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USING PARTICLE SIZE DISTRIBUTIONS AS AN AID TO SOURCE APPORTIONMENT

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Sources of Particles from a Vehicle

Emissions dependent upon

- vehicle speed (resuspension, tyre and road surface wear)
- engine revs and load (exhaust)
- driving mode (exhaust, brake, tyre, road surface)
- materials (brakes, tyres, road surface)
- fuel and lubricant (exhaust)
- vehicle weight and aerodynamics (resuspension)
- road surface silt loading (resuspension)

SOURCE APPORTIONMENT BY PMF OF WIDE RANGE PARTICLE SIZE SPECTRA

CONTENT

- A new way of merging SMPS and APS data
- Merged data from Marylebone Road, London
- Application of PMF and interpretation of results

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DATA MERGING METHOD

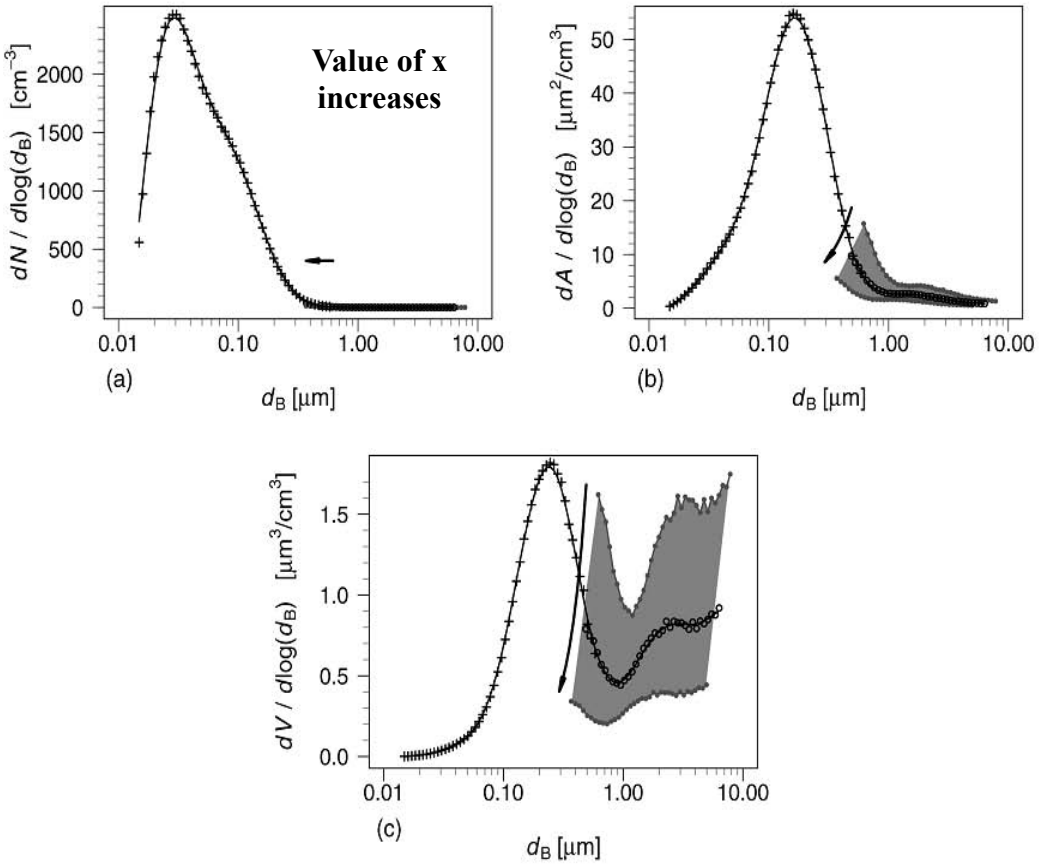

FIG. 1. Illustration of the merging routine. The middle row show the optimum fit and the row above and below this show the results using a high and low x value. (Crosses mark the SMPS data and open circles mark the APS.)

Aerodynamic to mobility diameter

Cunningham Slip Correction Factor

$$d_B^t = \frac{d_a^t}{x}\sqrt{\frac{C\left(d_a^t\right)}{C\left(d_B^t\right)}}$$

Transition-Regime Effective Density

$$x = \sqrt{\frac{\rho_e^t}{\rho_0}}$$

Unit density

Free-parameter x

Beddows, D.C.S., Dall'Osto, M., Harrison, Roy M. (2010). An Enhanced procedure for the merging of atmospheric particle size distribution data measured using electrical mobility and time-of-flight analysers, Aerosol Sci. Technol. 44, 930–938.

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MEAN MERGED SMPS-APS SPECTRA

- REPARTEE II data from the Marylebone Road
- October 2007
- SMPS TSI 3080 Classifier and TSI 3776 CPC
- APS TSI 3321

CRAN – R GUI

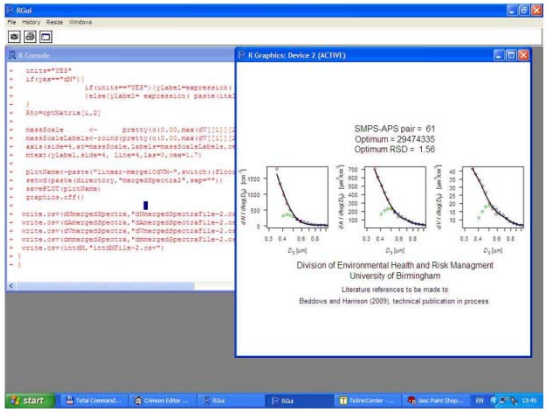

Figure 1. Latest Graphical User Interface for the merging script. The red and blue circles show respectively the part of the SMPS and APS spectrum that are used in the merging routine. The green circles show the APS bins excluded due to a high diffusional losses in comparison to the overlapping SMPS spectra.

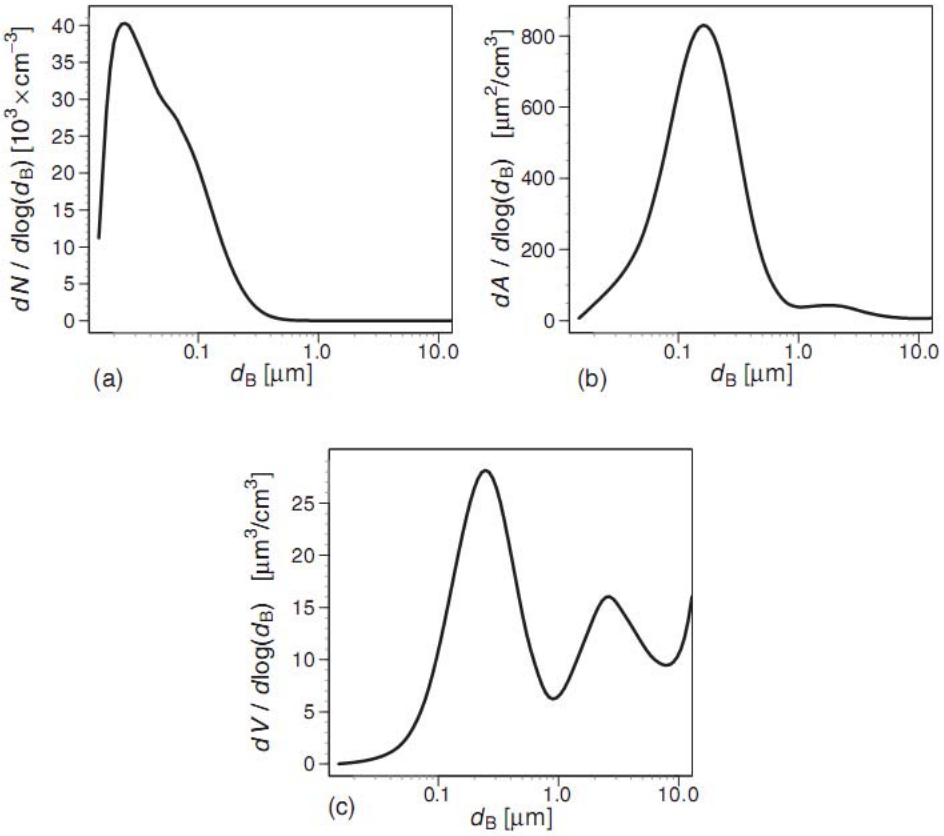

FIG. 4. The mean spectra of the merged data collected from Marylebone Road during the October 2007 campaign.

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PMF ANALYSIS OF MERGED SMPS+APS DATA

PMF Analysis of Wide-Range Particle Size Spectra Collected on a Major Highway, R.M. Harrison, D.C.S. Beddows and M. Dall'osto, Environ. Sci. Technol., 5522-5528 (2011).

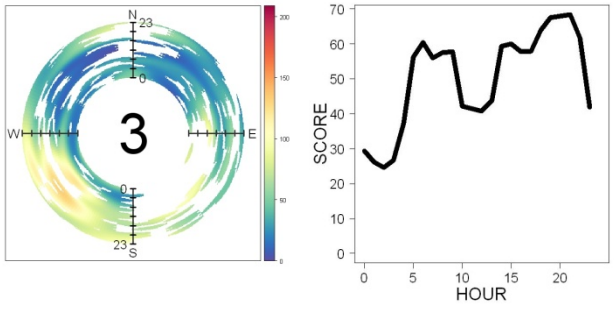
Matrix of Hourly Measurements:

1. Merged SMPS+APS
2. Traffic Counts: LDV/ HDV
3. Meteorological

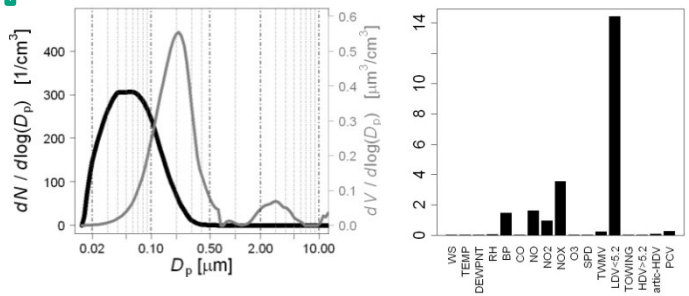
10 factors optimise the fit.

$$x_{ij} = \sum_{h=1}^{p} g_{ij} \cdot f_{hj} + e_{ij}$$

SCORES

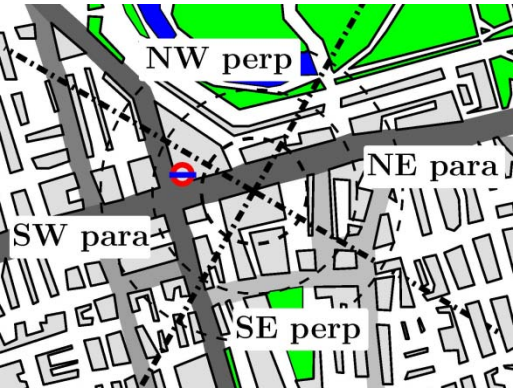


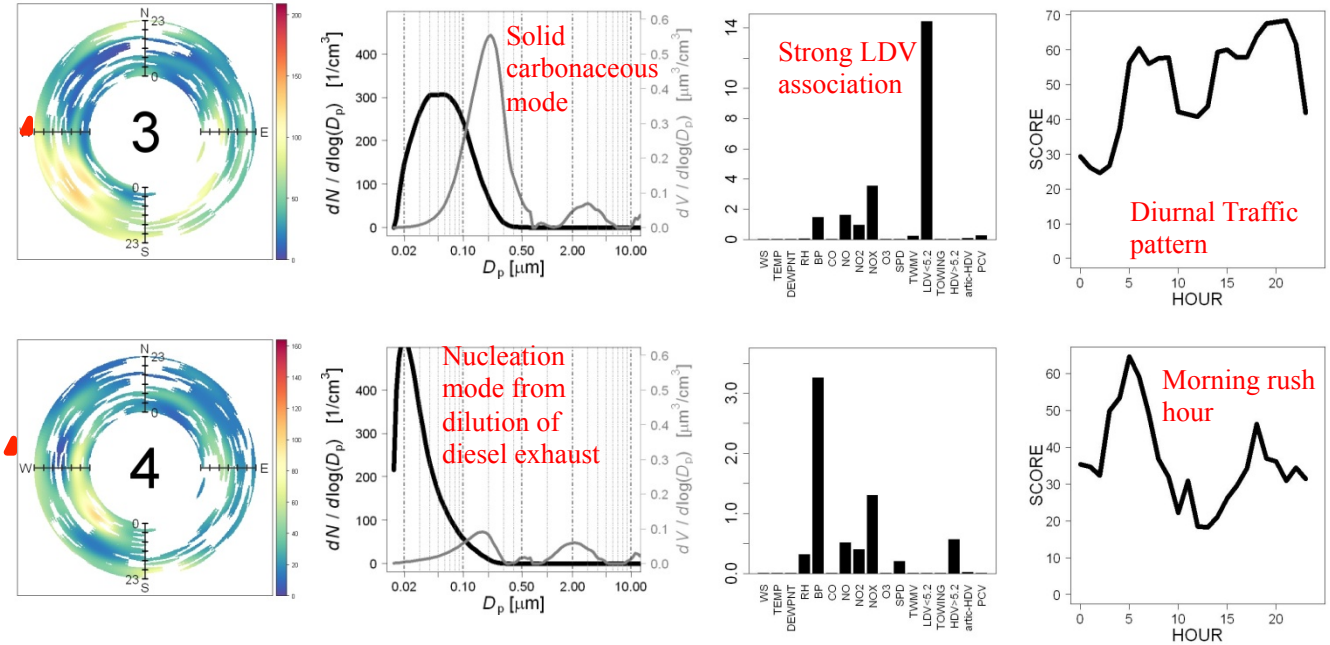
FACTORS



NUMBER FACTORS AND SCORES

	Mean Concentration (%)	
	Volume	Number
Marylebone Road Emissions		
Exhaust - solid mode (factor 3)	***18.8***	***38.0***
Exhaust - nucleation mode (factor 4)	3.6	***27.4***





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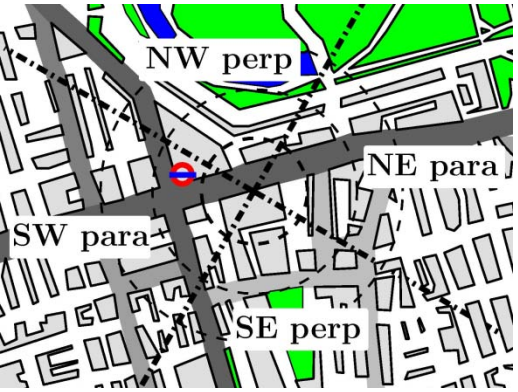
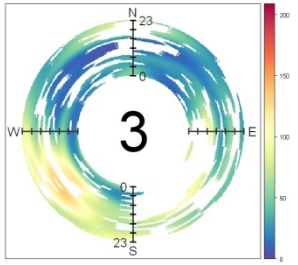
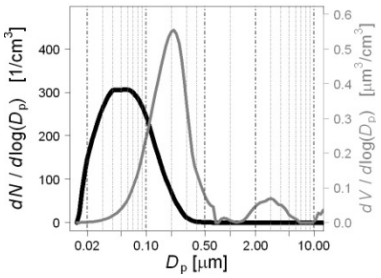
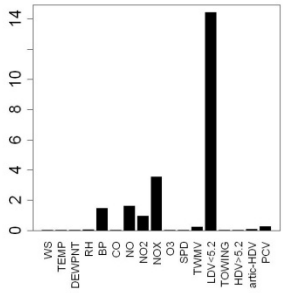
VOLUME FACTORS AND SCORES

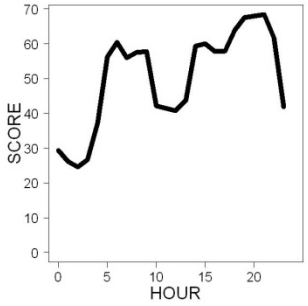
	Mean Concentration (%)	
	Volume	Number
Marylebone Road Emissions		
Exhaust - solid mode (factor 3)	*18.8*	*38.0*
Brake dust (factor 2)	*13.7*	1.7

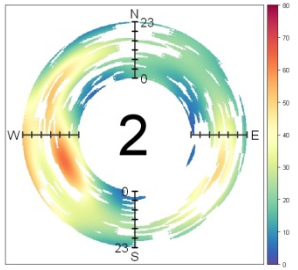


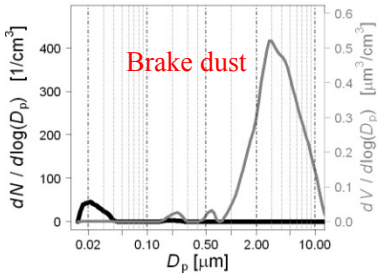


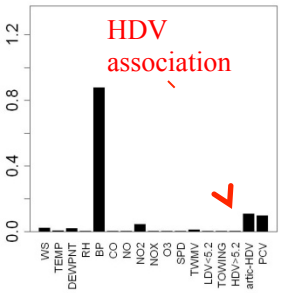


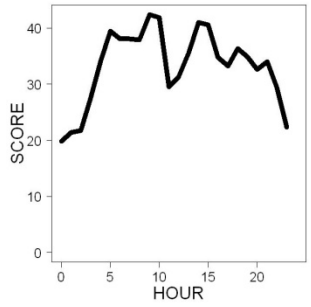












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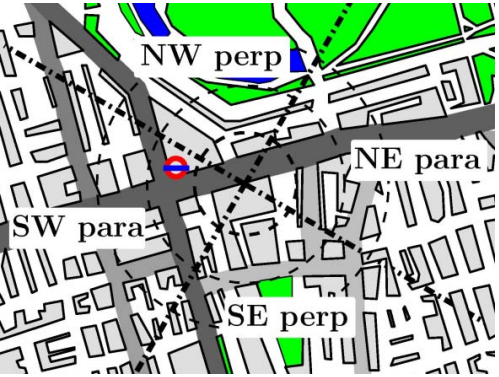
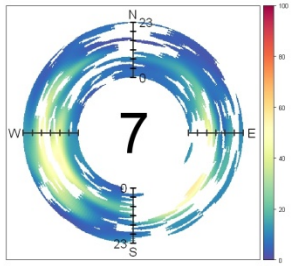
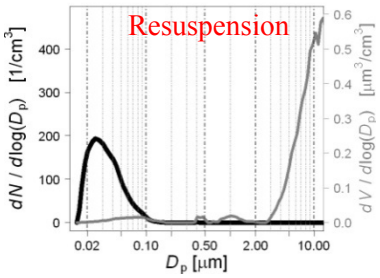
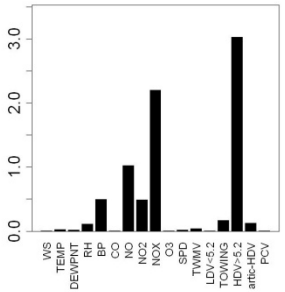
VOLUME FACTORS AND SCORES

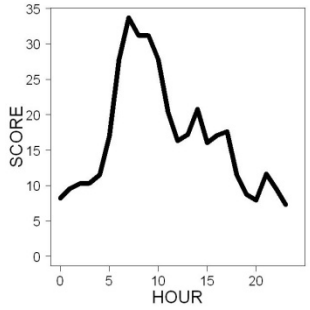
	Mean Concentration (%)	
	Volume	Number
Marylebone Road Emissions		
Resuspension (factor 7)	**4.4**	**4.8**











PMF analysis of wide-range particle spectra collected on a major highway

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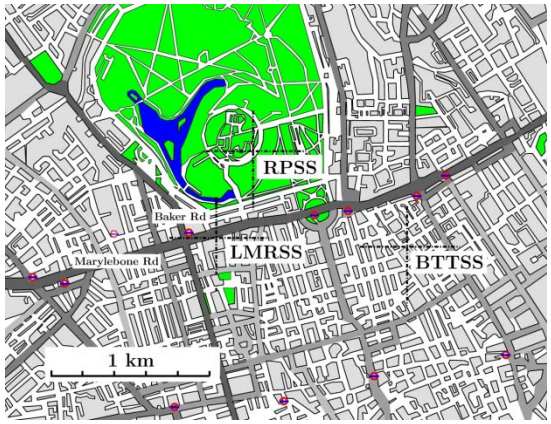
Attribution of mean particle volume and number to tentatively assigned sources



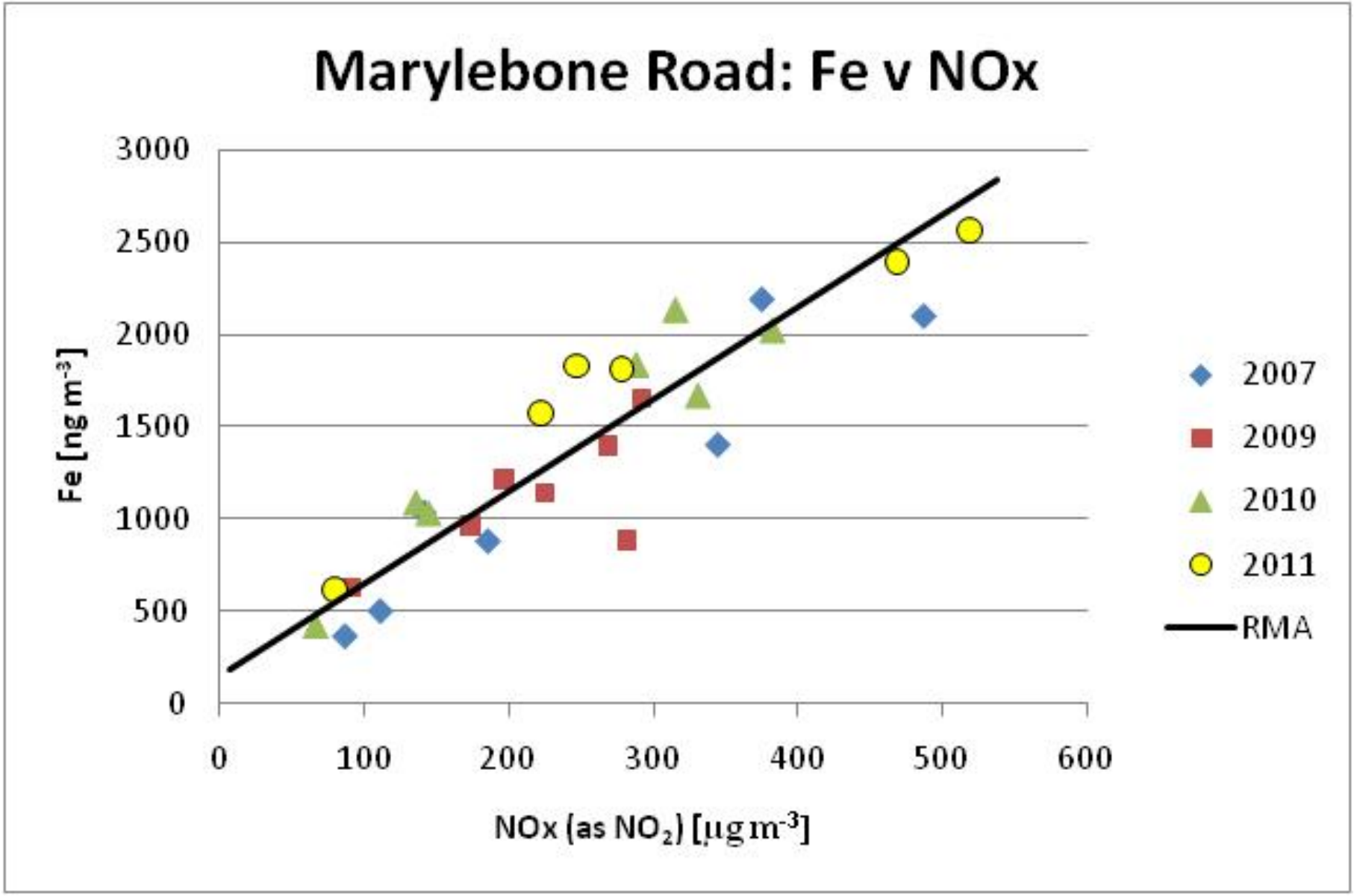
	Mean Concentration (%)	
	Volume	Number
Marylebone Road Emissions		
Exhaust - solid mode (factor 3)	***18.8***	***38.0***
Exhaust - nucleation mode (factor 4)	3.6	***27.4***
Brake dust (factor 2)	***13.7***	1.7
Resuspension (factor 7)	4.4	4.8
Sub-total	**40.5**	**71.9**
Urban Background		
Accumulation mode (factor 1)	***12.8***	6.3
Suburban traffic (factor 5)	2.3	7.6
Nitrate (factor 6)	8.4	2.0
Regional (factor 8)	2.5	2.7
Cooking (factor 9)	6.7	6.6
Regional (factor 10)	***26.8***	3.0
Sub-total	**59.5**	**28.2**

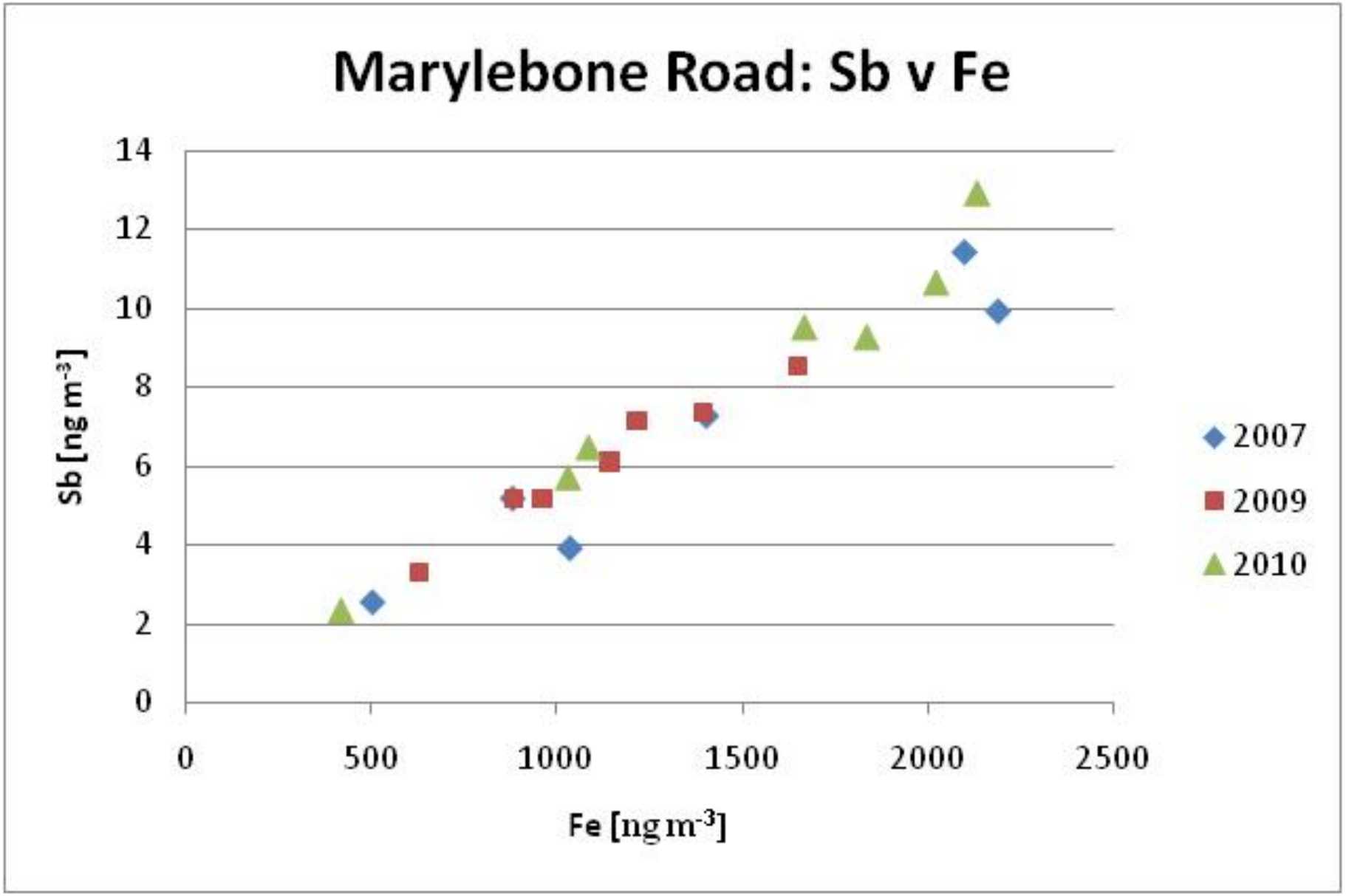
Elemental Data as Tracers of Non-Exhaust Emissions

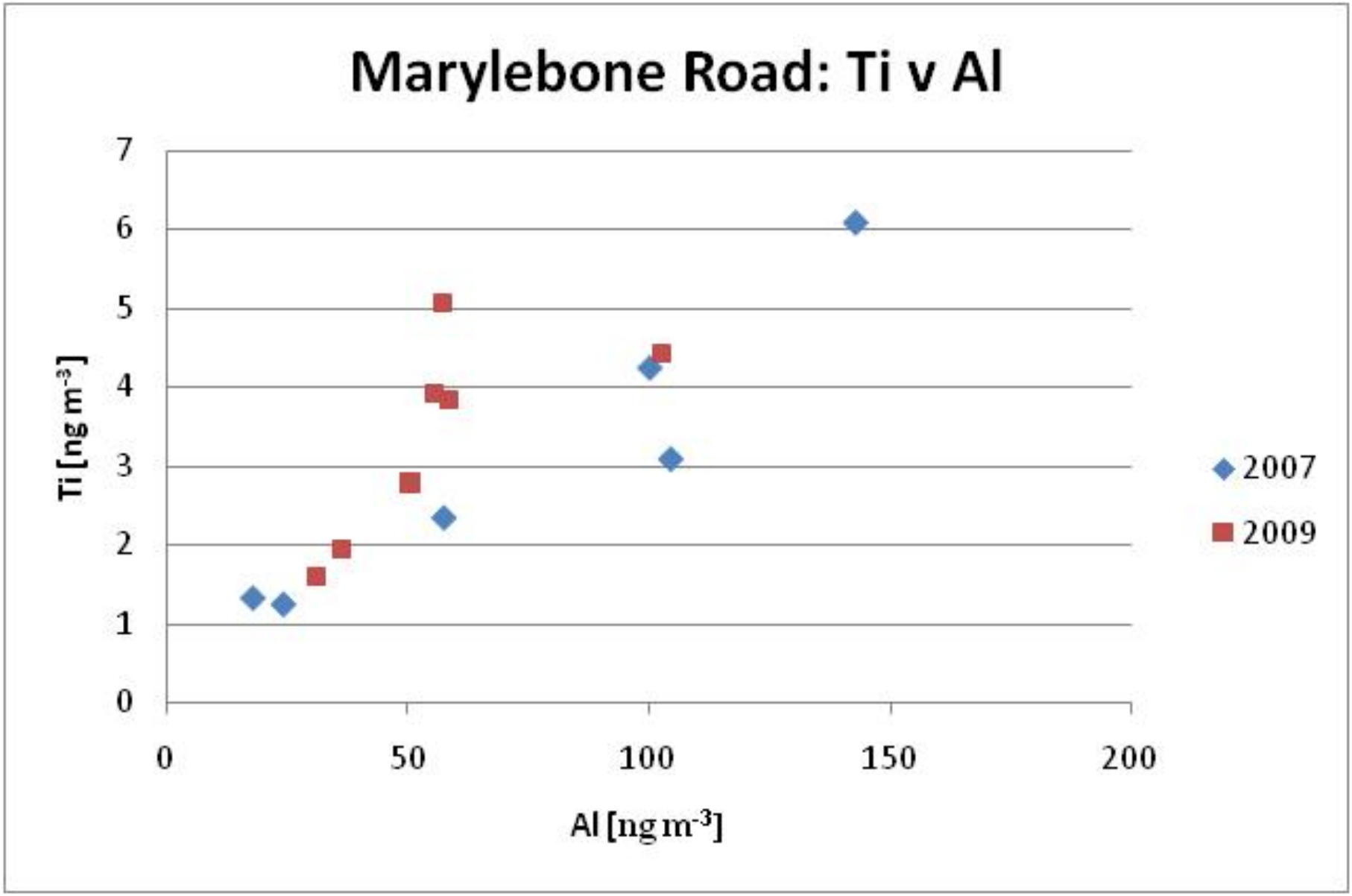
Examine:

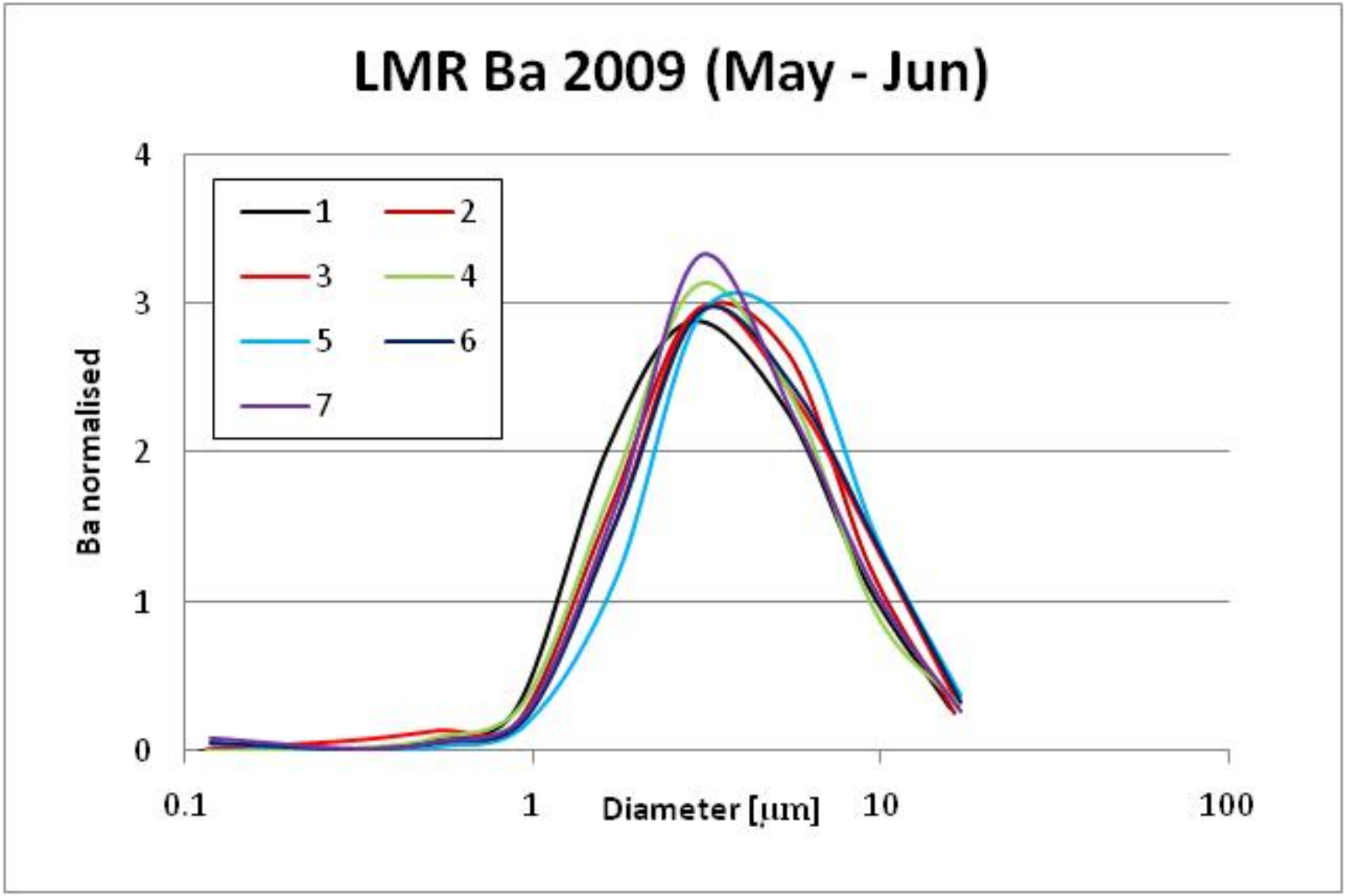
- **Relationship between metals to identify those with a common source**
- **Consider typical chemical origins of metals**
- **Fe, Cu, Sb and Ba characteristic of brake dust**
- **Al, Si, Ca, Ti are typically crustal and likely to arise from soil or resuspension**
- **Size distributions are indicative of source**

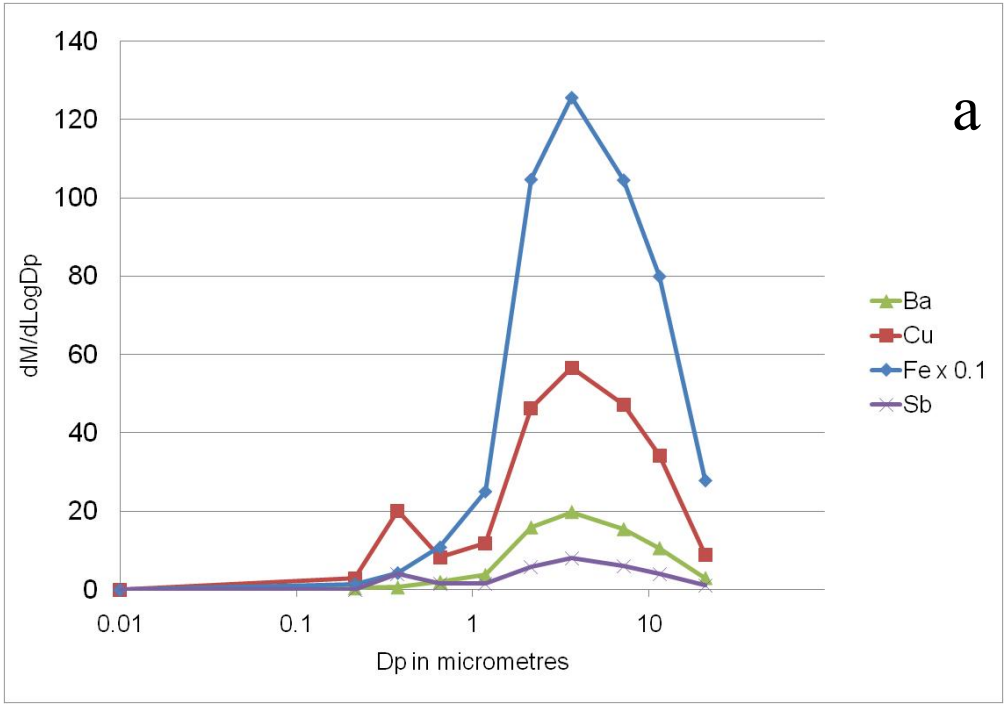
MARYLEBONE ROAD

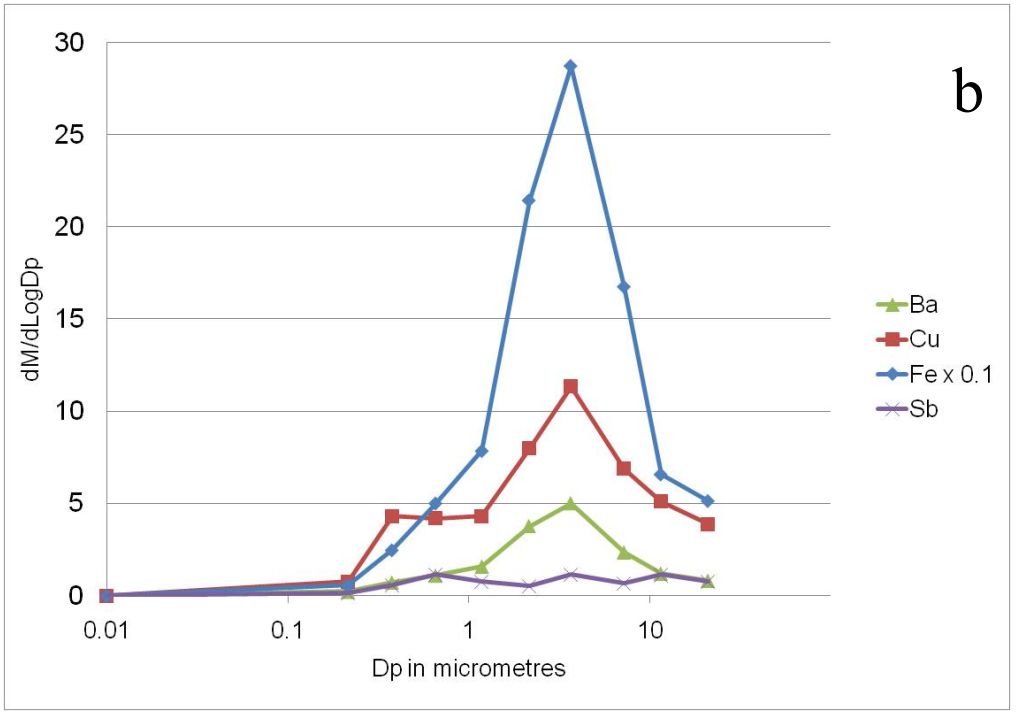

Marylebone Road: Fe v NOx
Fe [ng m-3]
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
600
NOx (as NO2) [µg m-3]
2007
2009
2010
2011
RMA


Marylebone Road: Sb v Fe
Sb [ng m-3]
Fe [ng m-3]
0
2
4
6
8
10
12
14
0
500
1000
1500
2000
2500
2007
2009
2010

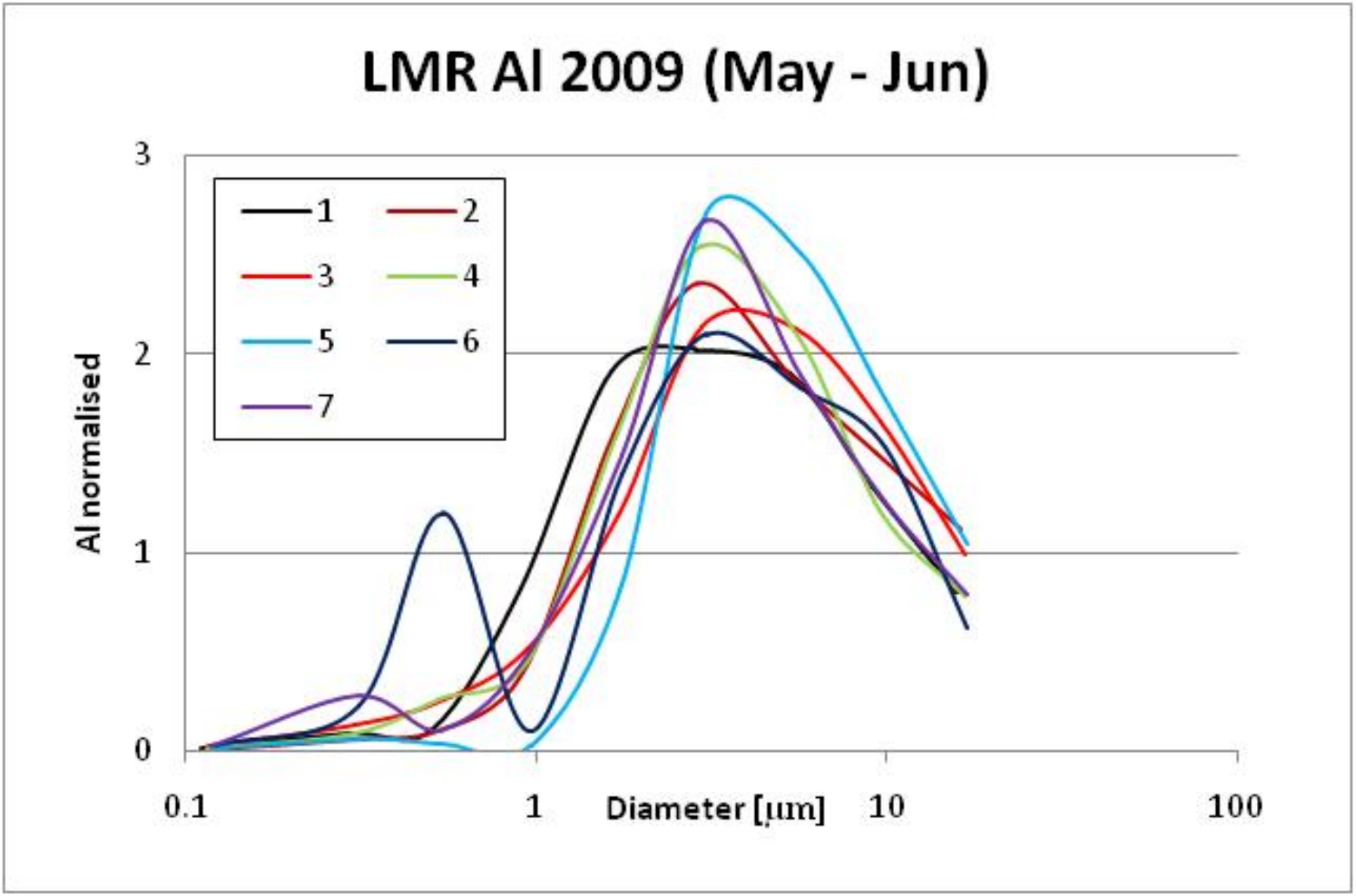

Marylebone Road: Ti v Al
Ti [ng m-3]
Al [ng m-3]
0
1
2
3
4
5
6
7
0
50
100
150
200
2007
2009

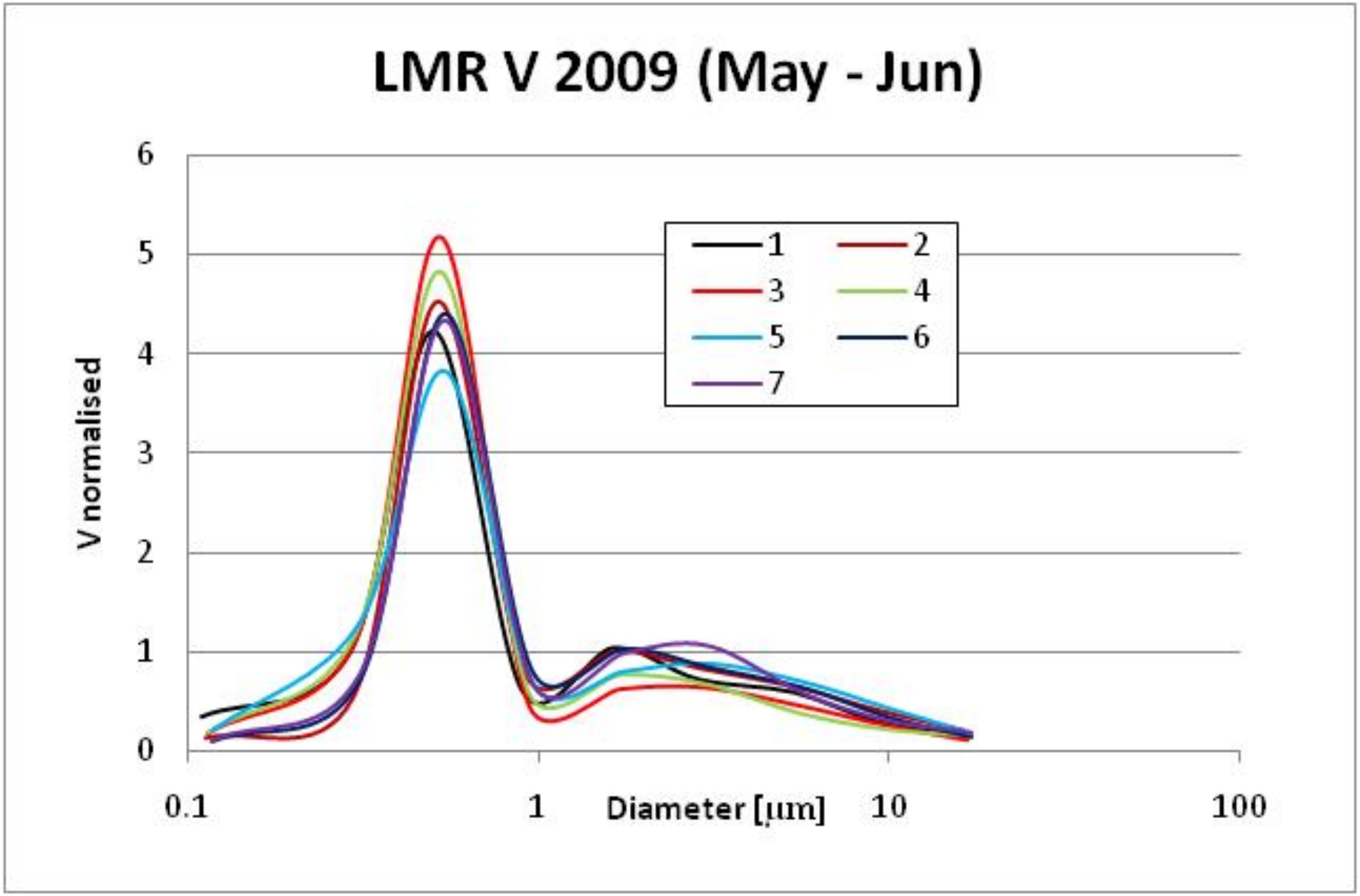

LMR Ba 2009 (May - Jun)
Ba normalised
4
3
2
1
0
1
2
3
4
5
6
7
0.1
1
Diameter [µm]
10
100





Size Distribution of Ba, Cu, Fe, and Sb at (a) Marylebone Road and (b) Regent's Park


LMR Al 2009 (May - Jun)
Al normalised
0
1
2
3
0.1
1
10
100
Diameter [µm]
1
2
3
4
5
6
7


LMR V 2009 (May - Jun)
V normalised
6
5
4
3
2
1
0
0.1
1
10
100
Diameter [µm]
1
2
3
4
5
6
7

CONCLUSIONS

1. Particle size distributions contain a great deal of valuable information.
2. Application of PMF to repetitively collected size distributions can provide valuable disaggregation of sources with different size distributions, even separating two types of vehicle exhaust particle.
3. Chemical components with the same predominant source will show strong correlations. If present in the same particles, they will have the same size distribution.
4. In UK roadside and urban background samples, brake dust and road dust can be identified from their size-related chemical profiles.