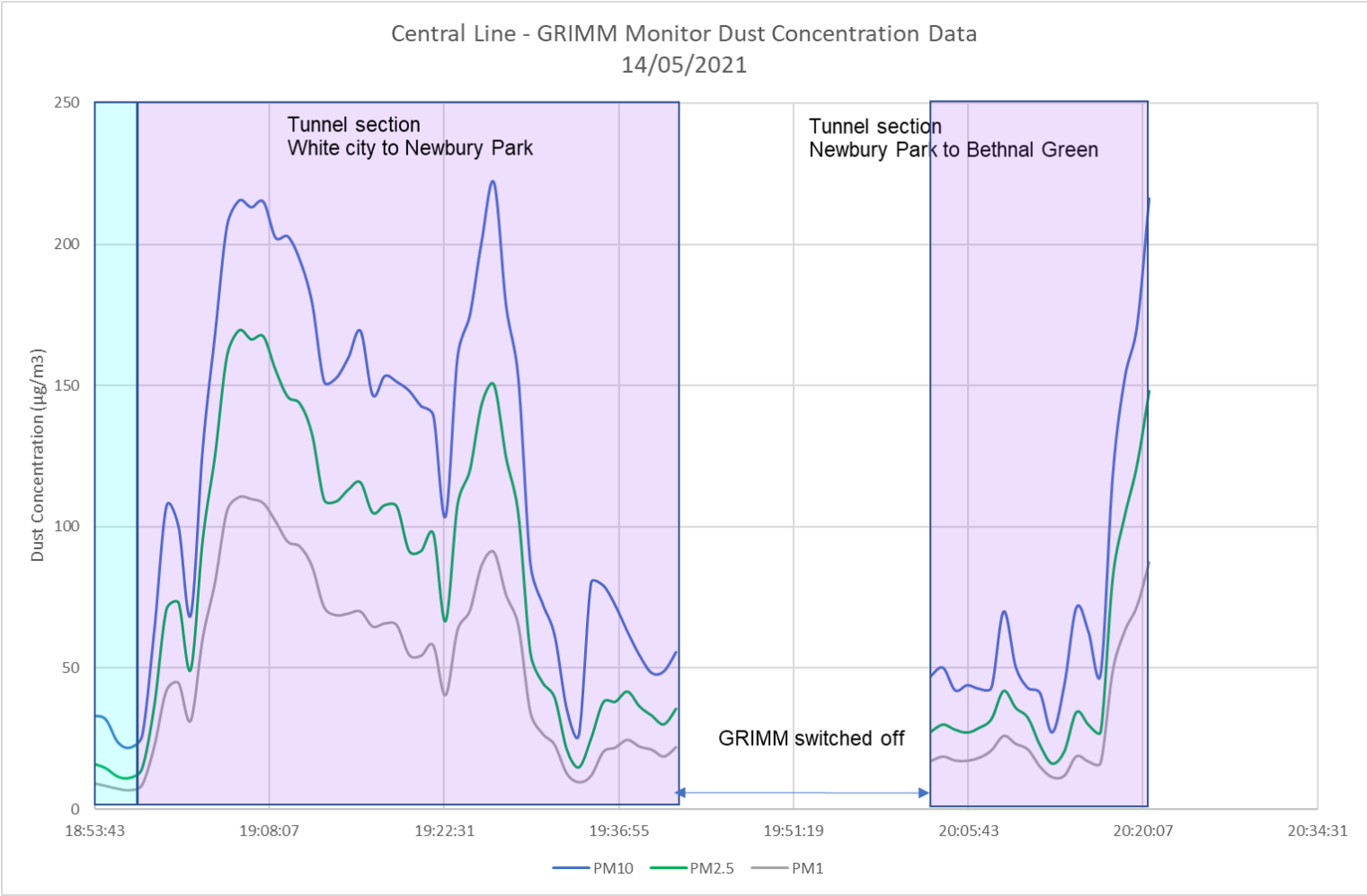


Figure 4. GRIMM monitoring data – Northern Line.

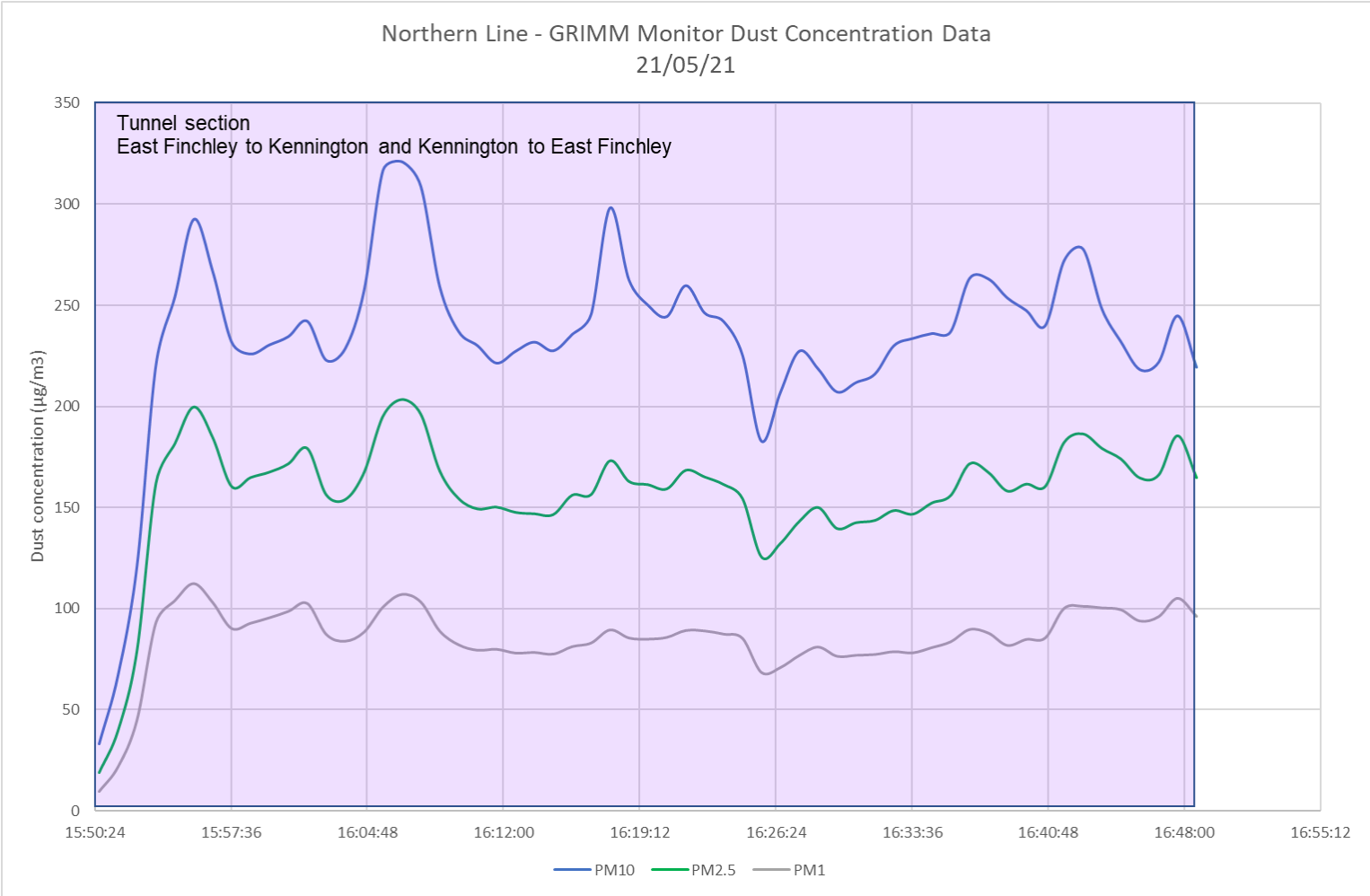


Figure 5. GRIMM monitoring data – Hammersmith & City Line.

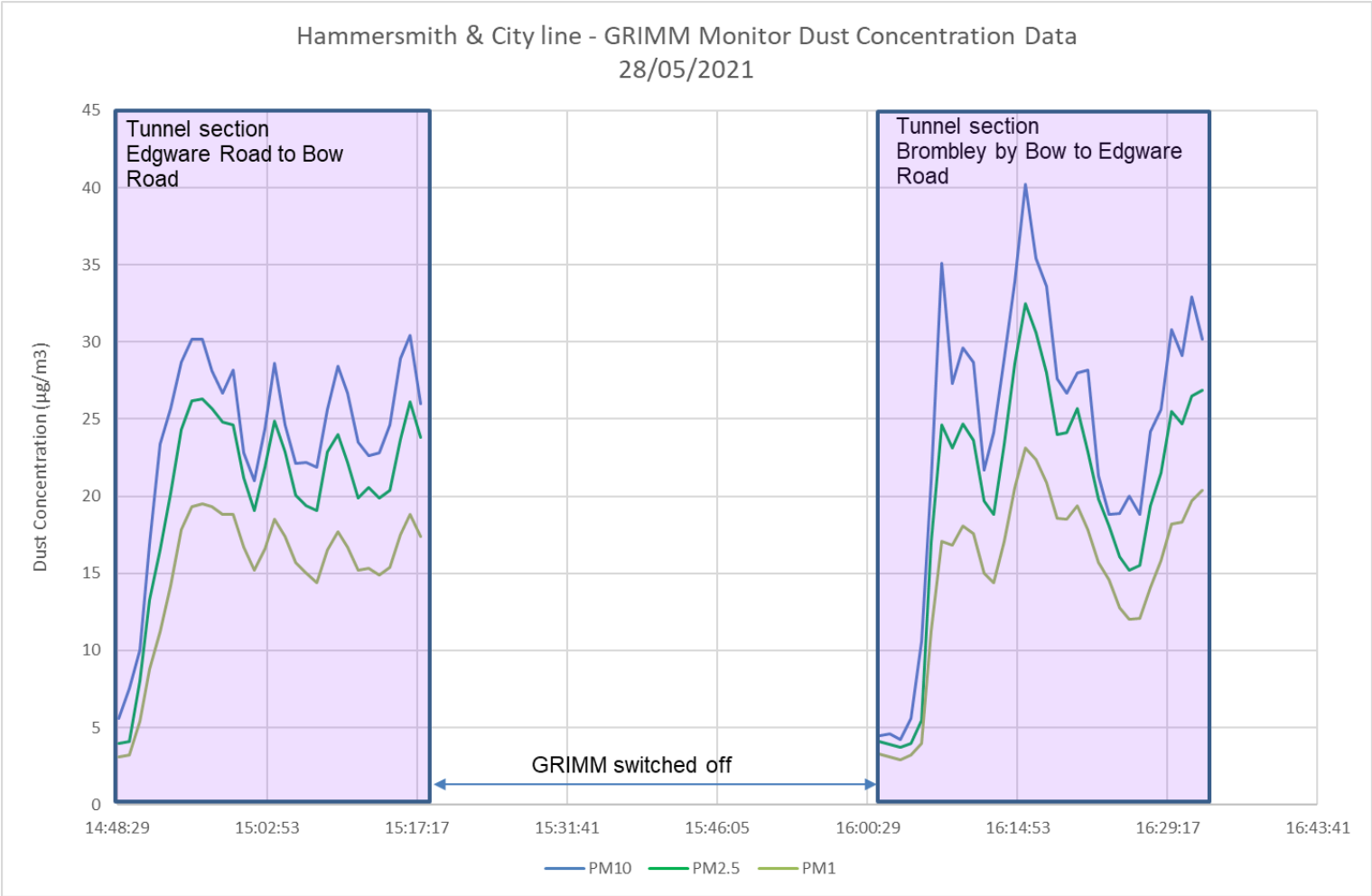


Figure 6. GRIMM monitoring data – District Line.

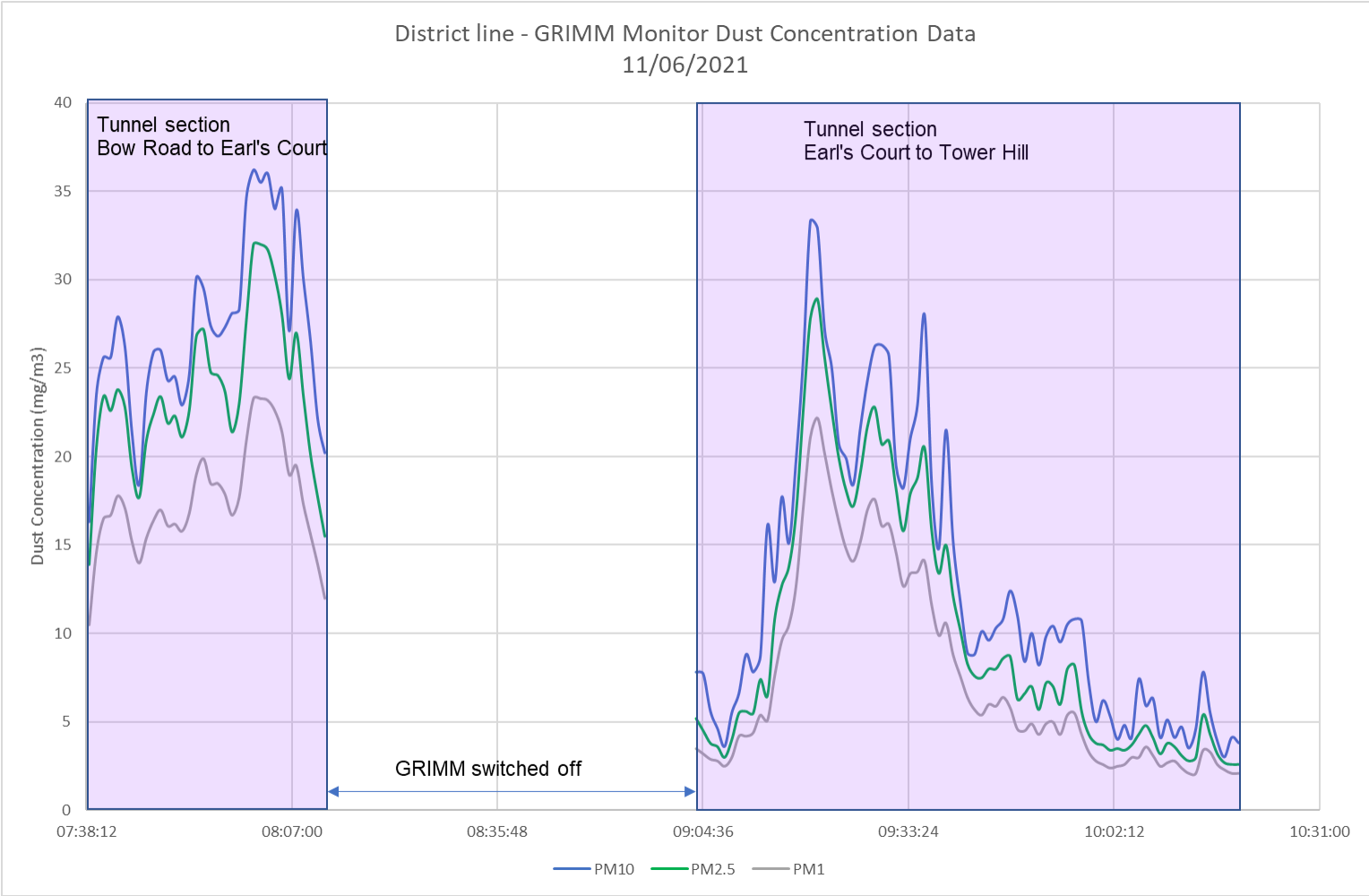


Figure 7. GRIMM monitoring data – Piccadilly Line.

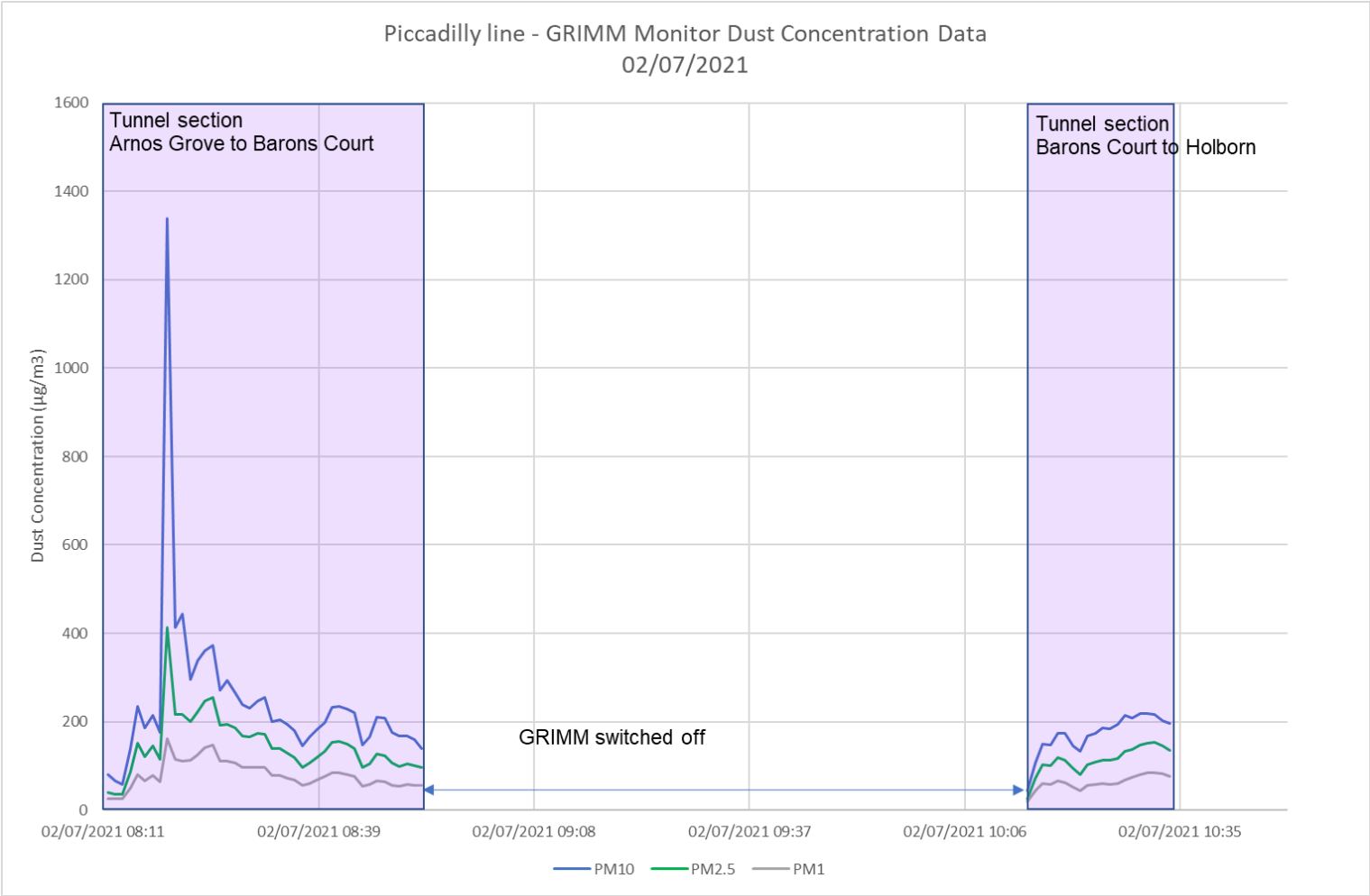
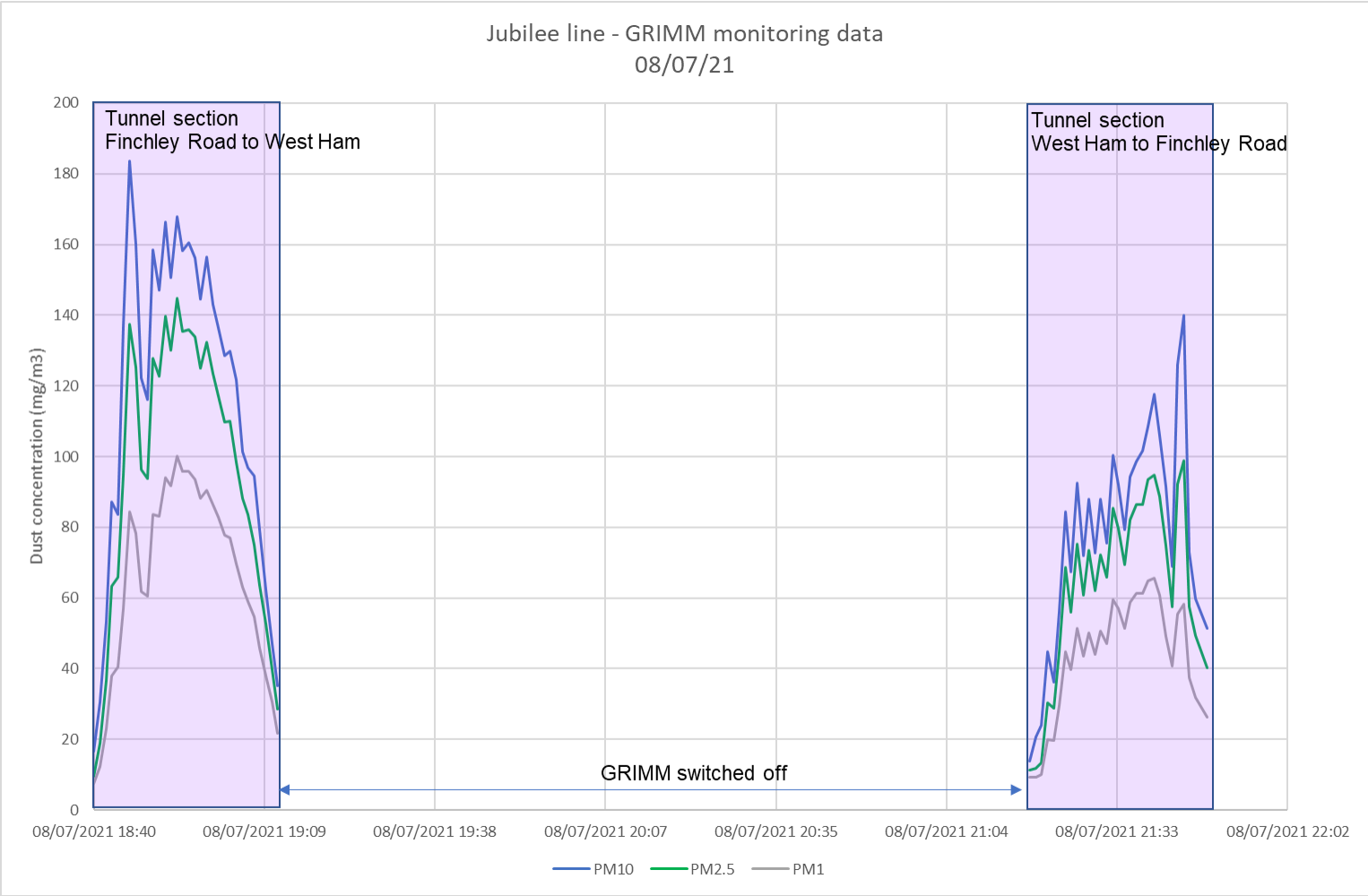


Figure 8. GRIMM monitoring data – Jubilee Line.



Appendix 3. Photos of types of samplers and sampling heads used in the monitoring programme.

Figure A. IOM Dust Head to monitor Inhalable Dust.



Figure B. Impactor Heads to monitor PM_{2.5} and PM₁₀ aerodynamic diameter dust fraction size.



Figure C. Cyclone Dust Head to monitor Respirable Dust.



Figure D. Examples of air samplers used for collecting airborne dust.



END OF REPORT