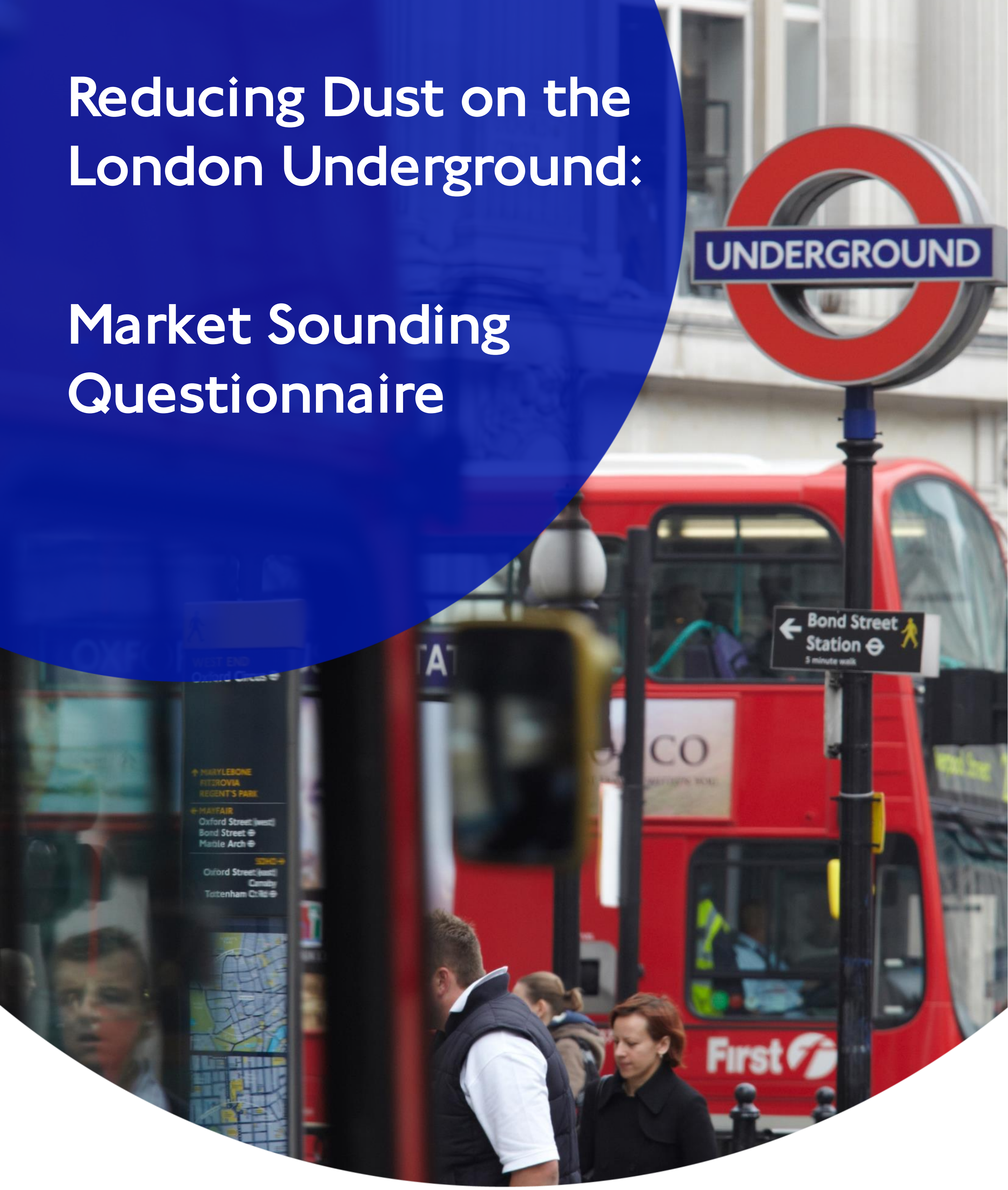
Reducing Dust on the London Underground:

Market Sounding Questionnaire



30 November 2023

EVERY JOURNEY MATTERS

Contents

1. Introduction

This Market Sounding Questionnaire (MSQ) is issued by Transport for London (TfL).

Our monitoring shows that airborne particulate matter (PM) levels on the Tube are below occupational limits set by the Health and Safety Executive (HSE), but we're not complacent.

TfL is seeking information on solutions that can improve air quality in London Underground stations, passenger carriages and driver cabs.

The goals of this MSQ are to:

- Understand what additional solutions exist that could supplement the work already taking place
- Understand what technologies exist in other industries that might be applicable to this problem area
- Gauge suppliers' interest, capabilities, and capacity to engage in a trial

2. Background Information

The accumulation of dust is a common feature of all underground networks across the world, and London's Tube network is no exception. Trains moving over rails, engineering works, and customer use all contribute to dust levels. TfL are working to reduce dust on the Tube to ensure the air quality there stays safe for our staff and customers.

The quality and content of the air we breathe is impacted by a variety of factors. In the London Underground network these factors include:

- Tunnel depth
- Station & platform design
- Frequency of train service
- Ventilation systems (Mechanical & train induced)

The London Underground was the world's first underground railway, opening in 1863. Modern stations are now designed to be more spacious with better ventilation systems. However, retrofitting this into our existing Underground network is extremely costly, as well as a significant engineering challenge.

'Dust', as defined in this document, is a catch-all term for both fine and coarse dust which includes particulate matter (PM), inhalable dust (<100μm) and respirable dust (<4μm). It refers to any particle 200 microns or smaller.

Where are dust levels on the Tube higher?

The older and deeper lines tend to be dustier. This is likely to be because they do not have modern ventilation infrastructure and may have had old rolling stock operating there previously.

Particulate matter concentrations may be higher at the sides of platforms by the tunnel entrance as opposed to the middle of the platform due to mid-platform passenger access tunnels, as noted in a study of Barcelona Metro (T Moreno, 2014).
Newer parts of the network such as the Northern Line Extension, as well as older areas which have been recently deep cleaned, tend to have lower dust levels.

What is in the dust and where does it come from?

Dust on the Tube is made up of a mix of:

- Metal particles - most of which are iron oxide
- Organic matter like skin and hair
- Mineral dust

For a more detailed breakdown please see table 1 and 2 in the Appendix.

What are the limits and how does TfL comply?

The London Underground is well below the legal limits set by the Health and Safety Executive (HSE). We also measure against lower limits recommended by the Institute of

Occupational Medicine (IOM) and in the vast majority of cases levels are also below those lower limits. An example of our compliance is shown in table 3 in the Appendix.

Where do these particles come from?

These materials originate from several different sources. It mostly comes from the wheels and rails, through general use and maintenance.

It can also come from braking. We use different types of braking, but friction braking is what most commonly creates metallic swarf (small pieces of metal). Therefore, higher train frequencies also contribute to PM concentrations, as increased acceleration and faster braking is required. Modern trains use friction brakes less. See table 4 in the Appendix for more information about braking.

This is supported by analysis on the Barcelona subway which suggests the particles are formed “due to high-temperature frictional processes” because of their “planar and flake-like” shape (Guidance for Improving Subway Quality, Health Canada, 2022).

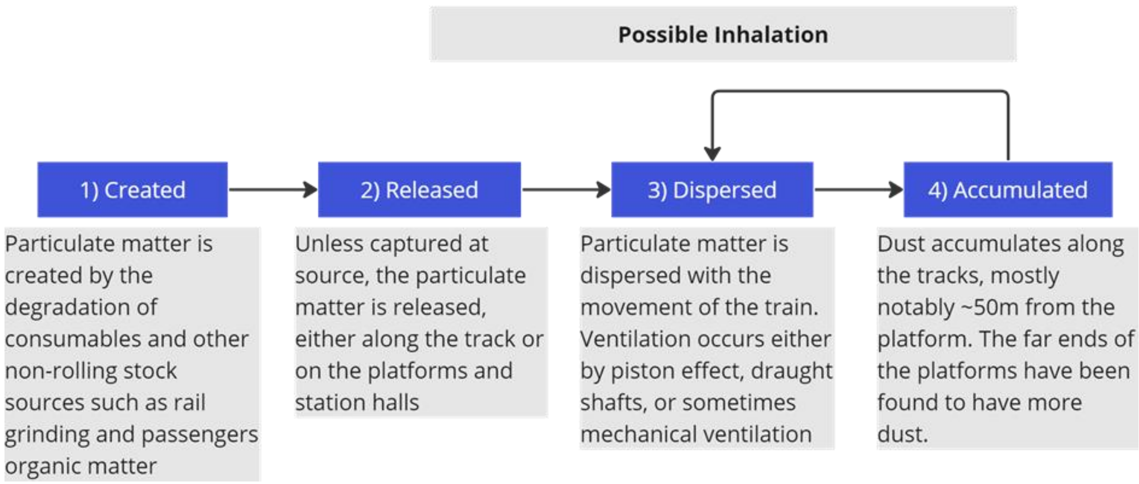
Table 5 in the Appendix shows an estimation, specific to the London Underground, of which parts are likely to degrade to dust and why.

Table 6 in the Appendix gives information about other sources of dust, such as people, rail grinding, older trains, and engineering works.

The Journey of a Dust Particle

Below is a diagram showing the semi-cyclical nature of dust dispersal. Viewing the problem in this way helps us to categorise problem areas and evaluate which solution areas could be most cost-effective.

The resuspension of dust is caused mostly by trains coming and going. See table 7 in the Appendix for more information on our ventilation systems.



3. Problem Statements

Below are the following problems statements TfL is seeking market feedback on:

1. How might we **reduce the amount of dust created**?
    a) Due to braking
    b) Due to trains moving through curves in the track

2. How might we **prevent dust from being released** into the air after it has been created?
    a) Due to rail grinding
    b) Due to braking
    c) Due to trains moving through curves in the track

3. How might we **filter the air** to reduce the concentration of particulate matter?
    a) On the platform
    b) In the train driver's cab
    c) In train carriages

4. How might we better **control the accumulation** of dust so that it can be cleaned more easily?
    a) Of old and new dust
    b) In the tunnels, on the tracks, in vents, on walls

4. Solutions

Intervention TfL are undertaking include:

Intervention	Equipment
Monitoring We use an independent company to do annual air quality monitoring across the Tube network. They carry out periodic gravimetric monitoring in 12 core stations (since 2005), and an additional 12 (since 2021). These reports can be found on our website.	Sampling was carried out using pumps with a variety of sampling heads to collect the different fractions of dust needed, as follows: • PM2.5 – sampled using SKC Personal Environmental Monitor (PEM) PM2.5 impactor heads with glass fibre filters • PM10 – sampled using SKC Personal Environmental Monitor (PEM) PM2.5 impactor heads with glass fibre filters • Respirable dust – sampled using cyclone heads with polyvinyl chloride (PVC) filters • Inhalable dust – sampled using IOM Inhalable heads with PVC filters Airborne concentrations are also measured from inside the train cab using Grimm particle monitors.
Cleaning We use an independent company to clean 40% of all tunnels every year. This means that we clean ~10km per month. We inspect all tunnels and prioritise them accordingly.	• H-Class Industrial HEPA Dust Extractor by V-Tuf • Magnetic Swarf Collector • Dustpan and Brush
Carriage and Cab Filters We have filters fitted on all our LU trains to reduce tunnel dust in the carriages and drivers' cabs.	• Coarse grade G3 filters • ISO 16890-1 class ISO Coarse 60 % or greater (S Stock Saloon Filters) • ISO 16890-1 class ISO Coarse 55 % or greater (S Stock Cab Filters)

Interventions TfL has explored include:

There are other solutions which we have explored, some of which may improve air quality on Underground platforms and trains to some extent. However, they have limitations and constraints to being scaled.

Solution	How does it help?	Limitations
Platform edge doors	Restricts air flow from tunnels onto platforms	• Increases PM concentration on trains • Cost & engineering challenges
Air filtration on trains and platforms	Removes PM from tunnel air as it flows into train carriages/cabs and onto the platform	• Cost, space and service impact to retrofit onto older trains • Limited space for large units, questionable scalability, and PPM intervention frequencies
Deep cleaning tunnels walls and track floor	Removes old dust and improves air quality significantly	• Time consuming • Air quality levels returned to what they were within a few months
Newer trains	Less wear from newer train components Modern braking systems use less friction braking	• Cost to retrofit • Would need the redesign of existing rolling stock akin to a full replacement
Water interventions, algae and pressure washing	Brings dust down and cleans away very old dust	• Risk of legionella • Poor drainage, potential damage to assets
Track Trolleys	Fitted with either a vacuum or a large magnet, to attract metallic swarf	• Cumbersome to get onto the tracks
Dust Suppressant Spray	Keeps the finer particles on the surface	• Expensive • Requires carefully managed cleaning schedule
Cleaning Train	Sucks up dust from the ballast and tracks	• Expensive • Significant power consumption • Potentially caused damage to lineside infrastructure

Solutions we would like more information about

Below is an overview of the types of solutions we are interested to learn more about. Whilst solutions would ultimately need to suit our network and technical specifications, at this stage we are keen to learn from suppliers more broadly. Following this MSQ we may carry out follow ups with suppliers to understand more about their technical specifications.

Filtration

- **Static dust filters.** We would need them to have a good air flow rate (m3/h), not be too big, or too noisy.
- **Vent filters.** We would need them to fit out rolling stock grilles, be affordable, and not increase the frequency of how often they need changing
- **Electrostatic filters.** We would need them to not be cumbersome to clean or maintain.
- **Micron diameter.** We are interested in filters which catch inhalable (<100μm) and respirable dust (<4μm) fractions.

Cleaning

We would need the cleaning equipment to be easy to get down onto the tracks and to be relatively unobtrusive, so as not to cause damage, for example to the signalling system. Equipment could only be used during engineering hours (01:00-04:30) and couldn't compromise service the next morning,

Rolling Stock

The parts listed below would need to suit our rolling stock specifications, and not compromise on safety or performance.

- Brake blocks
- Stick lube
- Current collector shoes and wheels materials

Monitoring

Permanent monitoring devices. We would need sensors to be easily and affordably retrofitted into our trains, stations, equipment, and tunnels. We would also need them to be easy to connect, calibrate and maintain.

Data management platform. We would need the data platform and associated software to be open source, easy to access and conduct analysis, and possible to integrate into our existing systems.

Open Call

We are also open to ideas that we have perhaps not yet considered, for example:

- Friction brake conditioning
- Ventilation/fans
- Localised dust capture

Requirements and constraints for solutions

The London Underground network is a complex environment, and any potential solution to the problem must be able to be implemented in the context of this constrained environment. If any solution is to be trialled, the detailed practical implications of these constraints can be explored in more detail. However, as a high-level indication of constraints which should be considered:

- Fire standards and type approval
- Operating hours / engineering hours
- Depth of tube stations
- Limited physical space
- Access to power and connectivity

The solution/supplier must:

- Reduce concentrations of particulate matter as measured on station platforms
- Tackle inhalable dust (100μm or below), with a preference for tackling respirable dust (4μm or below)
- Have considered their environmental impact and minimised their use of energy and resources where possible

5. Feedback request

Feedback is requested in relation to Problem Statements in this document. Your input is important as it will allow us to understand how we might go forward from here in terms of a potential future procurement process or trial.

Please complete the questionnaire in Section 5 and submit it via SAP Ariba. If you have any issues submitting via SAP Ariba please email innovation@tfl.gov.uk

For your feedback to be taken into account, your completed MSQ must be received **by 1pm GMT the 2nd February 2024.**

All timelines provided are subject to change at TfL's discretion:

Activity	Date
Market Sounding Questionnaire Issued	30 November 2023
Market Sounding Questionnaire Deadline	2 February 2024

6. Questionnaire

As part of this market sounding exercise, TfL wishes to seek your knowledge of potential solutions, as well as your views on the extent of your capabilities and appetite to participate in a potential future trial.

TfL would appreciate your feedback in the form of a response to the following questionnaire, with the specific questions to be answered in the blank tables/boxes provided. Should you consider a particular question is not applicable to your organisation, please state "not applicable" in the tables/boxes provided.

This exercise does not form part of a formal procurement process. All responses will be carefully considered but will not bind TfL to undertaking a procurement or any particular approach to a procurement, nor will responses be treated as conveying any promise or commitment on the part of the respondent.

Please complete your details below, followed by the MSQ questions.

Organisation Name:
Key Contact Name:
Key Contact Email:
Key Contact Telephone Number:

1. Which stage/s of the 'journey of a dust particle' does your solution address? (1. Created, 2. Released, 3. Dispersed, 4. Accumulated) In the comments, please include which fraction of dust you tackle (inhalable 100 μm, respirable 4 μm, PM2.5, PM10)

Stage	**(Yes / No)**	**Comments** Where relevant, please explain which fraction of dust your solution/s tackles (inhalable <100 μm, respirable <4 μm, PM2.5, PM10)
1. Created Degradation of consumables and other non-rolling stock sources such as rail grinding and passengers, and organic matter		
2. Released Mostly along the track		
3. Dispersed Piston effect, draught shafts, or mechanical ventilation		
4.Accumulated On the tracks, walls, in corners of the rails, etc		

2. Based on your understanding of the background information and problem statements, please provide details of any proposed solution(s) your organisation would be able to provide, including:

    a. How the solution would result (either directly or indirectly) in a measurable reduction in particulate matter inhaled by TfL customers and staff
    b. How the solution/technology would be applied on the London Underground network
    c. Any assumptions about TfL's infrastructure and resources
    d. If you would intend to subcontract for any part of the solution

    If you have photos, diagrams and/or videos you would like to share in response to this answer, please include them in your submission as an attachment via SAP Ariba. If you are having issues with attaching content, please send the attachments via email to innovation@tfl.gov.uk with the subject 'Air Quality London Underground MSQ'. Please only send us attachments directly addressing the question (Maximum 500 words):

3. Please indicate at what stage of development and deployment your solution(s) is at:

Stage of solution	**Please indicate one box only (Yes / No)**	**Comments**
Concept (the solution is in the design stage)		
Prototype (the solution has been developed and is being tested)		
Deployed (the solution has been deployed in a live environment)		
Other		

If you selected "Yes" for "Deployed" please complete the following question.

Was your solution deployed or trialled in a similar environment to the London Underground? What were the conditions of this deployment? What were the outcomes? (Max 500 words)

4. If you were to participate in a trial to test your solution, what would you need from TfL, including infrastructure, resource and any ongoing maintenance requirement? How long should we run the trial to test your solution? What are your expectations beyond a trial? (Maximum 500 words)

5. Based on your answer to the previous question, how much would it cost to *trial* your solution in a non-live and/or live test environment? Can you provide an estimate of the cost to *scale* your solution across the London Underground network? Please explain your answer (Maximum 300 words)

6. What would encourage or deter you from participating in a trial? Please list and explain up to 2 factors for each.

	Encourage	**Deter**

1		
2		

7. What minimum monetary value would be required to keep you, as a supplier, engaged in a Trial, please explain your answer? (Maximum 300 words)

8. What does your organisation consider to be the top three risks to the successful delivery of a trial? What action do you think can be taken by TfL and/or the supplier to mitigate these risks?

	Risk and description	Mitigation
1		
2		
3		

9. Please provide any further comments you would like to share below. (Maximum 300 words)

7. Appendix

Table 1: Dust sample PM2.5 from London Underground analysis showing % of substances by mass (*PM2.5 on the London Underground,* J. D. Smith, 2020)

Substance	% (by mass, PM2.5)
Iron Oxide	47
Organic Carbon	11
Elemental Carbon	7
Mineral and Metal Oxides	14
Unidentified	21

Table 2: Dust sample PM2.5 from 3 busy London Underground stations, analysis showing % of substances by mass (*The London Underground: dust and hazards to health*, A. Seaton, 2005)

Substance	% (by mass, PM2.5)
Iron Oxide	64-71
Chromium	0.1–0.2
Manganese	0.5–1
Copper	0.1–0.9

Table 3: Comparison of HSE and IOM limits against 2021 average levels across 24 London Underground stations

Concentration	HSE *Workplace Exposure Limits EH40/05, 4th Edition, January 2020* *Long-term exposure limit of (8-hour time weighted average) / MG.M^{-3}*	IOM	TfL *Airborne dust monitoring at various London Underground stations – 2021[1] (Pages 24-25, 27-67) (8-hour time weighted average) / MG.M^{-3}*
Inhalable Dust (<100μm)	10	5	0.45 to 1.78

[1] https://content.tfl.gov.uk/dust-monitoring-lu-stations.pdf

Respirable Dust (<4µm)	4	1	0.02 to 2.27
PM 2.5	There are currently no workplace exposure limits for these particulate matter fractions.	There are currently no workplace exposure limits for these particulate matter fractions.	0.17 to 3.25
PM 10	There are currently no workplace exposure limits for these particulate matter fractions.	There are currently no workplace exposure limits for these particulate matter fractions.	0.53 to 4.12

Table 4: Types of braking on London Underground trains

Type of Braking	Description
Dynamic	This type of braking minimises dust generation. During service braking, the dynamic brake is given priority, so as to maximise energy recovery and minimize the use of the friction brake. The traction motors are used to generate electricity hence producing a retardation which slows the train down. The electricity is either: - Returned to the 3rd/4th rail through the shoegear (Regeneration) - Dissipated in the brake resistor on each car (Rheostatic)
Friction	This type of braking wears the brake blocks. Friction brakes are pneumatic and fed from the main line compressed air system. In emergency braking, the friction brake is the only brake used. At high speed or loads, brake blending adds some friction brake to supplement the dynamic brake

Table 5: Estimation of the main sources of metallic dust on the London Underground. Data from 2018.

Consumables	Material composition and process of degradation	Estimated Tonnes
Current collector shoes	The shoes are made from various grades of cast iron or steel. They wear against the steel or stainless-steel capped aluminium conductor rails.	40
Wheels	The wheels are made from steel. They wear where they contact the running rail, and to a lesser degree where they come into contact with the brake blocks.	83
Brake blocks	Blocks are made from a commercially sensitive composite material, and approximate composition is: • Inert organic Material 7.7% • Organic material 22.0% • Metal particles 17.1% • Filler 33.1% • Glass fibre 20.1%	63

	Blocks wear from contact with the steel wheel. London Underground uses tread brakes on all stocks, no disc brakes are used. All passenger fleets on LU and some Engineering Vehicles use the same composite material, other Engineering Vehicles use cast iron brake blocks.	
Rails	The rails are mostly made of iron bore. Rail will wear where either the collector shoe or the train wheel is in contact. The rails are typically harder that the train parts, so the rail contribution will be smaller than the overall Rolling Stock steel parts.	40 - 100

Table 6: Other sources of dust

Other sources of dust	Description
Passengers and staff	Human hair, skin flakes, and clothing fibres contributes significantly to “fluff” in the tunnels and platforms. This is accompanied by litter such as newspapers and packets.
Rail Grinding	Rails are regularly re-profiled by grinding using special trains. Most of the dust from these operations is collected, but there will be a contribution to the overall material from this source.
Old trains	Some older stock trains consumed more brake block and wheel material, but these have been replaced with newer stock. However, some of the dust generated by these trains will still be in the tunnels.
Works and infrastructure	This is usually site specific, with one relatively short section being worked at a time, so specific dust issues tend to be of short duration. There is a potential for dust that has been accumulated over time to be disturbed by the work and then only becomes airborne with the passage of trains.

Table 7: Types of ventilation in the London Underground

Type of Ventilation	Description
Train induced ventilation (Piston Effect)	Most of the ventilation within our tunnel network is caused by moving trains, with air pushed around or out of the network, and fresh air pulled into the network via entrances/exits and draught relief shafts.
Mechanical forced ventilation	This accounts for circa 10-15% of air flow. On our deep tube tunnel lines and is typically provided using industrial axial tunnel ventilation fans. The majority of the tunnel ventilation fans operate in extract mode. Tunnel ventilation fans are typically contained in a shaft, with new build shafts costs ranging £30-50 million. Not usually wanted by residents.
Draught relief outlets	These are typically located at either end of our more modern stations such as the Jubilee & Northern line extensions and disparate station locations across the rest of the network.

("blast shafts")	
Public area circulation routes	This refers to the platforms, adjoining circulation halls, cross passages, stairs, escalators and station entrance/exits, through which air is either pushed out and/or pulled in.

Anticipated Timelines

All timelines provided are subject to change at TfL's discretion:

Activity	Date
Early Market Engagement Questionnaire Issued	30 November 23
Early Market Engagement Questionnaire Response Deadline	2 February 24
Further Bidder Engagement	January-February 2024
Response Deadline	January February 2024
Contract Award	N/A
Contract Start	N/A

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