



## AIRBORNE DUST MONITORING ON, LONDON UNDERGROUND TRAIN OPERATORS 2023

**CLIENT REFERENCE: -**

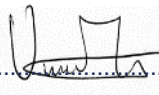
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# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

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REV 1	5 <sup>TH</sup> JANUARY 2024	AMENDMENT TO SECTION 3.6 FOLLOWING CLIENT FEEDBACK
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**CONDITIONS OF ISSUE OF REPORTS.**

THIS REPORT IS ISSUED IN CONFIDENCE AND SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT WRITTEN APPROVAL FROM 4-RAIL SERVICES.

**FURTHER INFORMATION.**

REQUESTS FOR ADDITIONAL INFORMATION ON THE SUBJECT OF THIS REPORT OR OTHER QUERIES SHOULD BE ADDRESSED TO THE AUTHOR.

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# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

## 1. INTRODUCTION

- 1.1. 4-RAIL Services limited were requested by the client, Claude Snowdon, London Underground, to undertake dust monitoring on London Underground train operators for each underground line.
- 1.2. The scope of works in based on ES12102, The Specification - London Underground Network: Occupational exposure to dust monitoring and survey.
- 1.3. The objectives listed in ES12102 for the train operator monitoring were the following:
  - To establish the work shift exposures to respirable dust for train operators for each underground line;
  - To establish the work shift exposure to respirable crystalline silica for train operators for each underground line;
  - To measure in real-time (on an photo-optical measurement device) the dust levels along each line in Respirable, PM10 and PM2.5 fractions.

## 2. SAMPLING STRATEGY

- 2.1. The following underground lines were monitored based on the client request:

Train Line	Description
Victoria	3 train operators, monitored for entire line (end to end)
Piccadilly	3 train operators, monitored for entire line (end to end)
Central	3 train operators, monitored for entire line (end to end)
Northern	3 train operators, monitored for entire line (end to end)
Jubilee	3 train operators, monitored for entire line (end to end)
Bakerloo	3 train operators, monitored for entire line (end to end)
Circle	3 train operators, monitored for entire line (end to end)
District	3 train operators, monitored for entire line (end to end)

- 2.2. The following analysis was undertaken for the above locations:

PARAMETER	SAMPLE MEDIA / TECHNIQUE	LOCATIONS	ANALYSIS
Respirable Dust	Active sampling pumps with PVC filters and Cyclone sampling heads. Monitoring undertaken in line with MDHS 14/4.	Train operators (three TO per line)	In-house Gravimetric Analysis accredited to UKAS ISO17025.
Inhalable Dust	Active sampling pumps with of PVC filters and IOM inhalable sampling heads. Monitoring undertaken in line with MDHS 14/4.	Train operators (one TO per line)	In-house Gravimetric Analysis accredited to UKAS ISO17025.
PM10	Active sampling pumps with of PVC filters and SKC PEM PM10 impactor sampling heads.	Train operators (three TO per line)	In-house gravimetric Analysis
PM2.5	Active sampling pumps with of PVC filters and SKC PEM PM2.5 impactor sampling heads.	Train operators (three TO per line)	In-house gravimetric Analysis

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PARAMETER	SAMPLE MEDIA / TECHNIQUE	LOCATIONS	ANALYSIS
Respirable crystalline silica	Infra-red spectroscopy	Train operators (three TO per line)	Subcontracted analysis to Institute of Occupational Medicine (IOM), UKAS lab. No. 0307.
Real-Time Dust	TSI DustTrak or GRIMM Aerosol Spectrometer (or similar) Laser light scattering technique for real time approximation of dust concentration. PM10, PM2.5 and Respirable	Train operators (one TO per line)	In-house analysis of data. Concentrations not corrected.

### 3. HAZARD INFORMATION, EXPOSURE LIMITS & GUIDELINE VALUES

#### 3.1. General

#### 3.2. Control of Substances Hazardous to Health

3.2.1. The Control of Substances Hazardous to Health (COSHH) regulations define substances as hazardous to health as follows:

- a) Substances with harmonised classification in Table 3.2 Part 3 of Annex VI of the CLP regulations which indicate the substance is very toxic, toxic, harmful, corrosive or an irritant;
- b) Substances with a Health and Safety Executive approved workplace exposure limit in EH40/2005;
- c) Which is a biological agent;
- d) Dust of any kind, except dust which is a substance within paragraph (a) or (b) which exceeds the limits given COSHH Regulation 2 for inhalable or respirable dust;
- e) Which, not being a substance falling within sub-paragraphs (a) to (d), because of its chemical or toxicological properties and the way it is used or is present at the workplace creates a risk health.

3.2.2. Where substances which are hazardous to health are present, the COSHH Regulations require employers to prevent or control the exposure to the hazardous substance.

3.2.3. Control is defined as adequate based on the following criteria:

- a) The principles of good practice are applied;
- b) Any WEL is not exceeded;
- c) Exposure to asthmagens, carcinogen and mutagens is reduced to as low as is reasonably practicable.

3.2.4. WELs are British Occupational exposure limits that are designed to protect the health of workers.

3.2.5. WELs are concentrations of a hazardous substance in air, averaged over a period of time. The two time periods generally used in WELs are:

- a) Long term 8-hour Time Weighted Average (8-hr TWA)
- b) 15-minute Short-Term Exposure Limits (15-minute STEL)

3.2.6. HSE document EH40/2005 (Fourth Edition 2020) is a list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations 2002.

3.2.7. Note, WELs are applicable to personal samples only. Static samples are for information purposes only.

#### 3.3. Inhalable Dust

3.3.1. Inhalable dust approximates to the fraction of airborne material that enters the nose and mouth during breathing, and is therefore available for deposition anywhere in the respiratory tract. Inhalable dust nominally comprises of dust particles with an aerodynamic diameter of <100µm (EN 481:1993 and ISO 7708:1995).

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3.3.2. Inhalable dust has a WEL in COSHH 2002 L5 6th Edition, Regulation 2, of 10mg/m<sup>3</sup> 8-hour TWA LTEL. Any substance above this limit would be considered a substance hazardous to health.

## **3.4. Respirable Dust**

3.4.1. Respirable dust is the fraction of dust that can penetrate down to the deep lung, where gas exchange takes place. Respirable dust will have a nominal aerodynamic diameter of 4µm (EN 481:1993 and ISO 7708:1995). Respirable dust, dependent upon the specific nature, can be linked to fibrosis, scarring of the lung as well as cancer and other health complaints.

3.4.2. Respirable dust has a WEL in COSHH 2002 L5 6th Edition, Regulation 2, of 4mg/m<sup>3</sup> 8-hour TWA LTEL. Any substance above this limit would be considered a substance hazardous to health.

## **3.5. Respirable Crystalline Silica**

3.5.1. There are three types of Crystalline Silica: Cristobalite, Tridymite and Quartz. Cristobalite and Tridymite are high temperature allotropes of Quartz. Quartz itself is the most common and naturally occurring form. Quartz dust is associated with granitoid rock, sandstone and dried clays and is the one of the main respiratory hazards when working with concrete, general construction sites and granite railway ballast.

3.5.2. Chronic exposure to all forms of Respirable Crystalline Silica can lead to Silicosis (fibrosis) scarring of the lungs that develops over time, ultimately reducing and impairing lung function by reducing the lungs' ability to absorb oxygen. IARC classify crystalline silica in the form of quartz or cristobalite dust is carcinogenic to humans (Group 1).

3.5.3. Respirable crystalline silica has a EH40/2005 WEL of 0.1mg/m<sup>3</sup> 8-hour TWA LTEL.

## **3.6. Particulate Matter 2.5 and 10**

3.6.1. 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.

3.6.2. 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 PM2.5. Due to their size differences, PM10 is known as the coarse fraction and PM2.5 is known as the fine fraction.

3.6.3. Exposure to particulate matter and dust can result in a wide range of health effects, predominantly to the respiratory and cardiovascular systems. Susceptibility to health effects can also be influenced by any pre-existing health conditions or age.

3.6.4. While particulate matter is known to cause adverse effects to human health, they are not assessed using Workplace Exposure Limits.

3.6.5. 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 PM2.5 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).

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## 4. RESULTS

- 4.1. See Tables 1 to 8 for the summary of airborne dust monitoring results.
- See Table 1 for a summary of the Train Operator results for the Bakerloo Line
  - See Table 2 for a summary of the Train Operator results for the Central Line
  - See Table 3 for a summary of the Train Operator results for the Circle/Hammersmith & City Line
  - See Table 4 for a summary of the Train Operator results for the District Line
  - See Table 5 for a summary of the Train Operator results for the Jubilee Line
  - See Table 6 for a summary of the Train Operator results for the Northern Line
  - See Table 7 for a summary of the Train Operator results for the Piccadilly Line
  - See Table 8 for a summary of the Train Operator results for the Victoria Line
- 4.2. See Table 9 for a summary of the respirable crystalline silica results.
- 4.3. See Figures 1 to 6 for the real-time particulate matter data.
- See Figure 1 for the real-time particulate matter data for the Circle/Hammersmith & City Line
  - See Figure 2 for the real-time particulate matter data for the District Line
  - See Figure 3 for the real-time particulate matter data for the Jubilee Line
  - See Figure 4 for the real-time particulate matter data for the Northern Line
  - See Figure 5 for the real-time particulate matter data for the Piccadilly Line
  - See Figure 6 for the real-time particulate matter data for the Victoria Line
- 4.4. See Table 10 for a comparison of the 2023 data to the data obtained in 2021.

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## 5. DISCUSSION

### 5.1. *Site Visit and Sampling*

5.1.1. Site attendances were carried out on the following dates:

- Jubilee Line – 20<sup>th</sup> July 2023
- Jubilee Line – 21<sup>st</sup> July 2023
- Victoria Line – 24<sup>th</sup> July 2023
- Jubilee Line – 28<sup>th</sup> July 2023
- Victoria Line – 28<sup>th</sup> July 2023
- Victoria Line – 31<sup>st</sup> July 2023
- Bakerloo Line – 2<sup>nd</sup> August 2023
- Bakerloo Line – 3<sup>rd</sup> August 2023
- Bakerloo Line – 4<sup>th</sup> August 2023
- Central Line – 7<sup>th</sup> August 2023
- Central Line – 8<sup>th</sup> August 2023
- Central Line – 10<sup>th</sup> August 2023
- Northern Line – 17<sup>th</sup> August 2023
- Northern Line – 18<sup>th</sup> August 2023
- Piccadilly Line – 29<sup>th</sup> August 2023
- Piccadilly Line – 30<sup>th</sup> August 2023
- Piccadilly Line – 31<sup>st</sup> August 2023
- Circle/Hammersmith & City Line – 7<sup>th</sup> September 2023
- Circle/Hammersmith & City Line – 15<sup>th</sup> September 2023
- Circle/Hammersmith & City Line – 26<sup>th</sup> September 2023
- District Line – 28<sup>th</sup> September 2023
- District Line – 29<sup>th</sup> September 2023
- District Line – 5<sup>th</sup> October 2023
- Northern Line – 6<sup>th</sup> October 2023

5.1.2. During the monitoring the train operators would keep windows shut. During change overs, the train cabin doors were occasionally left open to allow ventilation.

5.1.3. During the Central Line train operator monitoring on 7<sup>th</sup> August 2023, services were cancelled during the monitoring. Therefore, the monitoring duration was shorter than anticipated.

5.1.4. During the Circle/Hammersmith & City Line train operator monitoring on 7<sup>th</sup> September 2023, the train operator had a meal break towards the end of the shift. Therefore, the monitoring duration was shorter than anticipated.

5.1.5. The GRIMM Aerosol Spectrometer encountered faults on the following shifts:

- Bakerloo Line – 2<sup>nd</sup> August 2023. No data obtained.
- Central Line – 7<sup>th</sup> August 2023. No data obtained.

5.1.6. The TSI DustTrak encountered faults on the following shifts:

- Central Line – 8<sup>th</sup> August 2023. No data obtained.
- Piccadilly Line – 31<sup>st</sup> August 2023. Intermittent fault, less usable data obtained.

### 5.2. *Bakerloo Line*

5.2.1. The respirable dust concentrations recorded on Bakerloo Line Train Operators were between 0.21mg/m<sup>3</sup> and 0.32mg/m<sup>3</sup>, with the highest concentration recorded on Duty 120 Queens Park, 3<sup>rd</sup> August 2023.

5.2.2. The PM<sub>2.5</sub> dust concentrations recorded on Bakerloo Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.20mg/m<sup>3</sup>, with the highest concentration recorded on Duty 120 Queens Park, 3<sup>rd</sup> August 2023. Note, some of the PM<sub>2.5</sub> results are likely to be anomalous based on the other results.

5.2.3. The PM<sub>10</sub> dust concentrations recorded on Bakerloo Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.13mg/m<sup>3</sup>, with the highest concentration recorded on Duty 120 Queens Park, 3<sup>rd</sup> August 2023 and 4<sup>th</sup> August 2023. Note, the PM<sub>10</sub> results are likely to be anomalous based on the other results.

5.2.4. The inhalable dust concentration recorded on Bakerloo Line Train Operator Duty 120 Queens Park, 2<sup>nd</sup> August 2023, was 0.32mg/m<sup>3</sup>.



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## 5.3. *Central Line*

- 5.3.1. The respirable dust concentrations recorded on Central Line Train Operators were between 0.18mg/m<sup>3</sup> and 0.20mg/m<sup>3</sup>, with the highest concentration recorded on Duty 814 White City, 8<sup>th</sup> August 2023, and Duty 507 West Ruislip, 7<sup>th</sup> August 2023. Note, the monitoring on Duty 507 West Ruislip, 7<sup>th</sup> August 2023 was a short duration and may not be representative.
- 5.3.2. The PM<sub>2.5</sub> dust concentrations recorded on Central Line Train Operators were between 0.09mg/m<sup>3</sup> and 0.49mg/m<sup>3</sup>, with the highest concentration recorded on Duty 507 West Ruislip, 7<sup>th</sup> August 2023. Note, the monitoring on Duty 507 West Ruislip, 7<sup>th</sup> August 2023, was for a short duration and may not be representative. The next highest concentration was monitored on Duty 820 White City, 10<sup>th</sup> August 2023 with a concentration of 0.16mg/m<sup>3</sup>. Note, some of the PM<sub>2.5</sub> results are likely to be anomalous based on the other results.
- 5.3.3. The PM<sub>10</sub> dust concentrations recorded on Central Line Train Operators were between 0.12mg/m<sup>3</sup> and 0.31mg/m<sup>3</sup>, with the highest concentration recorded on Duty 507 West Ruislip, 7<sup>th</sup> August 2023. Note, the monitoring on Duty 507 West Ruislip, 7<sup>th</sup> August 2023 was for a short duration and may not be representative. The next highest concentration was monitored on Duty 814 White City, 8<sup>th</sup> August 2023, with a concentration of 0.23mg/m<sup>3</sup>. Note, some of the PM<sub>10</sub> results were anomalous based on the other results.
- 5.3.4. The inhalable dust concentrations recorded on Central Line Train Operators were between 0.22mg/m<sup>3</sup> and 0.40mg/m<sup>3</sup>, with the highest concentration recorded on Duty 507 West Ruislip 7<sup>th</sup> August 2023. Note, the monitoring on Duty 507 West Ruislip 7<sup>th</sup> August 2023 was for a short duration and may not be representative. The next highest concentration was monitored on Duty 820 White City 10<sup>th</sup> August 2023 with a concentration of 0.22mg/m<sup>3</sup>.

## 5.4. *Circle/Hammersmith & City Line*

- 5.4.1. The respirable dust concentrations recorded on Circle/Hammersmith & City Line Train Operators were between 0.07mg/m<sup>3</sup> and 0.30mg/m<sup>3</sup>, with the highest concentration recorded on Duty 19 Edgware Road, 15<sup>th</sup> September 2023.
- 5.4.2. The PM<sub>2.5</sub> dust concentrations recorded on Circle/Hammersmith & City Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.15mg/m<sup>3</sup>, with the highest concentration recorded on Duty 19 Edgware Road, 15<sup>th</sup> September 2023.
- 5.4.3. The PM<sub>10</sub> dust concentrations recorded on Circle/Hammersmith & City Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.14mg/m<sup>3</sup>, with the highest concentration recorded on Duty 19 Edgware Road, 15<sup>th</sup> September 2023. The PM<sub>10</sub> results are likely to be anomalous based on the other results.
- 5.4.4. The inhalable dust concentrations recorded on Circle/Hammersmith & City Line Train Operators were between 0.27mg/m<sup>3</sup> and 0.71mg/m<sup>3</sup>, with the highest concentration recorded on Duty 12 Edgware Road, 7<sup>th</sup> September 2023. Note, the monitoring on Duty 12 Edgware Road, 7<sup>th</sup> September 2023, was for a shorter duration and may not be representative. The next highest concentration was monitored Duty 19 Edgware Road, 15<sup>th</sup> September 2023, with a concentration of 0.27mg/m<sup>3</sup>.

## 5.5. *District Line*

- 5.5.1. The respirable dust concentrations recorded on District Line Train Operators were between 0.05mg/m<sup>3</sup> and 0.41mg/m<sup>3</sup>, with the highest concentration recorded on Duty 413 Barking, 28<sup>th</sup> September 2023.
- 5.5.2. The PM<sub>2.5</sub> dust concentrations recorded on District Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.08mg/m<sup>3</sup>, with the highest concentration recorded on Duty 407 Barking, 29<sup>th</sup> September 2023. Note, some of the PM<sub>2.5</sub> results are likely to be anomalous based on the other results.
- 5.5.3. The PM<sub>10</sub> dust concentrations recorded on District Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.04mg/m<sup>3</sup>, with the highest concentration recorded on Duty 413 Barking, 28<sup>th</sup> September 2023. Note, the PM<sub>10</sub> results are likely to be anomalous based on the other results.
- 5.5.4. The inhalable dust concentrations recorded on District Line Train Operators were between 0.21mg/m<sup>3</sup> and 0.61mg/m<sup>3</sup>, with the highest concentration recorded on Duty 413 Barking, 28<sup>th</sup> September 2023.

## 5.6. *Jubilee Line*

- 5.6.1. The respirable dust concentrations recorded on Jubilee Line Train Operators were between 0.08mg/m<sup>3</sup> and 0.16mg/m<sup>3</sup>, with the highest concentration recorded on Duty 640 Wembley Park, 20<sup>th</sup> September 2023.
- 5.6.2. The PM<sub>2.5</sub> dust concentrations recorded on Jubilee Line Train Operators were between <0.02mg/m<sup>3</sup> and 0.05mg/m<sup>3</sup>, with the highest concentration recorded on Duty 640 Wembley Park, 20<sup>th</sup> September 2023.

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5.6.3. The PM10 dust concentrations recorded on Jubilee Line Train Operators were between  $<0.02\text{mg}/\text{m}^3$  and  $0.08\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 625 Wembley Park, 21<sup>st</sup> September 2023. Note, the PM10 results are likely to be anomalous based on the other results.

5.6.4. The inhalable dust concentration recorded on Jubilee Line Train Operator Duty 640 Wembley Park, 20<sup>th</sup> September 2023, was  $0.21\text{mg}/\text{m}^3$ .

## 5.7. Northern Line

5.7.1. The respirable dust concentrations recorded on Northern Line Train Operators were between  $0.26\text{mg}/\text{m}^3$  and  $0.36\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 439 Edgware, 17<sup>th</sup> August 2023.

5.7.2. The PM2.5 dust concentrations recorded on Northern Line Train Operators were between  $0.10\text{mg}/\text{m}^3$  and  $0.24\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 646 Edgware, 18<sup>th</sup> August 2023

5.7.3. The PM10 dust concentrations recorded on Northern Line Train Operators were between  $0.05\text{mg}/\text{m}^3$  and  $0.46\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 439 Edgware, 17<sup>th</sup> August 2023. Note, some of the PM10 results are likely to be anomalous based on the other results.

5.7.4. The inhalable dust concentrations recorded on Northern Line Train Operators were between  $0.34\text{mg}/\text{m}^3$  and  $0.44\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 433 Edgware 6<sup>th</sup> October 2023.

## 5.8. Piccadilly Line

5.8.1. The respirable dust concentrations recorded on Piccadilly Line Train Operators were between  $0.23\text{mg}/\text{m}^3$  and  $0.33\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 428 Arnos Grove, 29<sup>th</sup> August 2023.

5.8.2. The PM2.5 dust concentrations recorded on Piccadilly Line Train Operators were between  $0.03\text{mg}/\text{m}^3$  and  $0.08\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 428 Arnos Grove, 29<sup>th</sup> August 2023.

5.8.3. The PM10 dust concentrations recorded on Piccadilly Line Train Operators were between  $0.22\text{mg}/\text{m}^3$  and  $0.29\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 416 Cockfosters, 30<sup>th</sup> August 2023. Note, some of the PM10 results are likely to be anomalous based on the other results.

5.8.4. The inhalable dust concentrations recorded on Piccadilly Line Train Operators were between  $0.31\text{mg}/\text{m}^3$  and  $0.36\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 428 Arnos Grove, 29<sup>th</sup> August 2023.

## 5.9. Victoria Line

5.9.1. The respirable dust concentrations recorded on Victoria Line Train Operators were between  $0.13\text{mg}/\text{m}^3$  and  $0.28\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 815 Brixton, 28<sup>th</sup> July 2023.

5.9.2. The PM2.5 dust concentrations recorded on Victoria Line Train Operators were between  $0.12\text{mg}/\text{m}^3$  and  $0.16\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 821 Brixton, 31<sup>st</sup> July 2023. Note, some of the PM2.5 results are likely to be anomalous based on the other results.

5.9.3. The PM10 dust concentrations recorded on Victoria Line Train Operators were between  $0.22\text{mg}/\text{m}^3$  and  $0.31\text{mg}/\text{m}^3$ , with the highest concentration recorded on Duty 815 Brixton, 28<sup>th</sup> July 2023

5.9.4. The inhalable dust concentration recorded on Victoria Line Train Operator Duty 815 Brixton, 28<sup>th</sup> September 2023, was  $0.41\text{mg}/\text{m}^3$ .

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

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## **5.10. Respirable Crystalline Silica**

- 5.10.1. The amount of respirable crystalline silica, as quartz, detected in the samples were all below the limit of detection for the methods used.
- 5.10.2. The calculated respirable crystalline silica were between  $<0.01\text{mg/m}^3$  and  $<0.07\text{mg/m}^3$ , these concentrations were below the HSE 8-hr TWA for respirable crystalline silica of  $0.1\text{mg/m}^3$ .

## **5.11. Real-Time Particulate Matter**

- 5.11.1. The real-time particulate matter concentrations show that the particulate matter concentrations vary during the train operator's journey.
- 5.11.2. Where the concentrations vary, they tend to remain relatively constant for 5-30minutes. This may be due to particulate matter concentrations associated with the trains being static, proximity with other trains or variations in tunnel sections.
- 5.11.3. The real-time particulate matter concentrations do not decrease to concentrations typically associated with outdoor air, this indicates that the rail environment tends to have elevated particulate matter concentrations.
- 5.11.4. The real-time particulate matter concentrations recorded on the Jubilee and Northern Line indicate that particulate matter concentrations decreased when the train is operating in areas outside of tunnels, see Figure 3 and 4.

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

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## 6. CONCLUSIONS

- 6.1. There were no exceedances to the COSHH limit for respirable and inhalable dust during the monitoring. The concentrations recorded were all below half the limit for dust of any composition to be considered hazardous to health.
- 6.2. There were no exceedances to the HSE EH40 Workplace Exposure Limits for respirable crystalline silica. The amount of respirable crystalline silica was below the limit of detection for the methods used during the monitoring. The amount of silica is likely below the limit of detection for the methods used due to the low respirable dust exposure, with the silica forming a small fraction of the total respirable dust.
- 6.3. The highest respirable dust concentration recorded during the monitoring was on the District Line Duty 413 Barking on 28<sup>th</sup> September 2023.
- 6.4. The line with the highest mean respirable dust concentration was for the Northern Line Train Operators. However, this concentration was within the standard deviation of the mean respirable dust concentrations recorded for the Piccadilly and Bakerloo Line Train Operators (second and third highest respectively).
- 6.5. The respirable dust concentrations recorded are compared to the data obtained in 2021, this is summarised in Table 10. Some observations on the comparison are as follows:
  - The mean respirable dust concentrations of the train operators across all lines were similar for the data obtained in 2021 and 2023;
  - The line with the highest mean respirable dust concentrations in 2021 and 2023 were recorded on the Northern Line train operators. However, the mean respirable dust concentration recorded was within the standard deviation of other lines and therefore may not be significant.
  - The lines with the lowest mean respirable dust concentrations in 2021 and 2023 were the Jubilee, Circle/Hammersmith & City and District Line. However, the mean respirable dust concentration recorded for these lines were within the standard deviation of other lines and therefore may not be significant.

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

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## 7. REFERENCES

EH40/2005 Workplace Exposure Limits, Fourth Edition 2020.

HSE L5 Sixth Edition, Control of Substances Hazardous to Health Regulations, 2002 (as amended) – Approved Code of Practice and guidance. 2013.

MDHS 14/4 – General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols. 06/2014.

J.D. Smith, B.M. Barratt, G.W. Fuller, F.J. Kelly, M. Loxham, E. Nicolosi, M. Priestman, A.H. Tremper, and D.C. Green. PM<sub>2.5</sub> on the London Underground. *Environ Int.* 2020 Jan; 134: 105188. doi: 10.1016/j.envint.2019.105188: 10.1016/j.envint.2019.105188.

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 1. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – BAKERLOO LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 120 Queens Park	02/08/2023 10:00 to 17:22	0.21	<0.02*	<0.02*	0.32
Duty 120 Queens Park	03/08/2023 10:01 to 17:24	0.32	0.18	0.13*	-
Duty 120 Queens Park (Friday)	04/08/2023 09:59 to 15:41	0.21	0.20	0.13*	-

\*anomalous result

## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 2. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – CENTRAL LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 507 West Ruislip - Central line services cancelled	07/08/2023 11:41 to 12:47	0.20	0.49*	0.31*	0.40
Duty 814 White City	08/08/2023 08:10 to 13:20	0.20	0.09	0.23	-
Duty 820 White City	10/08/2023 11:38 to 17:45	0.18	0.16	0.12*	0.22

\*anomalous result

## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 3. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – CIRCLE/HAMMERSMITH & CITY LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 12 Edgware Road - Shorter monitoring due to TO break	07/09/2023 07:22 to 09:47	0.07	<0.02	<0.02*	0.71
Duty 19 (Friday) Edgware Road	15/09/2023 09:09 to 14:26	0.30	0.15	0.14*	0.27
Duty 16 Edgware Road	26/09/2023 08:37 to 12:15	0.16	0.08	0.07*	-

\*anomalous result



## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 4. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – DISTRICT LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 413 Barking	28/09/2023 09:34 to 15:13	0.41	<0.02*	0.04*	0.61
Duty 407 (Friday) Barking	29/09/2023 07:51 to 11:27	0.07	0.08	Damaged Filter	0.21
Duty 414 Barking	05/10/2023 10:01 to 14:24	0.05	<0.02	<0.02*	-

\*anomalous result

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 5. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – JUBILEE LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 640 Wembley Park	20/07/2023 10:30 to 17:38	0.16	0.05	0.05*	0.21
Duty 625 (Friday) Wembley Park	21/07/2023 08:21 to 13:58	0.14	<0.02	0.08*	-
Duty 624 (Friday) Wembley Park	28/07/2023 10:40 to 16:42	0.08	<0.02	<0.02*	-

\*anomalous result

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 6. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – NORTHERN LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 439 Edgware	17/08/2023 09:19 to 14:54	0.36	0.10	0.46	-
Duty 646 (Friday) Edgware	18/08/2023 09:19 to 15:01	0.29	0.24	0.05*	0.34
Duty 433 (Friday) Edgware	06/10/2023 07:51 to 12:52	0.26	0.14	0.27	0.44

\*anomalous result

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 7. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – PICCADILLY LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 428 Arnos Grove	29/08/2023 10:18 to 16:35	0.33	0.08	0.22*	0.36
Duty 416 Cockfosters	30/08/2023 08:00 to 14:57	0.23	0.03	0.29	-
Duty 32 Cockfosters	31/08/2023 09:57 to 17:09	0.29	0.06	0.26	0.31

\*anomalous result

## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 8. SUMMARY OF TRAIN OPERATOR AIRBORNE DUST MONITORING RESULTS – VICTORIA LINE

LOCATION	DATE/TIME	RESPIRABLE CONCENTRATION / MG.M <sup>-3</sup>	PM2.5 CONCENTRATION / MG.M <sup>-3</sup>	PM10 DUST CONCENTRATION / MG.M <sup>-3</sup>	INHALABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Duty 544 Seven Sisters	24/07/2023 10:11 to 17:18	0.15	0.12	0.25	-
Duty 815 (Friday) Brixton	28/07/2023 08:13 to 15:32	0.28	0.14	0.31	0.41
Duty 821 Brixton	31/07/2023 10:25 to 18:10	0.13	0.16*	0.22	-

\*anomalous result

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

TABLE 9. SUMMARY OF TRAIN OPERATOR RESPIRABLE CRYSTALLINE SILICA RESULTS

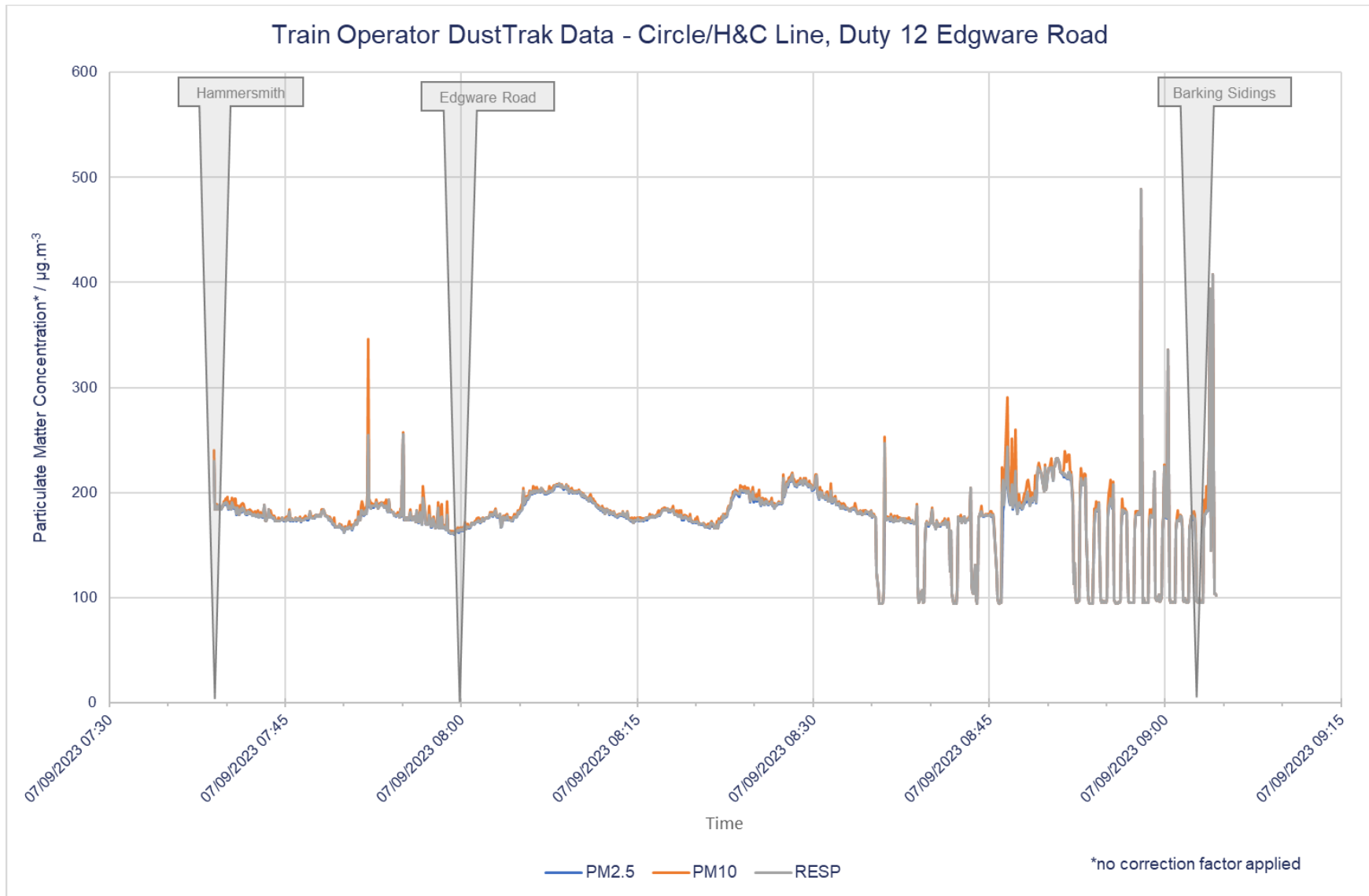
LINE	TRAIN OPERATOR DUTY	DATE/TIME	AIR VOLUME / L	SILICA WEIGHT / MG	RESPIRABLE CRYSTALLINE SILICA / MG.M <sup>-3</sup>
Bakerloo	Duty 120 Queens Park	02/08/2023 10:00 to 17:22	818.4	<0.01	<0.01
	Duty 120 Queens Park	03/08/2023 10:01 to 17:24	809.6	<0.01	<0.01
	Duty 120 Queens Park (Friday)	04/08/2023 09:59 to 15:41	602.80	<0.01	<0.02
Central	Duty 507 West Ruislip - Central line services cancelled	07/08/2023 11:41 to 12:47	145.20	<0.01	<0.07
	Duty 814 White City	08/08/2023 08:10 to 13:20	676.70	<0.01	<0.01
	Duty 820 White City	10/08/2023 11:38 to 17:45	688.60	<0.01	<0.01
Circle/Hammersmith & City	Duty 12 Edgware Road - Shorter monitoring due to TO break	07/09/2023 07:22 to 09:47	319.00	<0.01	<0.03
	Duty 19 (Friday) Edgware Road	15/09/2023 09:09 to 14:26	561.00	<0.01	<0.02
	Duty 16 Edgware Road	26/09/2023 08:37 to 12:15	479.60	<0.01	<0.02
District	Duty 413 Barking	28/09/2023 09:34 to 15:13	589.60	<0.01	<0.02
	Duty 407 (Friday) Barking	29/09/2023 07:51 to 11:27	470.75	<0.01	<0.02
	Duty 414 Barking	05/10/2023 10:01 to 14:24	578.60	<0.01	<0.02

## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

LINE	TRAIN OPERATOR DUTY	DATE/TIME	AIR VOLUME / L	SILICA WEIGHT / MG	RESPIRABLE CRYSTALLINE SILICA / MG.M <sup>-3</sup>
Jubilee	Duty 640 Wembley Park	20/07/2023 10:30 to 17:38	811.80	<0.01	<0.01
	Duty 625 (Friday) Wembley Park	21/07/2023 08:21 to 13:58	605.00	<0.01	<0.02
	Duty 624 (Friday) Wembley Park	28/07/2023 10:40 to 16:42	635.80	<0.01	<0.02
Northern	Duty 439 Edgware	17/08/2023 09:19 to 14:54	534.40	<0.01	<0.02
	Duty 646 (Friday) Edgware	18/08/2023 09:19 to 15:01	653.40	<0.01	<0.02
	Duty 433 (Friday) Edgware	06/10/2023 07:51 to 12:52	528.00	<0.01	<0.02
Piccadilly	Duty 428 Arnos Grove	29/08/2023 10:18 to 16:35	690.80	<0.01	<0.01
	Duty 416 Cockfosters	30/08/2023 08:00 to 14:57	605.00	<0.01	<0.02
	Duty 32 Cockfosters	31/08/2023 09:57 to 17:09	767.80	<0.01	<0.01
Victoria	Duty 544 Seven Sisters	24/07/2023 10:11 to 17:18	811.80	<0.01	<0.01
	Duty 815 (Friday) Brixton	28/07/2023 08:13 to 15:32	664.40	<0.01	<0.02
	Duty 821 Brixton	31/07/2023 10:25 to 18:10	827.20	<0.01	<0.01

# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

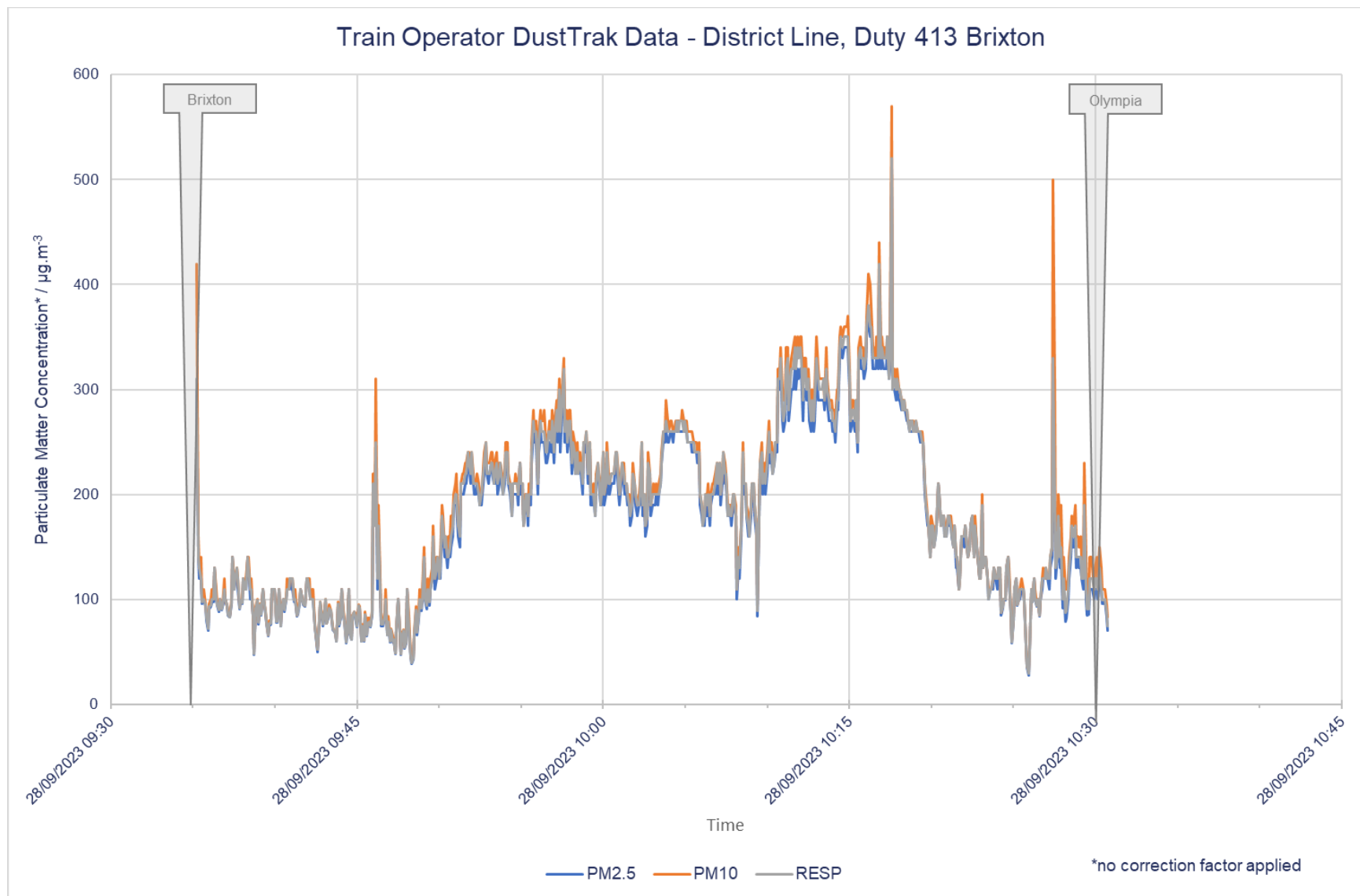
FIGURE 1. REAL-TIME PARTICULATE MATTER DATA – CIRCLE/HAMMERSMITH & CITY LINE





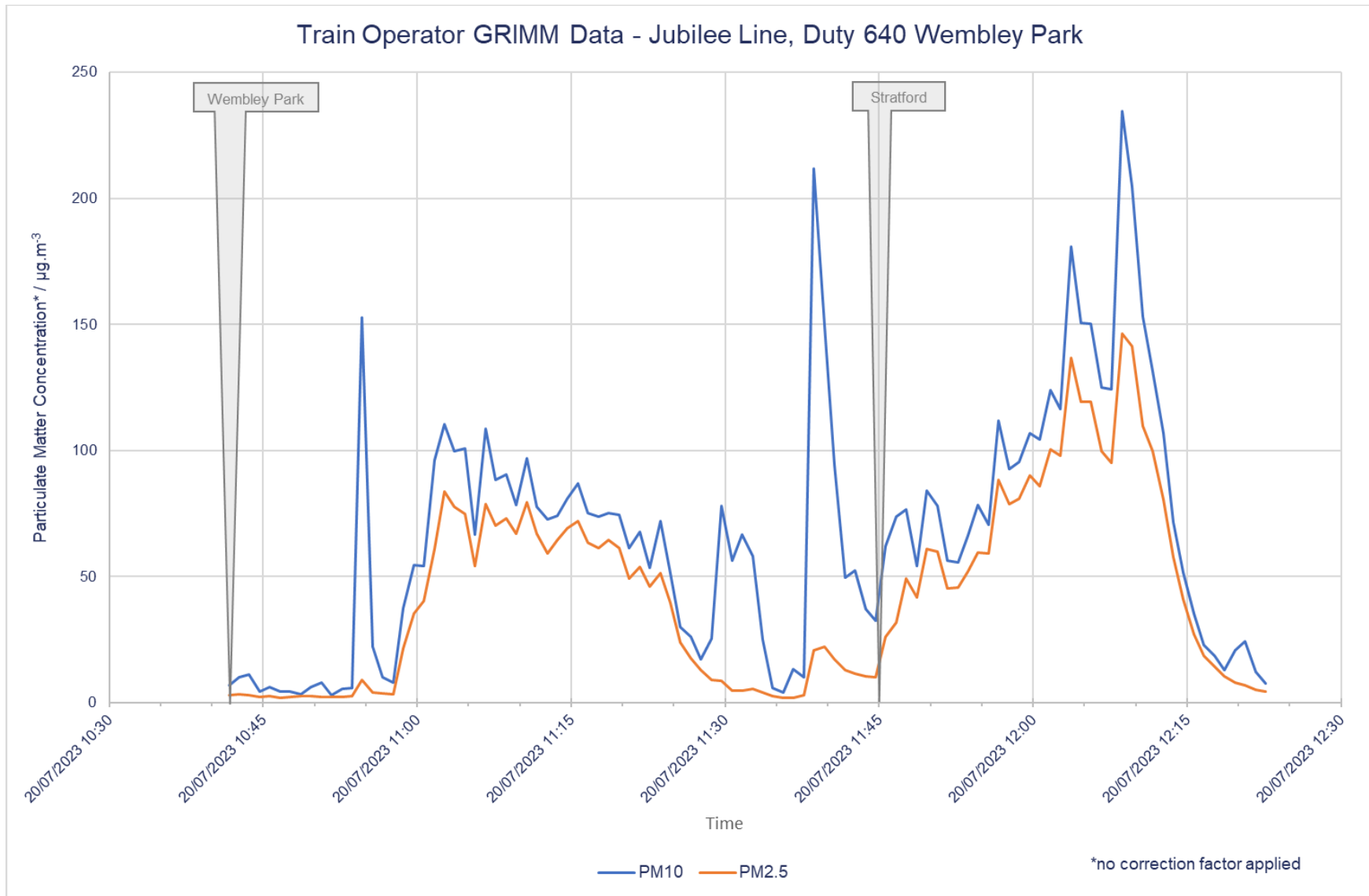
# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

FIGURE 2. REAL-TIME PARTICULATE MATTER DATA – DISTRICT LINE



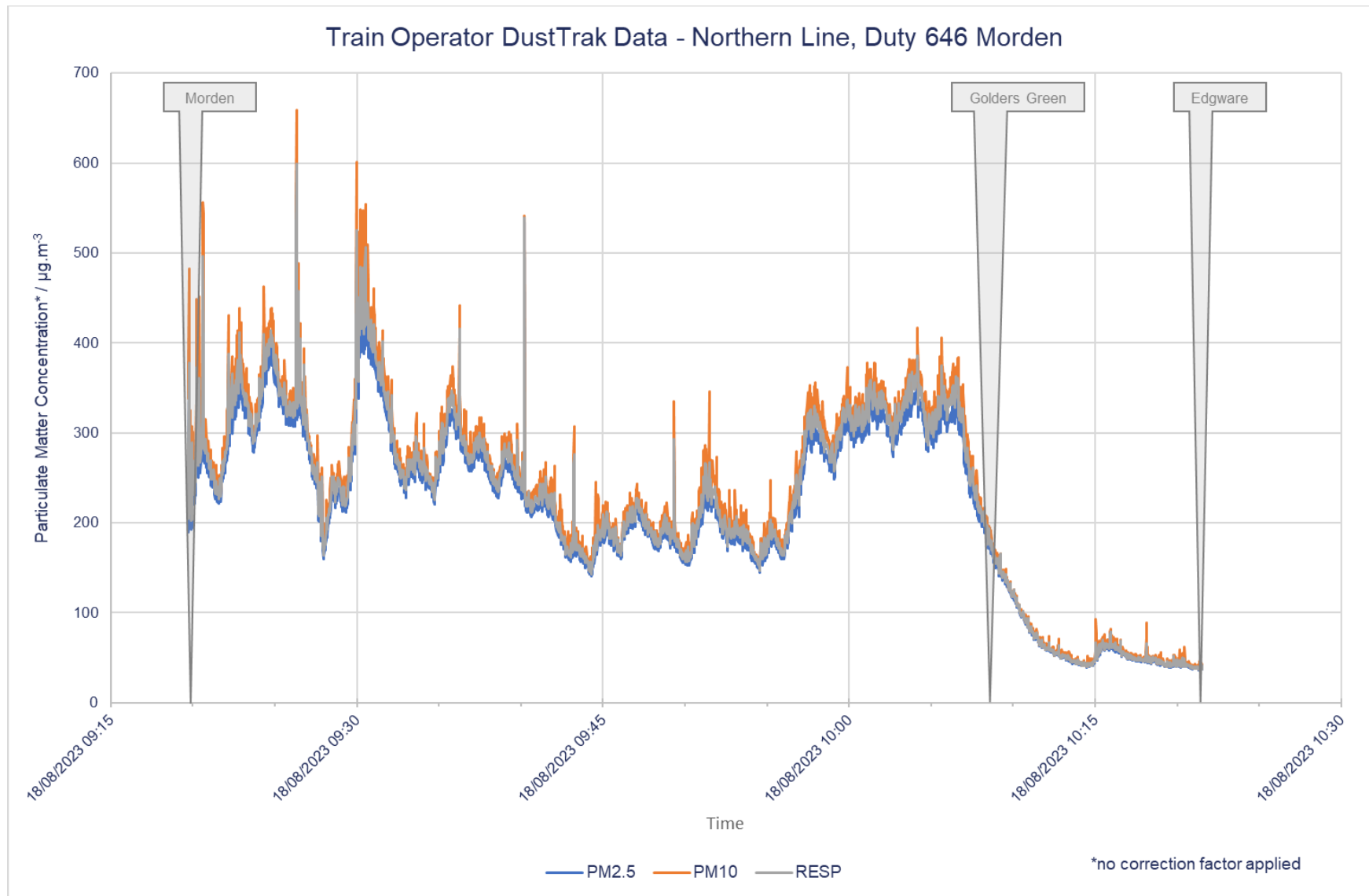
# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

FIGURE 3. REAL-TIME PARTICULATE MATTER DATA – JUBILEE LINE



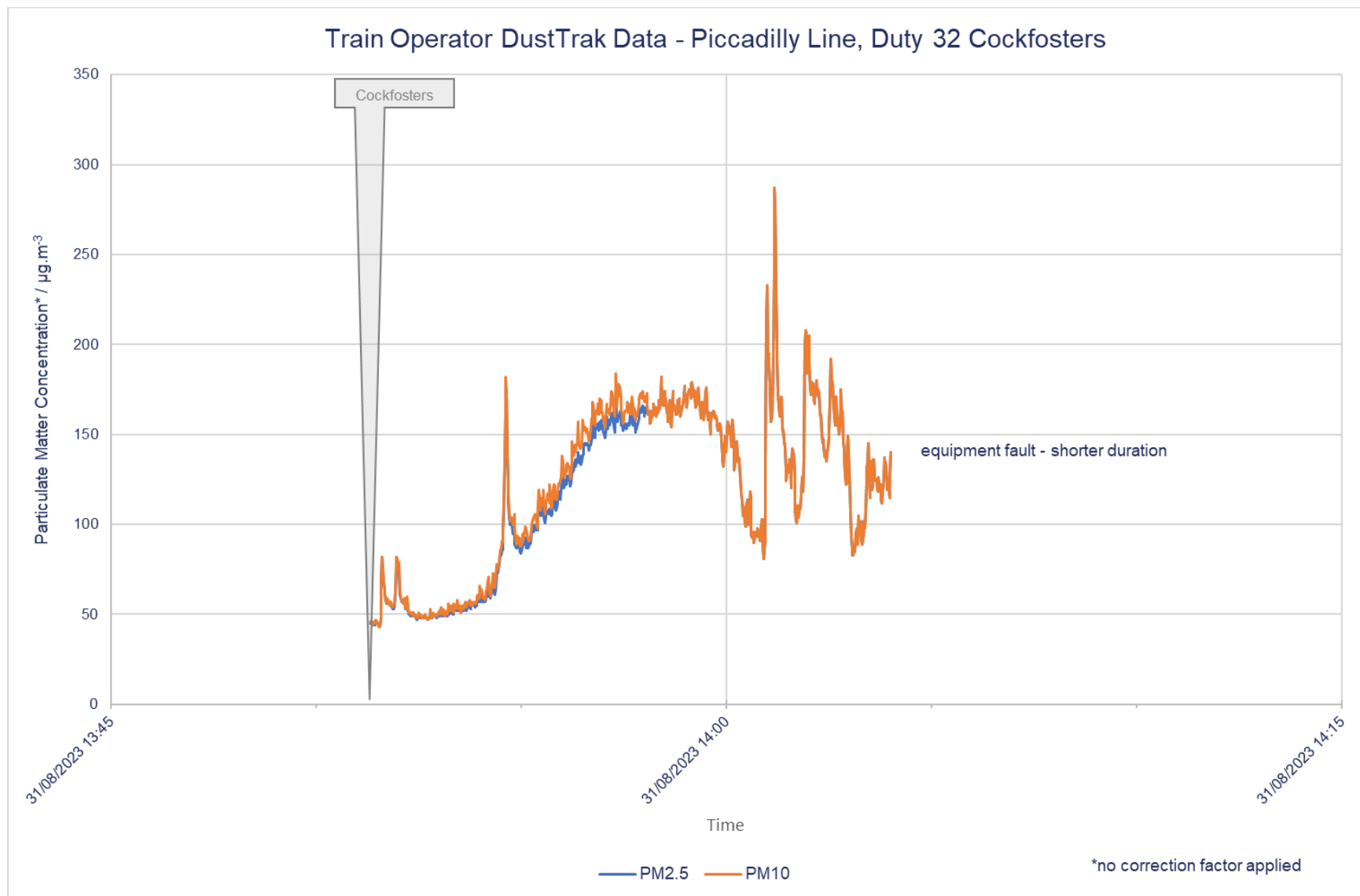
# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

FIGURE 4. REAL-TIME PARTICULATE MATTER DATA – NORTHERN LINE



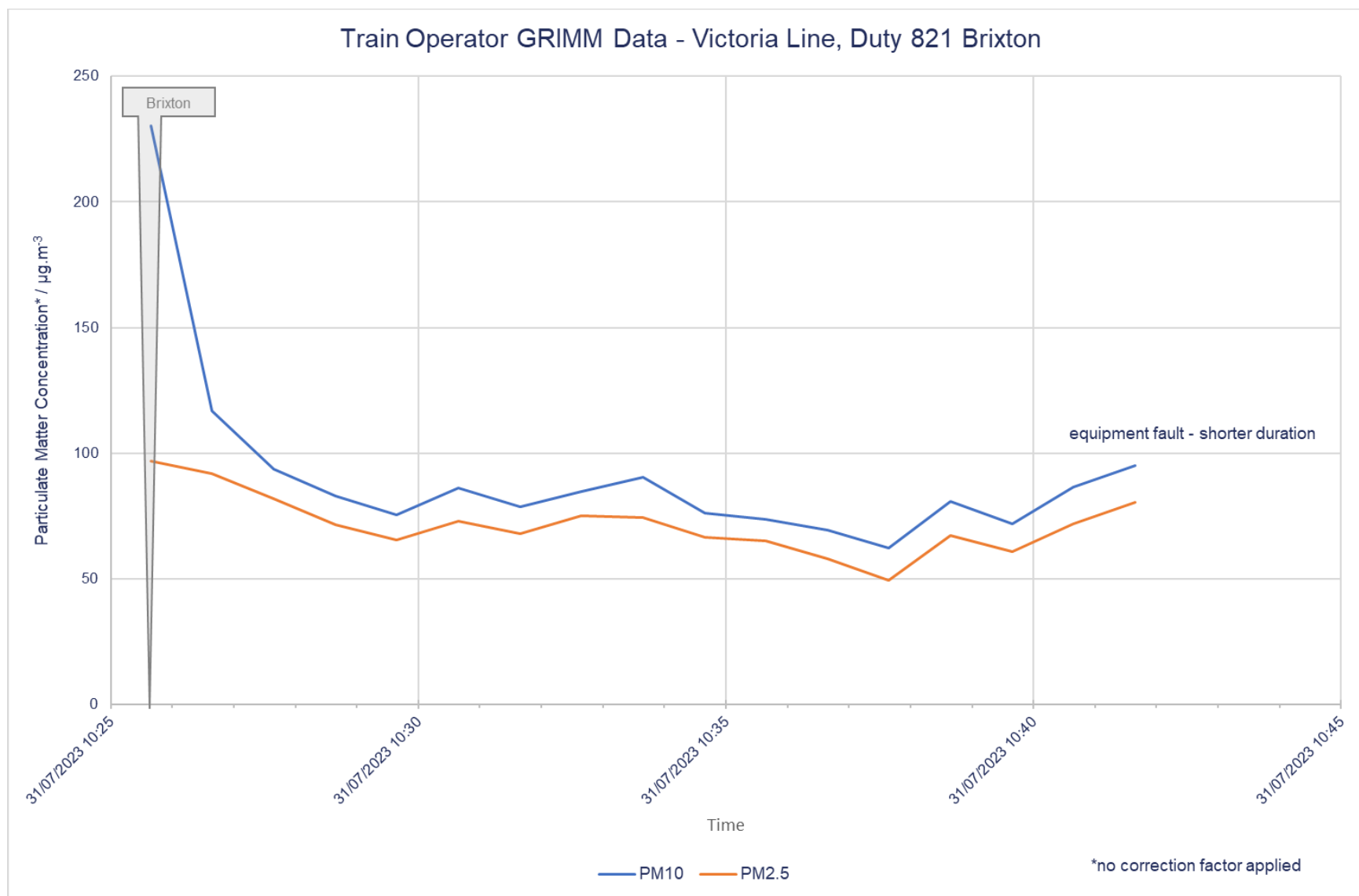
# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

FIGURE 5. REAL-TIME PARTICULATE MATTER DATA – PICCADILLY LINE



# AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

FIGURE 6. REAL-TIME PARTICULATE MATTER DATA – VICTORIA LINE



## AIRBORNE DUST MONITORING ON LONDON UNDERGROUND TRAIN OPERATORS 2023

**TABLE 10. COMPARISON OF 2021 AND 2023 DATA – RESPIRABLE DUST CONCENTRATIONS**

2021			2023		
LINE	DATES	RESPIRABLE DUST CONCENTRATION / MG.M <sup>-3</sup>	LINE	DATES	RESPIRABLE DUST CONCENTRATION / MG.M <sup>-3</sup>
Northern	19/05/2021 to 21/05/2021	0.37 (SD=0.03)	Northern	17/08/2023, 18/08/2023 and 06/10/2023	0.30 (SD = 0.05)
Bakerloo	28/04/2021 to 30/04/2021	0.35 (SD=0.08)	Piccadilly	29/08/2023 to 31/08/2023	0.28 (SD = 0.05)
Victoria	21/04/2021 to 23/04/2021	0.31 (SD=0.11)	Bakerloo	02/08/2023 to 04/08/2023	0.25 (SD = 0.06)
Piccadilly	30/06/2021 to 02/07/2021	0.26 (SD=0.02)	Central	07/08/2023, 08/08/2023 and 10/08/2023	0.19 (SD = 0.01)
Central	12/05/2021 to 14/05/2021	0.23 (SD=0.05)	Victoria	24/07/2023, 28/07/2023 and 31/07/2023	0.19 (SD = 0.08)
Jubilee	06/07/2021 to 08/07/2021	0.12 (SD=0.00)	Circle/H&C	07/09/2023, 15/09/2023 and 26/09/2023	0.18 (SD = 0.12)
Circle/H&C	26/05/2021 to 28/05/2021	0.05 (SD=0.02)	District	28/09/2023, 29/09/2023 and 05/10/2023	0.18 (SD = 0.20)
District	09/06/2021 to 11/06/2021	0.04 (SD=0.01)	Jubilee	20/07/2023, 21/07/2023 and 28/07/2023	0.13 (SD = 0.04)
<b>Mean – 2021 (all lines)</b>		<b>0.22 (SD = 0.13)</b>	<b>Mean – 2023 (all lines)</b>		<b>0.21 (SD = 0.06)</b>