

# Air quality on UK diesel and hybrid trains

Anna Font <sup>a,b</sup>, Michael Hedges <sup>a</sup>, Yiqun Han <sup>a</sup>, Shanon Lim <sup>a,c</sup>, Brendan Bos <sup>a,d</sup>,  
Anja H. Tremper <sup>a</sup>, David C. Green <sup>a,e</sup>

<sup>a</sup> MRC Centre for Environment and Health, Environmental Research Group, Imperial College, London, United Kingdom

<sup>b</sup> IMT Nord Europe, Europe, Institut Mines-Télécom, Univ. Lille, Centre for Education, Research and Innovation in Energy Environment (CERI EE), Lille, France

<sup>c</sup> Pattle Delamore Partners, Auckland, New Zealand

<sup>d</sup> E.A. Gibson Shipbrokers Ltd, London, United Kingdom

<sup>e</sup> NIHR HPRU in Environmental Exposures and Health, Imperial College, London, United Kingdom

**EAC 26/08/2024**

# Introduction

Rail services, particularly those operated by diesel-powered trains, also emit air pollutants relevant to passengers and staff inside trains.

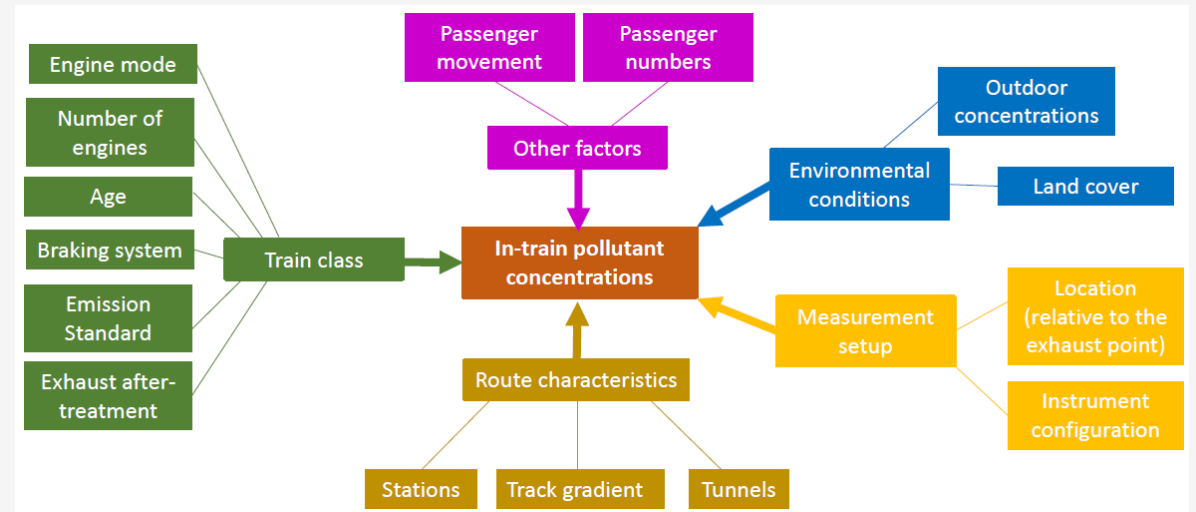
In 2020, 62% of the UK rail tracks were non-electrified.

Emissions on trains can be due to engine exhaust and non-exhaust wear-processes.

Train environments are complex, and many factors are responsible for the in-train concentrations of air pollutants.

This study aimed to characterize the air quality inside diesel and hybrid trains in the UK.

*Factors affecting in-train concentrations (adapted from Otuyo et al., 2023).*



# Methods

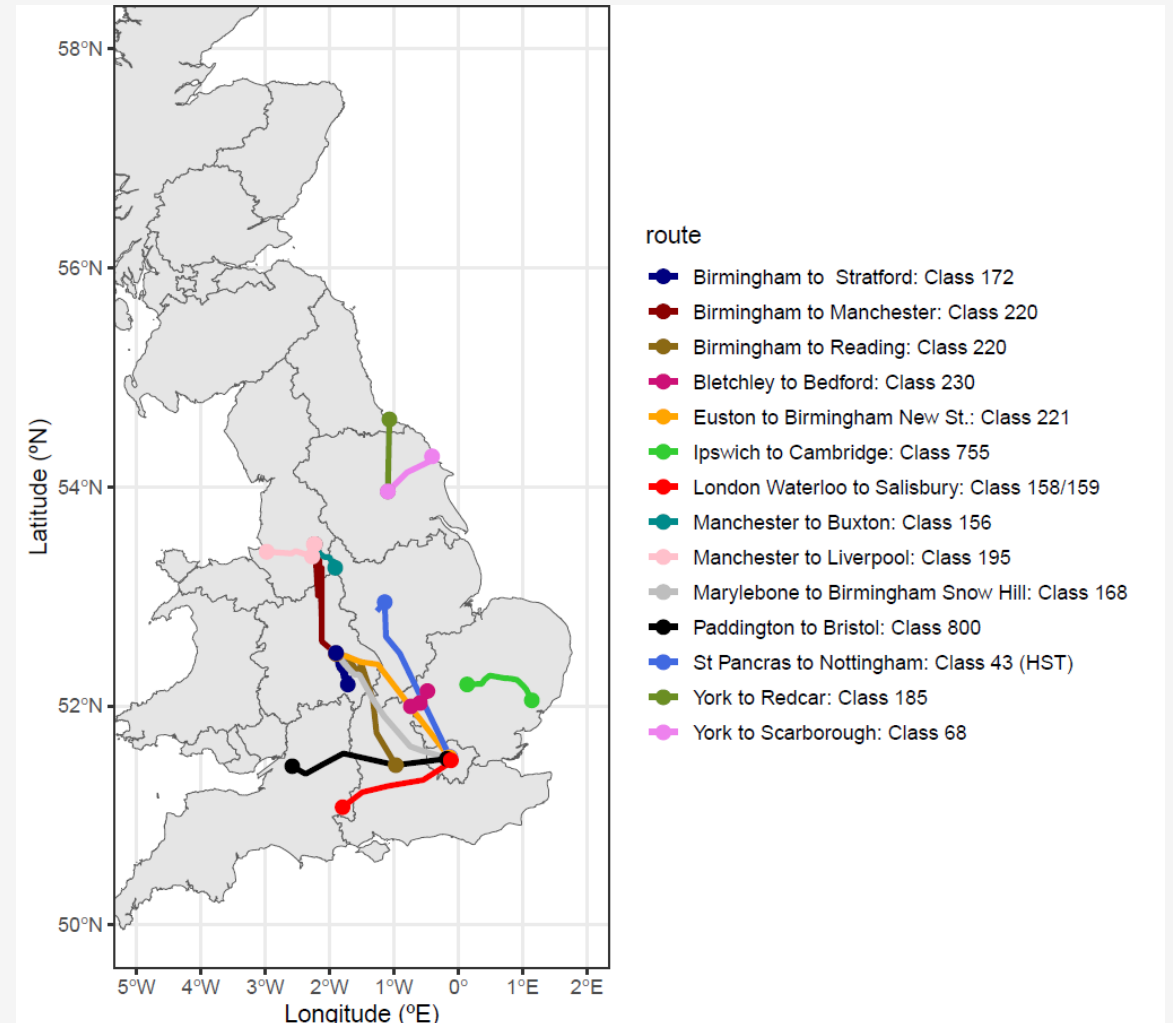
- Measurement campaigns in 2020 & 2021
- Measured NO<sub>2</sub>, (NO<sub>x</sub>), PM<sub>10</sub>, PM<sub>2.5</sub>, UFP, PNC and Black Carbon.
- These are the major pollutants of concern to health that may be elevated by railway sources.
- The longest journey was between London St Pancras and Nottingham, covering 172 km in approximately 90 min. The shortest route was Bletchley to Ridgmont and Bedford, covering 23 km in under 20 min.



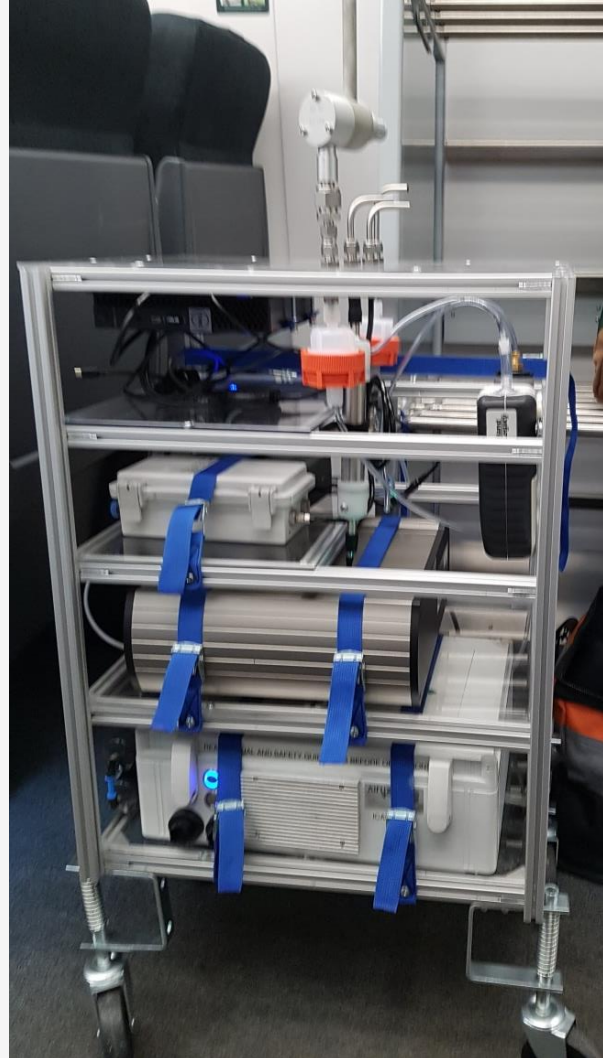
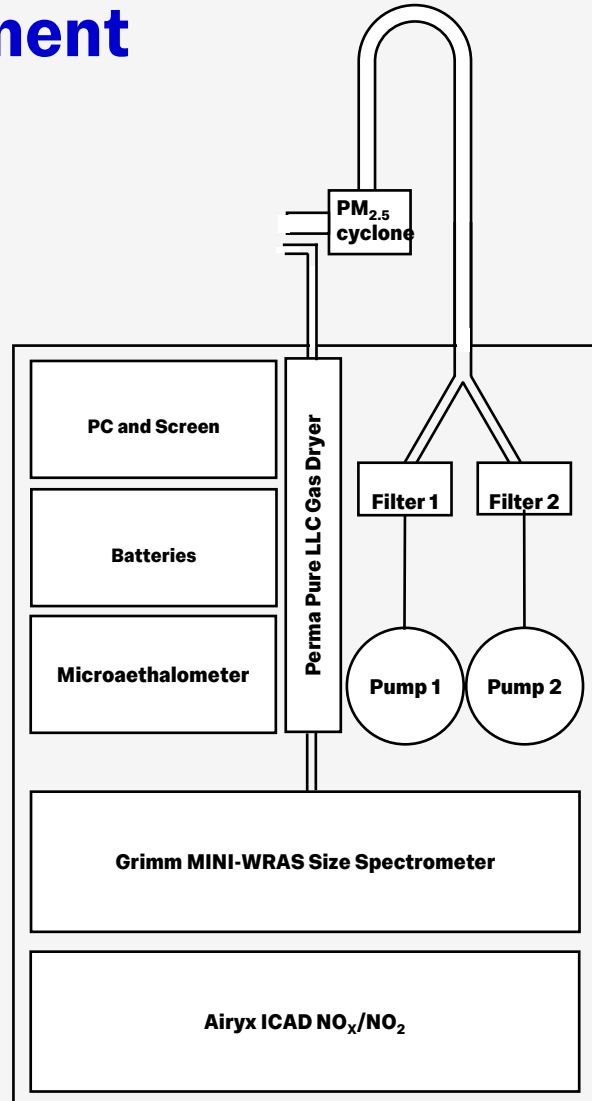
- **13 routes**
  - **11 fully diesel-powered**
  - **2 diesel bi-mode**
  - **Electric trains were planned but could not be measured due to COVID**
- **~5 return journeys per train**
- **119 journeys in total**

# Routes

Route	Type	Approx Age
London St Pancras – Nottingham	Diesel	45
York – Scarborough	Diesel	8
Manchester Piccadilly - Buxton	Diesel	34
London Waterloo – Salisbury	Diesel	30
Marylebone – Birmingham Snow Hill	Diesel	22
Birmingham New St - Whitlocks End	Diesel	11
York – Redcar	Diesel	15
Manchester Piccadilly – Liverpool Lime St	Diesel	3
Birmingham New St – Manchester Piccadilly/Reading	Diesel	18
London Euston – Birmingham New St.	Diesel	18
Bletchley-Ridgmont/ Bletchley- Bedford	Diesel	1
Ipswich – Cambridge	Hybrid	<1
London Paddington – Bristol Temple Meads	Hybrid	2



# Equipment





Atmospheric Environment

Volume 315, 15 December 2023, 120160



## Characterising a mobile reference station (MoRS) to quantify personal exposure to air quality

Michael Hedges <sup>a</sup>  , Max Priestman <sup>a</sup>, M. Chadeau-Hyam <sup>c</sup>, R. Sinharay <sup>d</sup>, Frank J. Kelly <sup>a, b</sup>, David C. Green <sup>a, b</sup>

12:15pm - 12:30pm

**Particle number size distributions in subway and underground train carriages**

**Michael Hedges, Max Priestman, Marc Chadeau-Hyam, Rudy Sinharay, Frank J Kelly, David C Green**

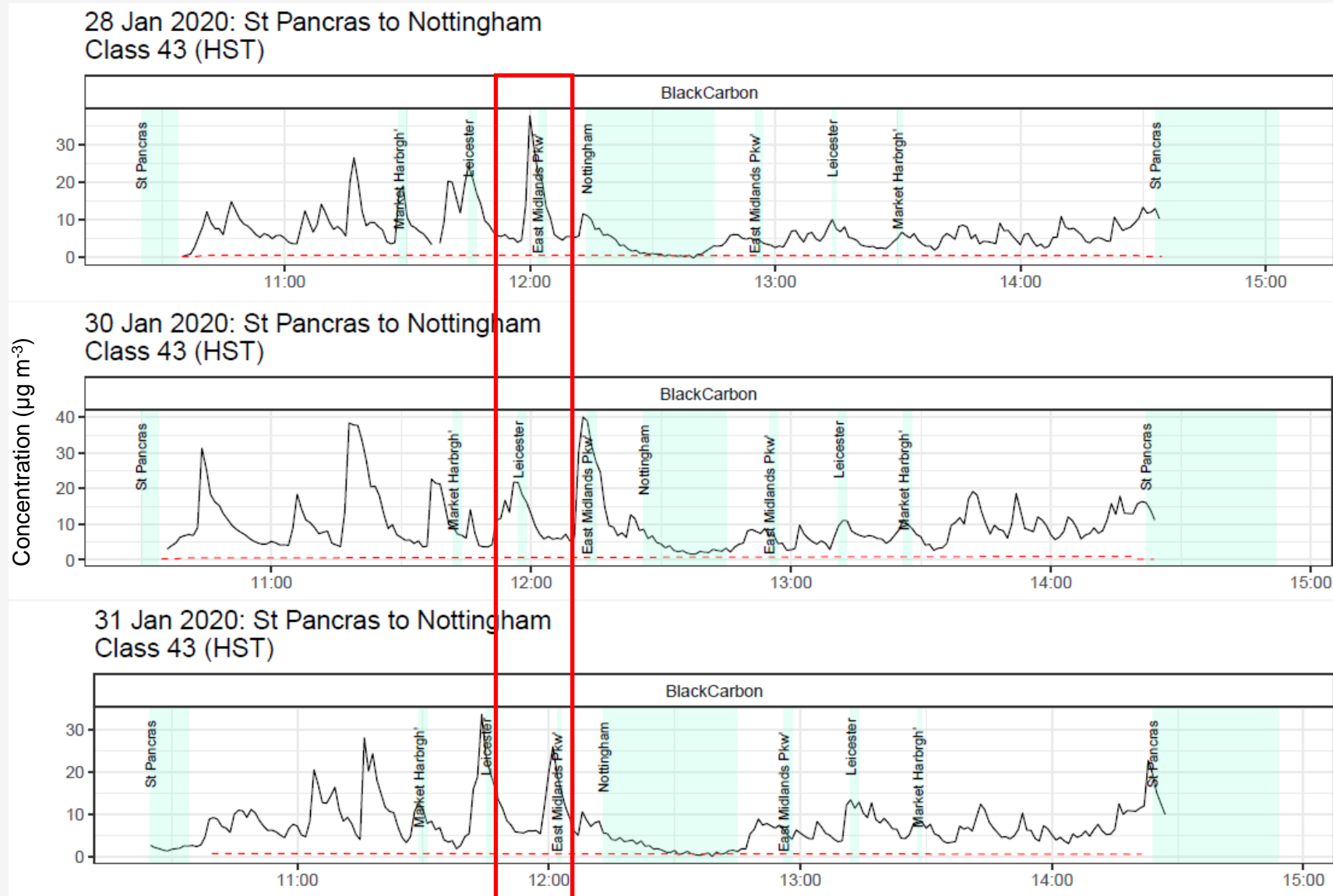
Imperial College, United Kingdom

*Session Details:*

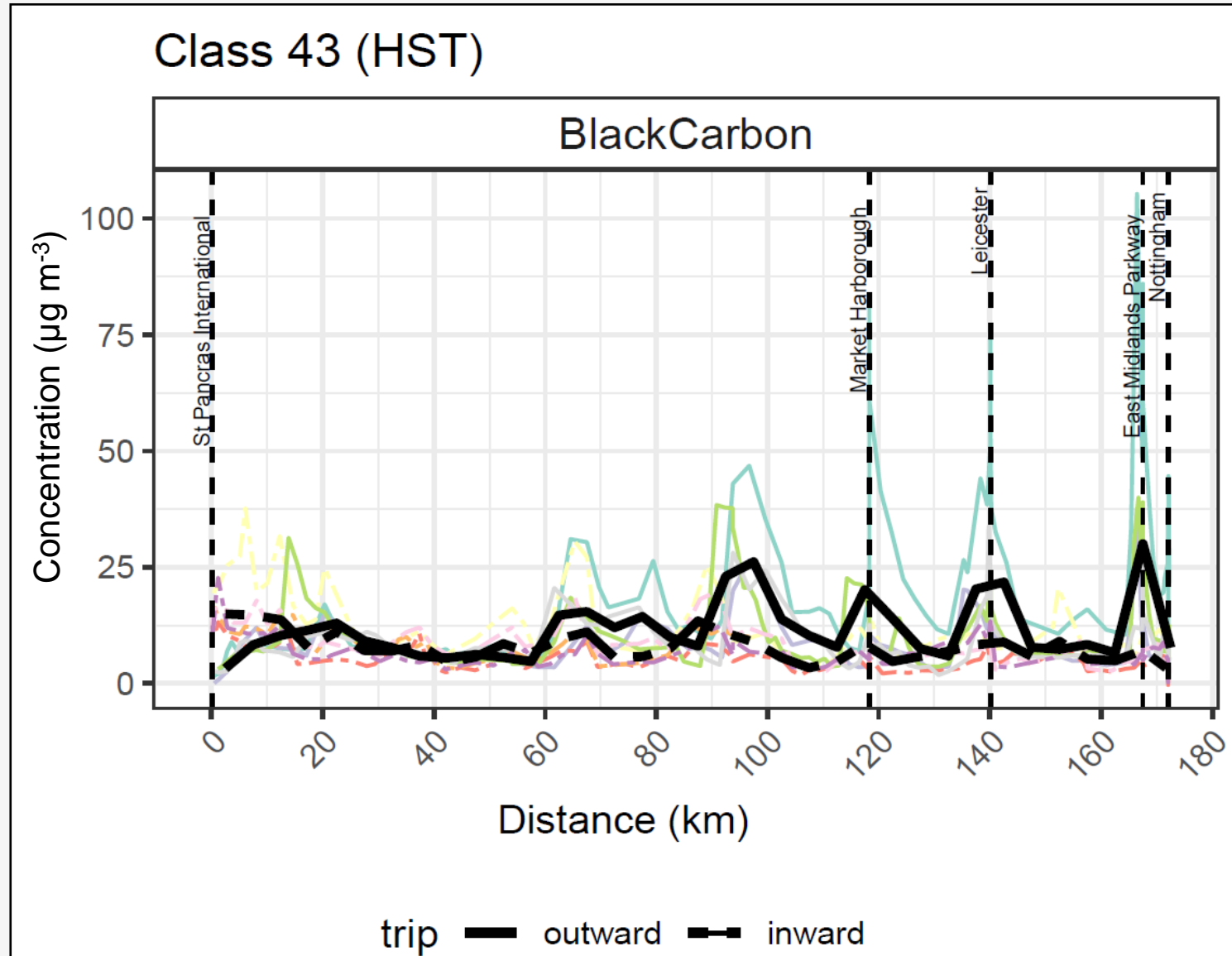
**Health effects of aerosols (II)**

Time: 28/Aug/2024: 12:15pm-1:45pm · Location: Duetto 1

# Data analysis development: time vs distance



# Data analysis development: time vs distance





# Results overview

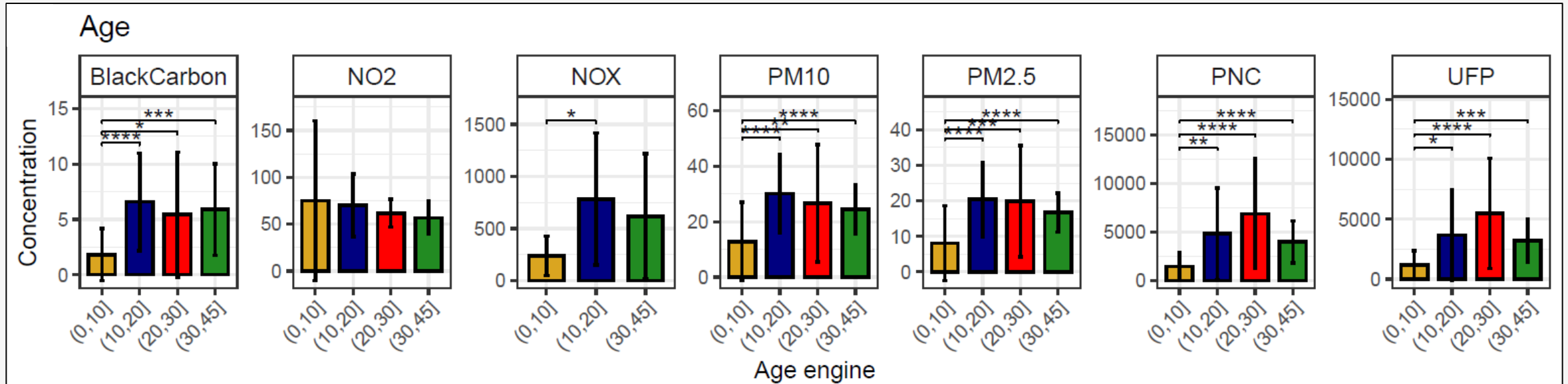
Class	Appr. Age	N	Duration	Distance	BC	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	PNC	UFP
	(years)		(min)	(km)	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(# cm <sup>-3</sup> )	(# cm <sup>-3</sup> )
Class 755	<1	9	41	70.6	0.6 ± 0.7	40 ± 28.7	--	7.5 ± 2.1	4.4 ± 2.1	1867 ± 1398	1550 ± 1174
Class 230	1**	10	85	23	0.6 ± 0.6	76 ± 19.2	--	24 ± 22	17 ± 17	2056 ± 1,320	1721 ± 1122
Class 800	2	10	77	166	1.4 ± 0.7	201 ± 115	--	12 ± 3.7	7.6 ± 2.4	2963 ± 1063	2456 ± 876
Class 195	3	8	68	46.5	2.4 ± 1.9	43 ± 30	3456 ± 173	8.8 ± 2.2	3.9 ± 1	333 ± 179	225 ± 127
Class 68	8	8	53	56.3	3.9 ± 3.7	28 ± 19	130 ± 134	16 ± 7.4	6.3 ± 3	623 ± 862	423 ± 631
Class 172	11	6	53	32.6	3.5 ± 1.3	37 ± 5.9	335 ± 175	27 ± 11	16 ± 6.6	1538 ± 1034	1008 ± 729
Class 185	15	10	74	73	7.8 ± 5.8	94 ± 37.2	1053 ± 675	31 ± 25	16 ± 6.9	1735 ± 1663	1176 ± 1220
Class 220	18	8	88	117	5.3 ± 2.8	59 ± 24.7	823 ± 491	31 ± 11	18 ± 7.3	2130 ± 1602	1465 ± 1177
Class 221	18	10	94	160	7.3 ± 2.7	94 ± 18.5	--	52 ± 21	31 ± 14	10307 ± 3549	8172 ± 2809
Class 168	22	10	110	160	3.1 ± 2.5	57 ± 16	--	17 ± 6.7	13 ± 6.9	4839 ± 3183	3731 ± 2446
Class 158/9	30	4	89	126	11 ± 7.7	71 ± 9.1	--	51 ± 24	36 ± 18.6	11231 ± 7181	9131 ± 5840
Class 156	34	9	58	31.6	2.7 ± 1.8	52 ± 22	544 ± 510	28 ± 13	15 ± 6.8	2739 ± 2532	2310 ± 2284
Class 43 (HST)*	45	10	102	172	9.8 ± 4.5	56 ± 8.5	--	24 ± 4.6	18 ± 4.3	4615 ± 832	3593 ± 674
<b>All</b>					<b>4.6 ± 3.4</b>	<b>71 ± 47</b>	<b>538 ± 344</b>	<b>25 ± 14</b>	<b>16 ± 10</b>	<b>3613 ± 3437</b>	<b>2843 ± 2790</b>

\*This HST is not fully representative of the whole remaining fleet of HST trains, the majority of which are powered by the MTU4000 16V4000R41R engine. \*\*Repurposed London Underground D Stock

Site	BC	NO <sub>2</sub>	NO <sub>x</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	PNC	UFP
	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(µg m <sup>-3</sup> )	(# cm <sup>-3</sup> )	(# cm <sup>-3</sup> )
London Roadside	1.3 ± 0.7	22 ± 8.7	52 ± 31	17 ± 8.7	10 ± 7.0	13714 ± 7067	-
London Background	0.7 ± 0.6	8.5 ± 5.0	14 ± 12	13 ± 8.5	8.8 ± 6.9	6653 ± 4905	-

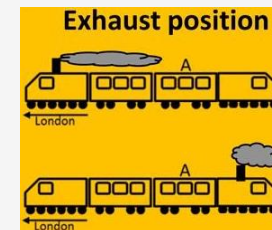
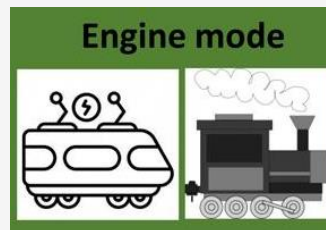


# Results overview

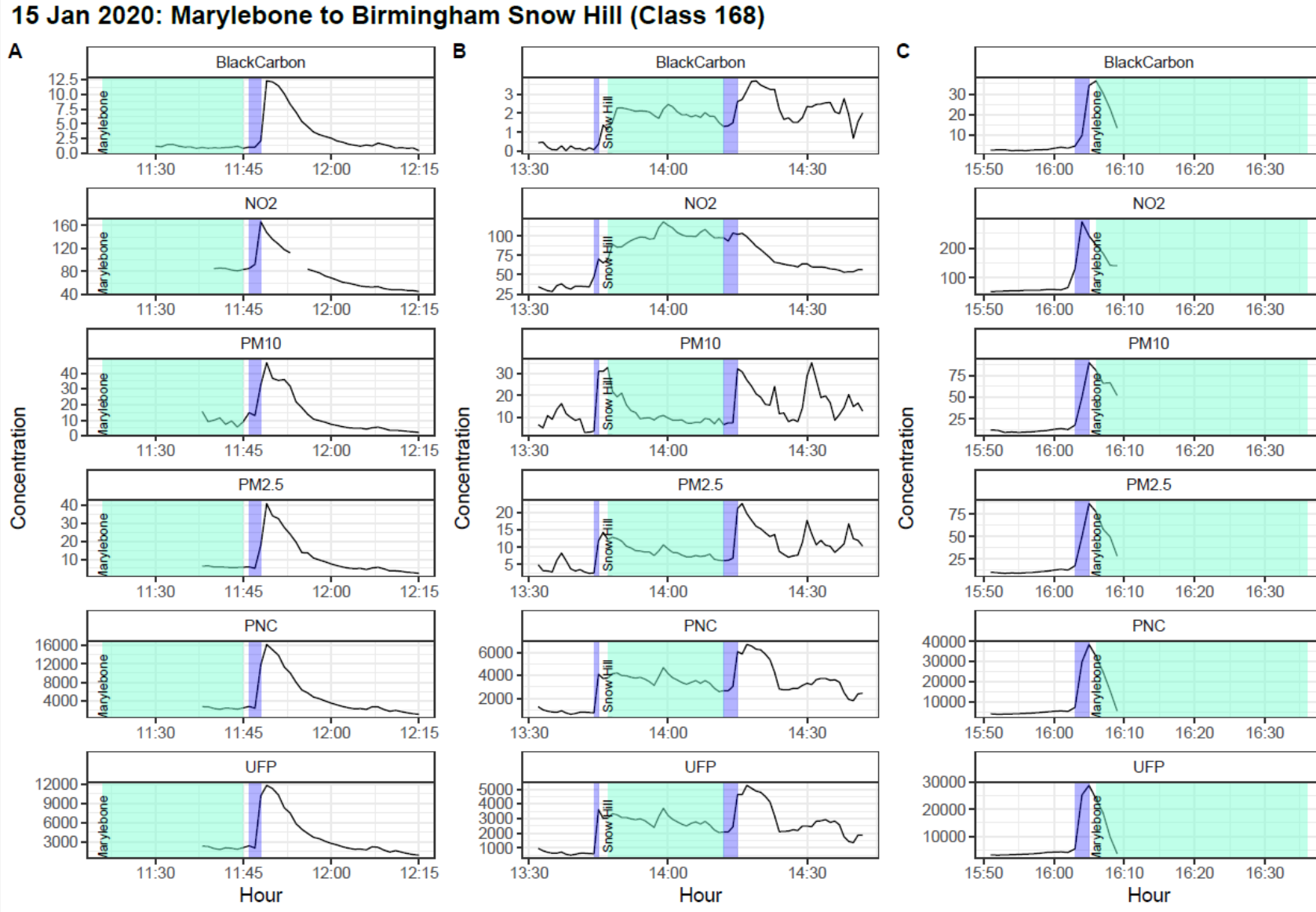


# What has the greatest impact on in-train concentrations?

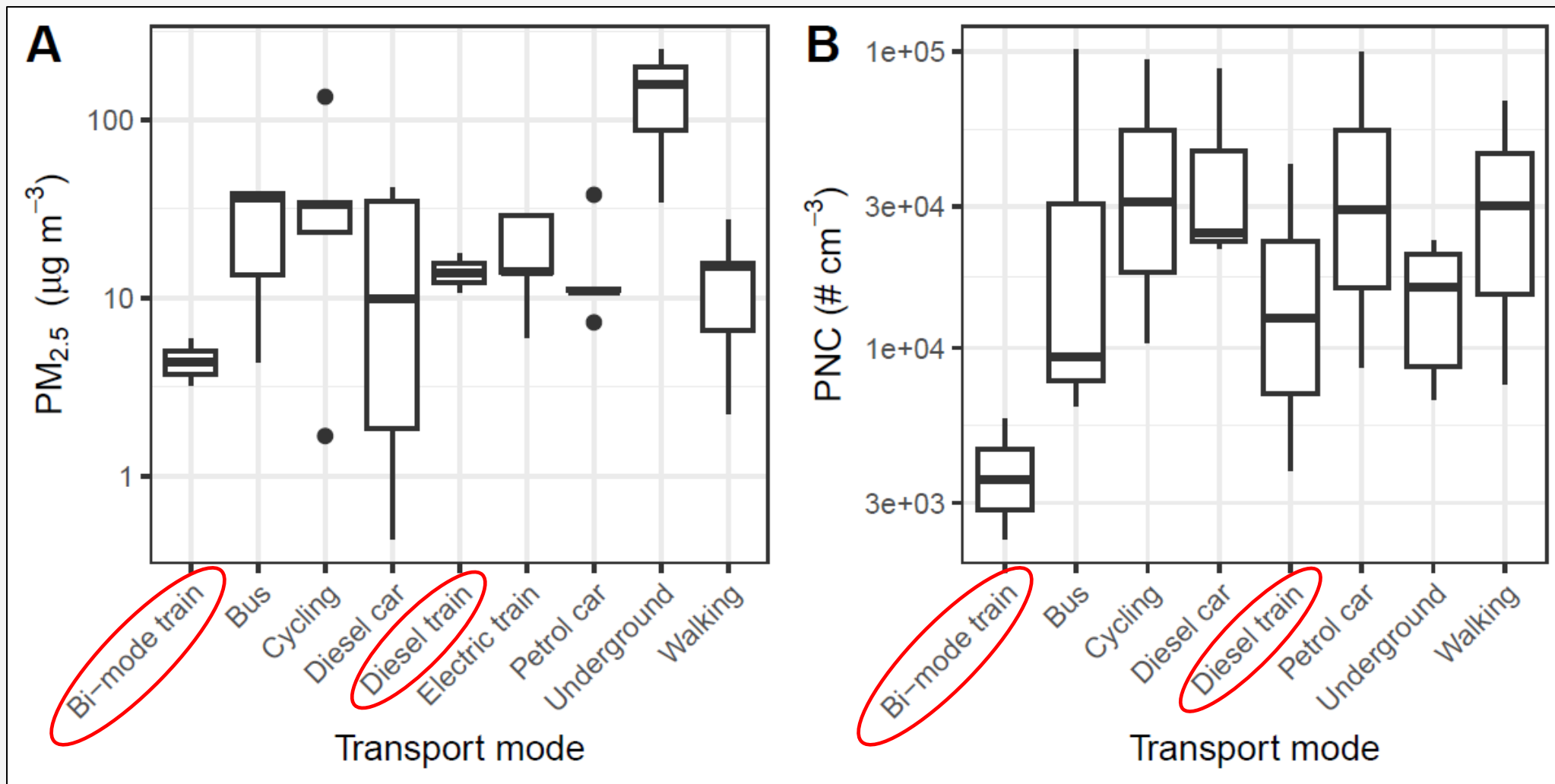
Controlling factor	Train class	Ratio	PM <sub>10</sub>	PM <sub>2.5</sub>	PNC	UFP	BC	NO <sub>x</sub>	NO <sub>2</sub>
<b>Engine mode</b>	755	Diesel/electric	1.1 [0.24 - 2.1] N = 9	1.3 [0.17 - 2.8] N = 9	1.9 [0.32 - 5.0] N = 9	2.0 [0.35 - 5.2] N = 9	1.5 [-4.3 - 10] N = 9	--	1.5 [0.36 - 2.9] N = 8
<b>Engine mode</b>	800	Diesel/electric	1.4 [0.88 - 2.2] N = 7	1.9 [0.9 - 2.8] N = 7	4.2 [0.86 - 8.1] N = 7	4.3 [0.79 - 8.4] N = 7	5.3 [1.6 - 10] N = 9	--	13 [2.8 - 38] N = 9
<b>Exhaust</b>	168, 755, 230	In front/behind	1.9 [1.4 - 2.5] N = 3	2.4 [2.1 - 2.8] N = 3	3.0 [1.7 - 4.4] N = 3	3.1 [1.7 - 4.5] N = 3	7.0 [3.8 - 12.8] N = 3	--	3.0 [1.1 - 6.2] N = 3
<b>Tunnel</b>	168	Tunnel/baseline	6.9 [5.1 - 8.7] N = 10	6.4 [4.3 - 8.6] N = 10	7.6 [5.6 - 9.7] N = 10	7.6 [5.3 - 9.9] N = 10	40 [9.4 - 71] N = 10	--	2.8 [2.8 - 2.9] N = 6
<b>Station</b>	All	Station/free-run	1.6 [0.5 - 7.2] N = 109	1.2 [0.5 - 3.9] N = 109	1.0 [0.3 - 4.2] N = 109	1.0 [0.2 - 4.3] N = 109	1.0 [-33; -42] N = 117	1.0 [0.3 - 2.6] N = 55	1.2 [0.4 - 6.8] N = 114
<b>Track gradient</b>	221	Uphill/downhill	1.4 [0.8 - 2.7] N = 5	1.3 [0.7 - 2.7] N = 5	1.3 [0.7 - 2.5] N = 5	1.4 [0.7 - 2.6] N = 5	1.0 [0.4 - 2] N = 5	--	1.4 [1.0 - 1.9] N = 5
<b>Land cover</b>	All	Outdoor (urban)/in-train	0.60 [0.24 - 1.3] N = 14	0.53 [0.16 - 1.2] N = 3	--	0.64 [0.33 - 1.65] N = 6	0.33 [0.06 - 1.8] N = 14	0.05 [0.01 - 0.1] N = 7	0.28 [0.08 - 0.56] N = 14
<b>Land cover</b>	All	Outdoor (rural)/in-train	0.35 [0.23 - 0.45] N = 3	0.37 [0.23 - 0.45] N = 3	--	0.36 N = 1	0.09 [0.02 - 0.25] N = 10	0.01 [0.02 - 0.02] N = 7	0.08 [0.02 - 0.16] N = 10



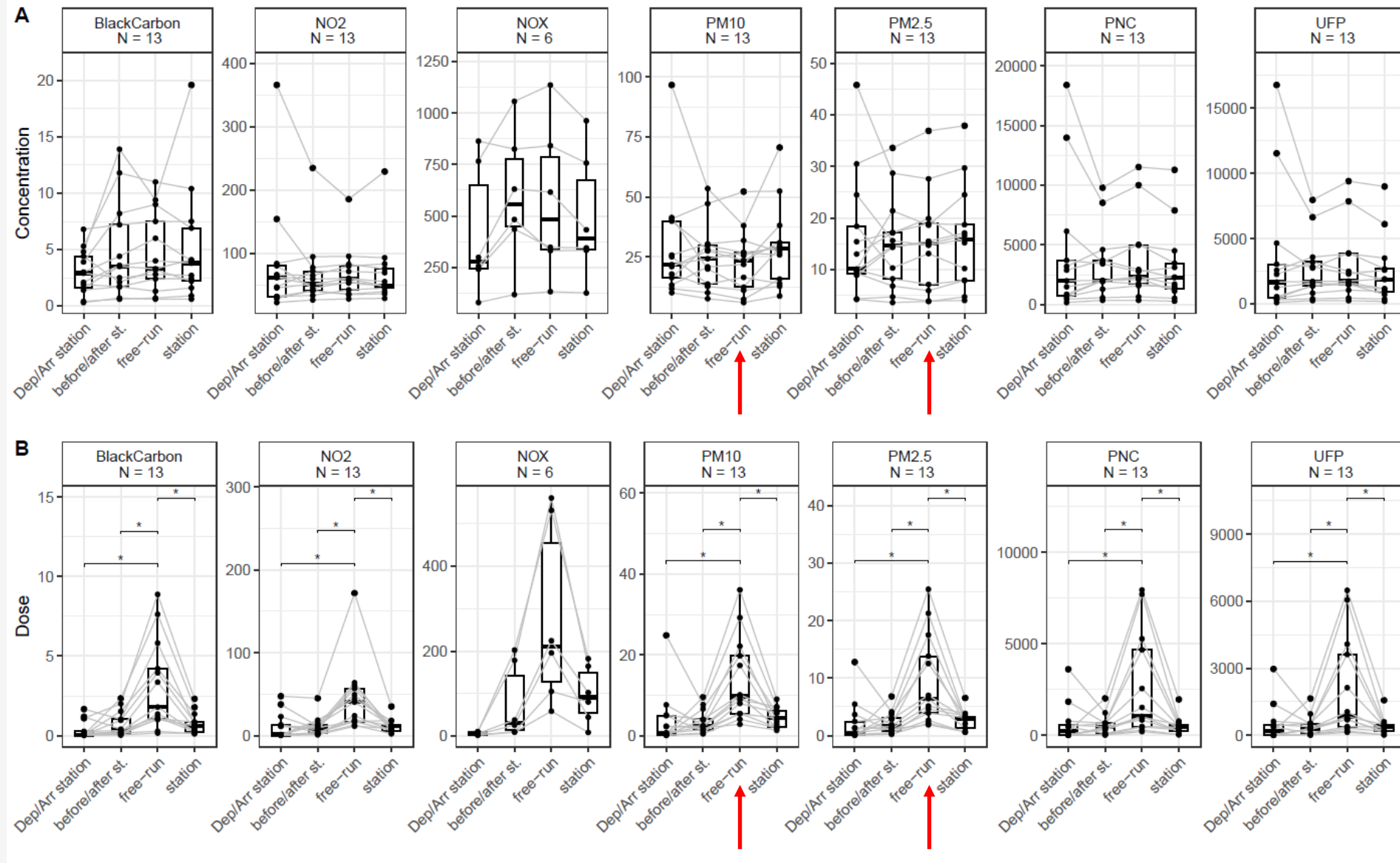
# Tunnels – example journey



# Comparison to other transport microenvironments in the UK



# Estimation of the inhaled dose



# Conclusions and recommendations

- **We successfully characterised in train pollution concentrations.**
- **Factors influencing concentration:**
  - The lowest NO<sub>x</sub>, BC, PM mass and PN concentrations were measured on the newest train classes.
  - The presence of tunnels along the journey had the greatest impact on concentrations.
  - For NO<sub>2</sub>, running on diesel mode was the factor associated with the largest enhancements in in-train concentrations.
- **The largest dose that passengers received was in the in-between-stations parts of the journey.**
- **Recommendations to industry:**
  - Focus on air filtering and purification during the journey as the most effective way to reduce passenger exposure.
  - Eliminate air ingress from exhaust, especially in tunnels.
  - Rolling stock renewal.
- **Limitations of the study:**
  - The calibration of data from portable instrumentation in the same type of environment (i.e., train carriages) was not possible.
  - Other health-relevant air pollutants such as PAHs were not measured
  - Complete characterization in element and metal composition in PM for source characterization was not investigated.

1:15pm - 1:30pm

**Exposures to metallic aerosols in transport microenvironments in London, UK.**

**Phillip Punter<sup>1</sup>, David Green<sup>1</sup>, Sean Beevers<sup>1</sup>, Tuan Vu<sup>1</sup>, Anja Tremper<sup>1</sup>**

Imperial College London, United Kingdom

*Session Details:* **Exposure: sources, levels and assessment techniques (I)**

**Time: 29/Aug/2024: 1:00pm-2:30pm - Location: Duetto 1**





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Full length article

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[Anna Font](#)<sup>a c</sup>  , [Michael Hedges](#)<sup>a</sup>, [Yiqun Han](#)<sup>a</sup>, [Shanon Lim](#)<sup>a 1</sup>, [Brendan Bos](#)<sup>a</sup>,  
[Anja H. Tremper](#)<sup>a</sup>, [David C. Green](#)<sup>a b</sup>

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# Thank you

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