Ji Ping Shi
University Birmingham
United Kingdom

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Particle number emission from diesel and petrol vehicles driving on road

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MEASUREMENT OF PARTICLE NUMBER EMISSIONS FROM DIESEL AND PETROL VEHICLES DRIVEN ON THE ROAD

Ji Ping Shi, Roy M. Harrison, Doug Evans, A. A. Khan

Division of Environmental Health and Risk management
The University of Birmingham
Edgbaston, Birmingham, B15 2TT
United Kingdom

Chris Barnes and Geoff Carter

Perkins Engines Company Limited
Peterborough PE1 5NA
United Kingdom

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INTRODUCTION

1. It is known now that measured particle emissions are influenced by dilution conditions on an engine test bed. Therefore, particle number emission measured from vehicles driven on the road with real dilution will be useful in the emission control and health study.

2. Three-way catalyst (TWC) and oxidation catalyst (OC) are widely used on petrol and diesel vehicles. However, there is little information on the evaluation of the efficiency of the catalysts on reducing particle emissions in different driving modes on the road.

3. This paper presents the development and validation of a novel and simple method of measuring particle emissions from vehicles driven on the road, and the application of the method to the investigation of particle emissions from 12 in-use diesel and petrol vehicles.

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METHOD DEVELOPMENT (1)

Procedures of Measurement

1. Place Condensation Particle Counter (CPC), and Ultrafine Condensation Particle Counter (UCPC) and CO_2 analyser in the downwind of a quite road where there is no interference from local emissions.

2. Driving a test vehicle in a required driving mode and speed passing the instruments.

3. If the instrument response is sufficiently fast, particle number emission from the passing vehicle can be estimated by using CO_2 as a dilution ratio index.

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METHOD DEVELOPMENT (2)

1. Estimation of dilution ratio

For a stoichiometric and complete combustion, one can write,

$$C_xH_y + (x + y/4)\,O_2 + 3.76\,(x + y/4)\,N_2 \longrightarrow x\,CO_2 + (y/2)\,H_2O + 3.76\,(x + y/4)\,N_2 \quad (1)$$

$$C_{rawCO_2} = \frac{x}{x + y/2 + 3.76(x + y/4)} \times 10^6 \text{ (ppm)} \qquad (2)$$

Considering the λ = 1.1 - 6.0 for diesel engine and 0.68 - 1.22 for petrol engine, the corrected C_{rawCO2} is

$$C_{rawCO2} = 0.75\text{-}1.28 \times 10^5 \text{ ppm} \qquad \text{for petrol} \qquad (4)$$

$$C_{rawCO2} = 0.24\text{-}1.25 \times 10^5 \text{ ppm} \qquad \text{for diesel} \qquad (5)$$

$$DR = (C_{rawCO2} - C_{plumeCO2}) / (C_{plumeCO2} - C_{bkCO2})$$
$$\approx C_{rawCO2} / (C_{plumeCO2} - C_{bkCO2}) \qquad (6)$$

2. Particle number emission rate

For a given mileage fuel ratio, particle number emission per km can be estimated from equations (1), (6) and the measurement of particle number concentration.

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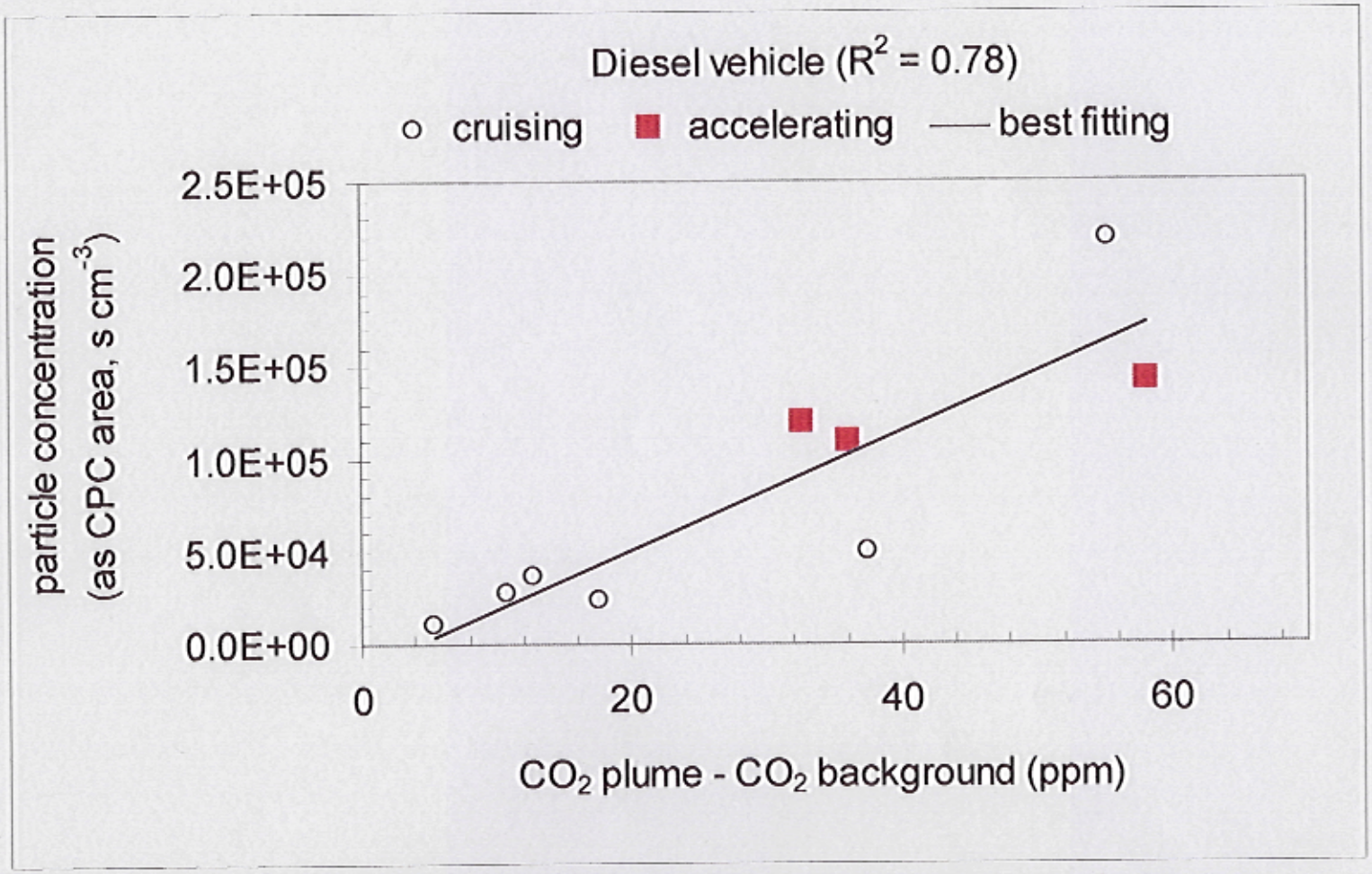
Method Validation (1)



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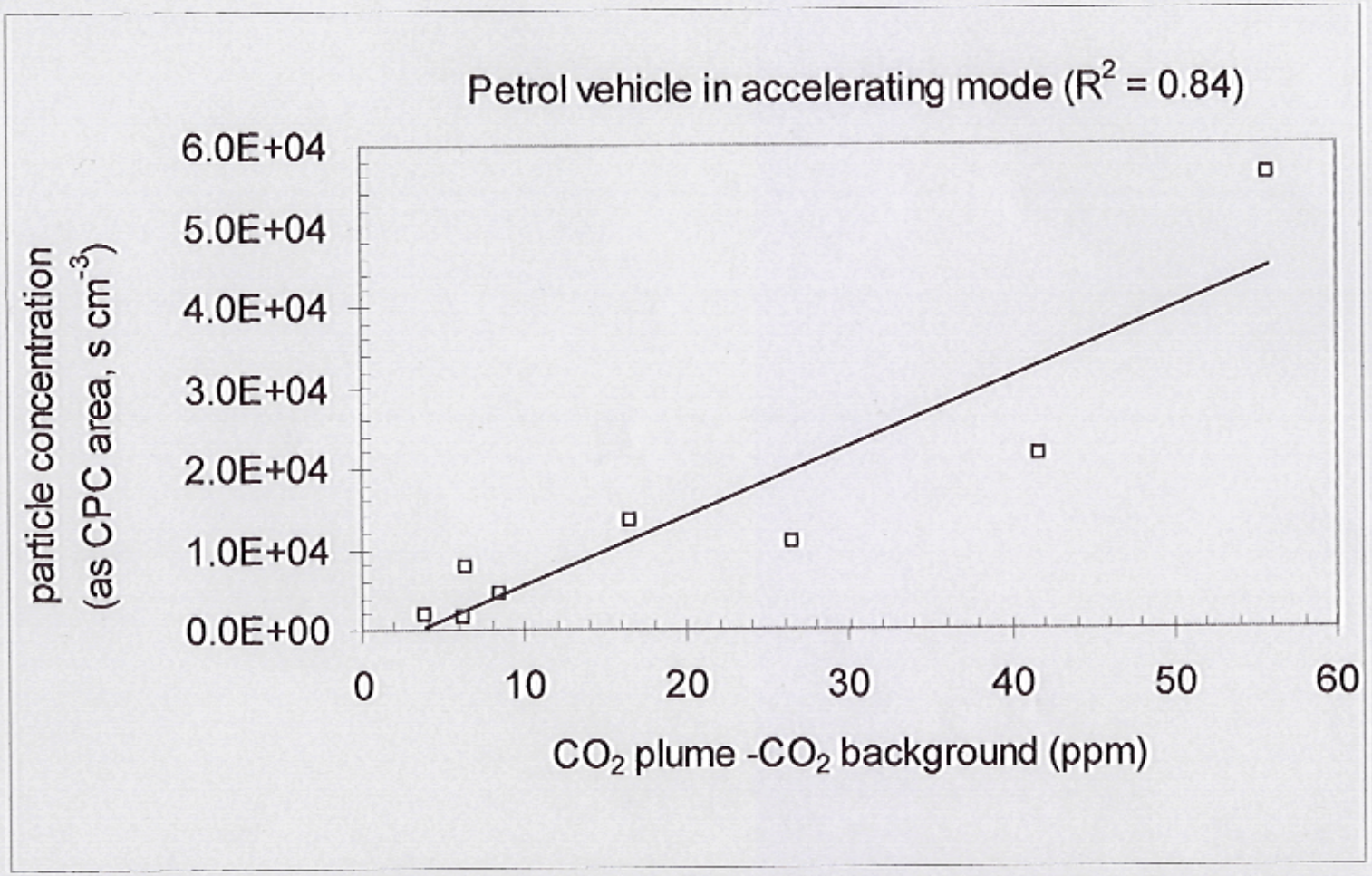
Method Validation (2)



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APPLICATION TO TWELVE IN-USE VEHICLES (1)

1. Test vehicles

No.	Diesel		Petrol	
	Catalyst (OC)	Non catalyst	Catalyst (TWC)	Non catalyst
12	3	2	6	1 (leaded)
Age (year)	1-4	8	1-4	8

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APPLICATION TO TWELVE IN-USE VEHICLES (2)

2. Results and Discussion

(a) Particle number emission (> 7 nm) in cruising mode

(b) Particle number emission (> 7 nm) in accelerating mode

(c) Nanoparticle (3-7 nm) emission

(d) Particle emission rate

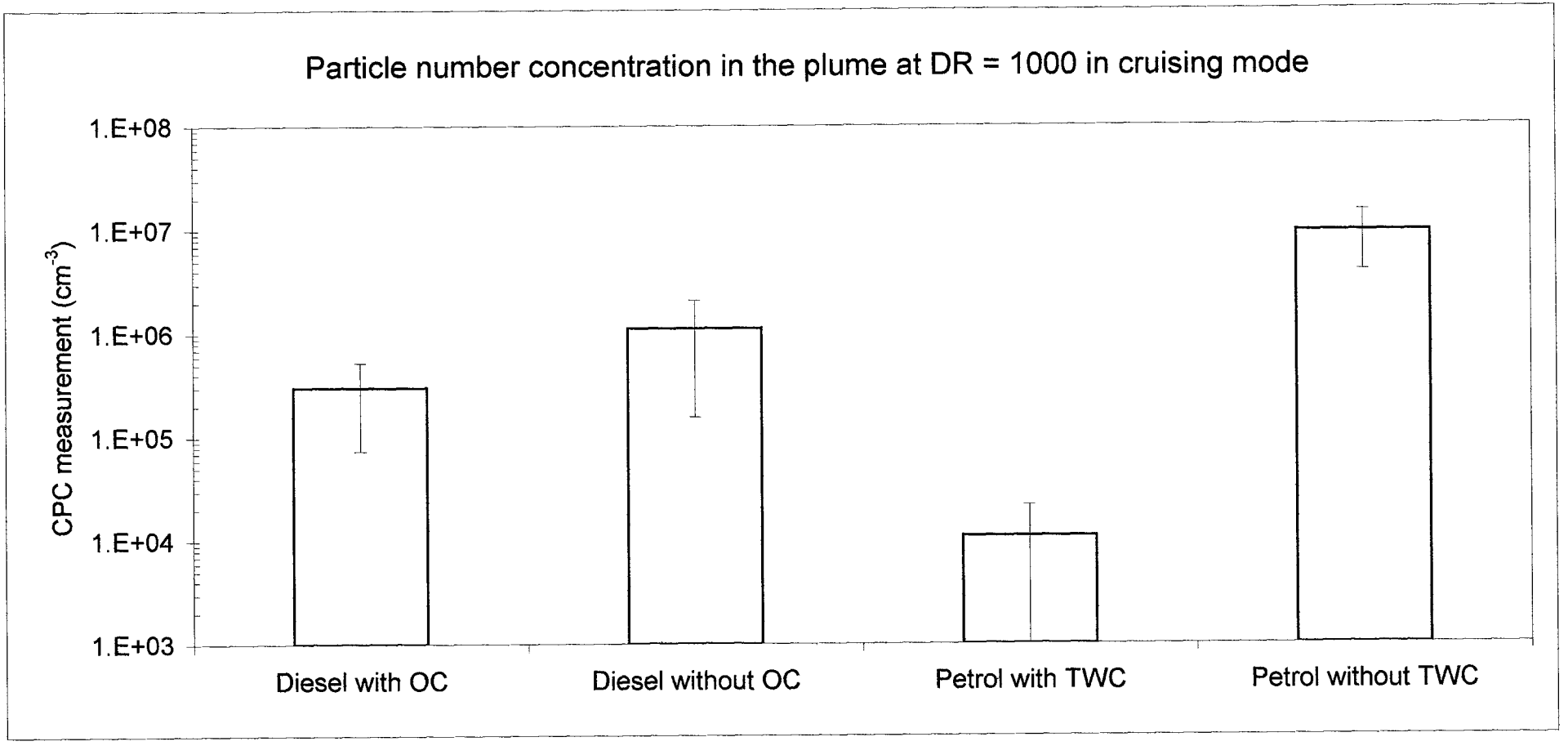


Figure 6. Comparison of average particle number concentration in the diluted plume under an adjusted dilution ratio (DR = 1000) from vehicles in cruising mode.

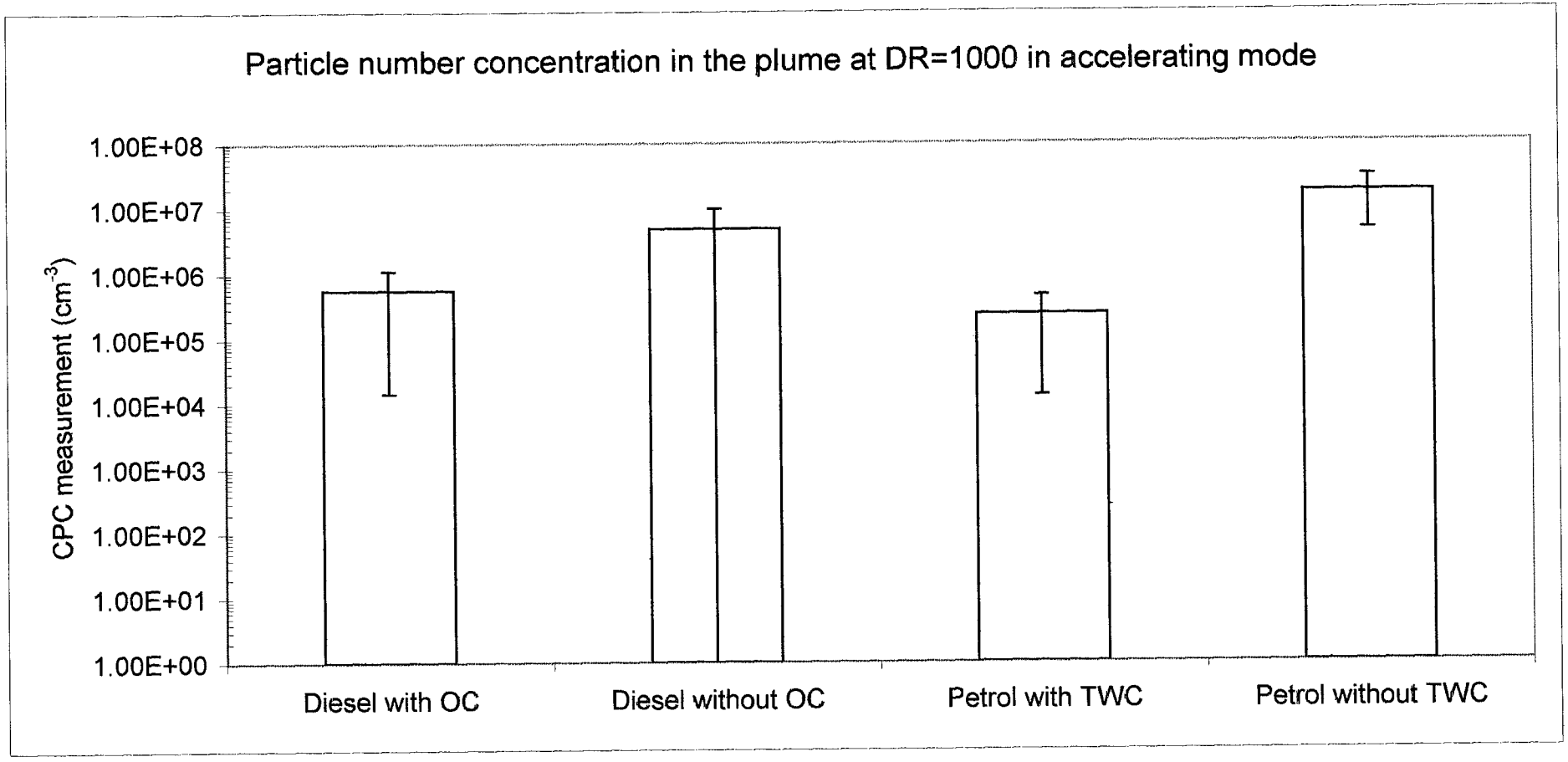
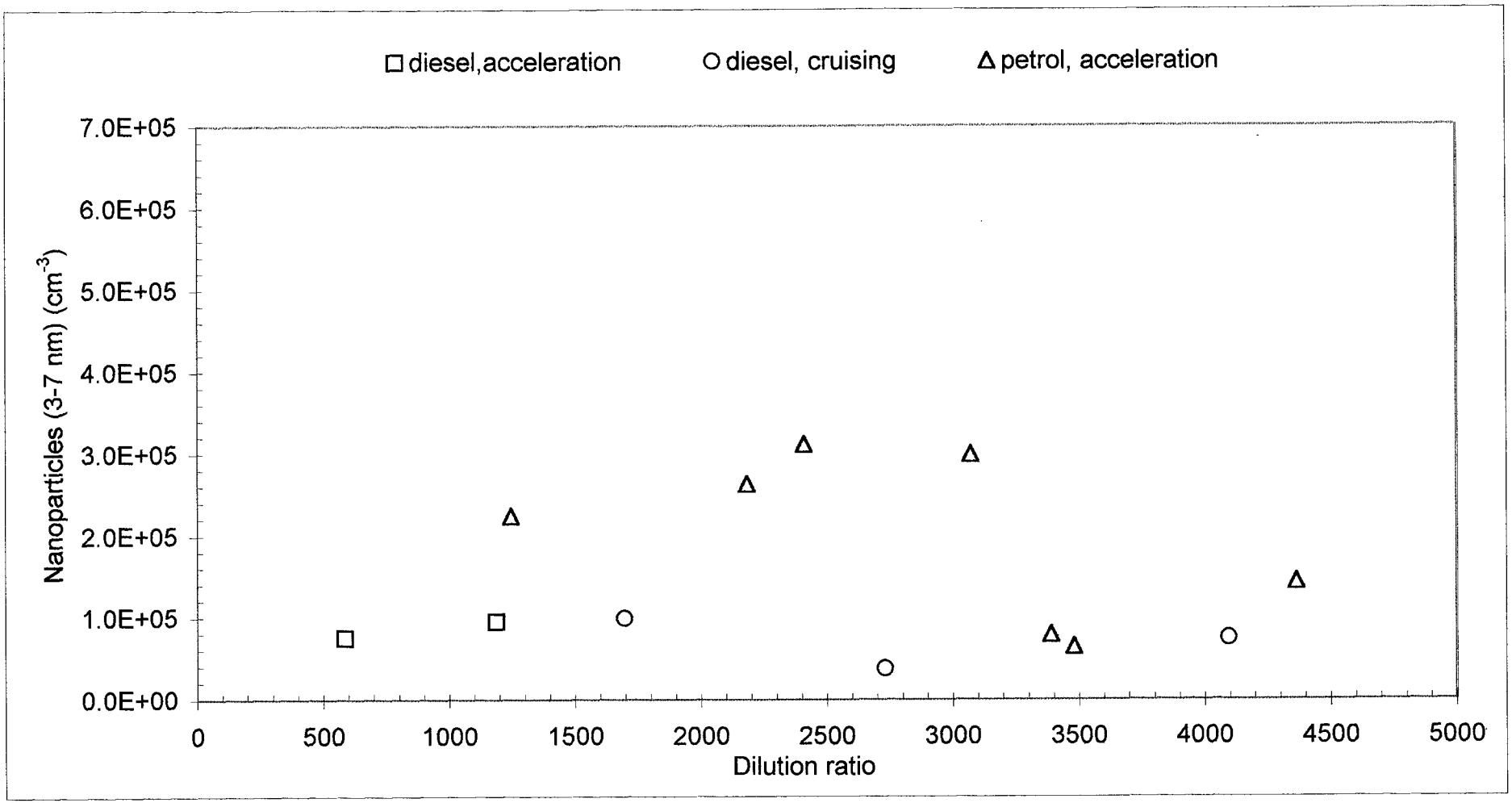


Figure 7. Comparison of average particle number concentration in the diluted plume under an adjusted dilution ratio (DR = 1000) from vehicles in accelerating mode.



Measured nanoparticle concentration (corrected to the dilution ratio of 1000) against dilution ratios where ther were measured.

Table 3. Comparison of correlation coefficients between particle number concentration and dilution ratio.

Correlation	Diesel with OC (> 7nm)	Diesel with OC (3-7 nm)	Petrol with TWC (> 7 nm)	Petrol with TWC (3-7 nm)
Cruising				
Dilution ratio	-0.51	**-0.77**	N/A	N/A
Available data set	5	3		N/A
Acceleration				
Dilution ratio	-0.64	**-0.87**	-0.09	**-0.91**
Available data set	6	4	10	7

Particle emission rate (particle number / km).

	Diesel vehicles		Petrol vehicles	
	With OC	without OC	With TWC	without TWC
	10^{14} /km	10^{14} /km	10^{14} /km	10^{14} /km
Cruising mode				
Particles (3-7 nm)	0.9	N/A	N/A	N/A
Particles (> 7 nm)	3.0	11.3	< 0.1	88.2
total	3.9			
Acceleration mode				
Particles (3-7 nm)	2.8	N/A	1.8	N/A
Particles (> 7 nm)	5.7	49.2	2.0	161.9
total	8.5		3.8	

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CONCLUSION

- A novel method to measure particle emissions from vehicles during road driving has been developed and validated.

- In terms of providing realistic data, this development has major advantages, i.e. true road dilution, direct comparison between different vehicles, after-treatments and fuel types.