

The Regulated And Unregulated Exhaust Emissions Performance Of 5 Modern Motorcycles Over Euro 3 & WMTC Test Cycles

A joint Ricardo/AECC Programme of Work

Objectives

- To select four Euro 3 and 1 Indian specification motorcycles, of varying technologies, fitted with catalyst-based emissions control systems
- To test each machine over Euro 3 and WMTC cycles and provide regulated emissions data
- To evaluate the PMP mass and number measurement protocols for use with motorcycles and determine typical particle number and mass emissions from the cycles studied

Experimental Facility and Test Vehicles

- The Ricardo motorcycle emissions test facility
 - approved for both European and US certification testing
 - Brush 120kW, 275kph motorcycle chassis dynamometer
 - Road speed proportional vehicle cooling fan
 - Raw and dilute exhaust emissions measurement capabilities
 - Controllable cell temperatures
 - 15 channel logging device



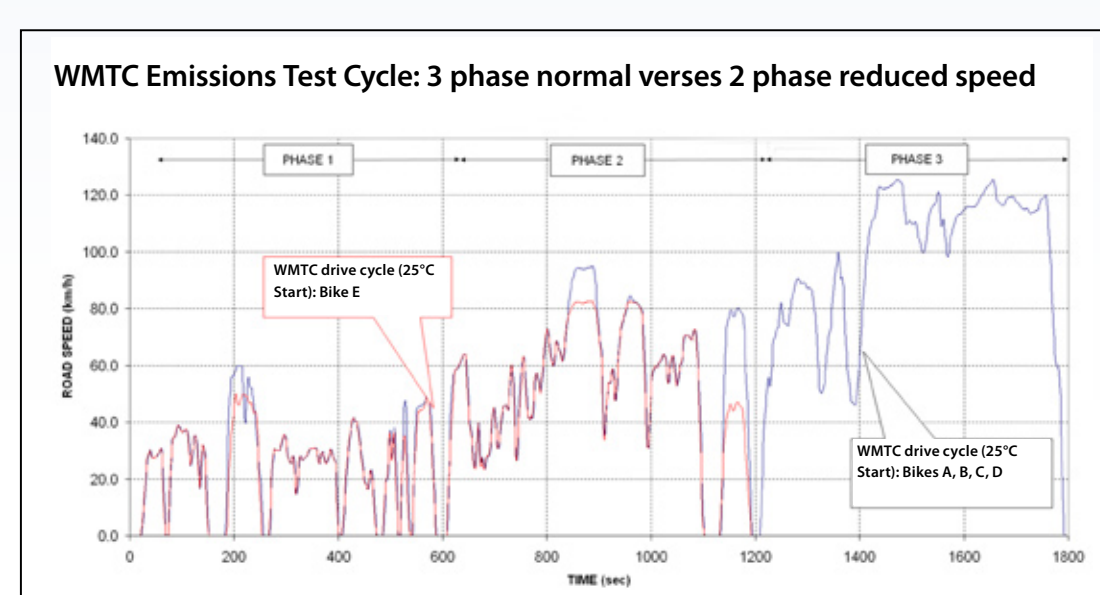
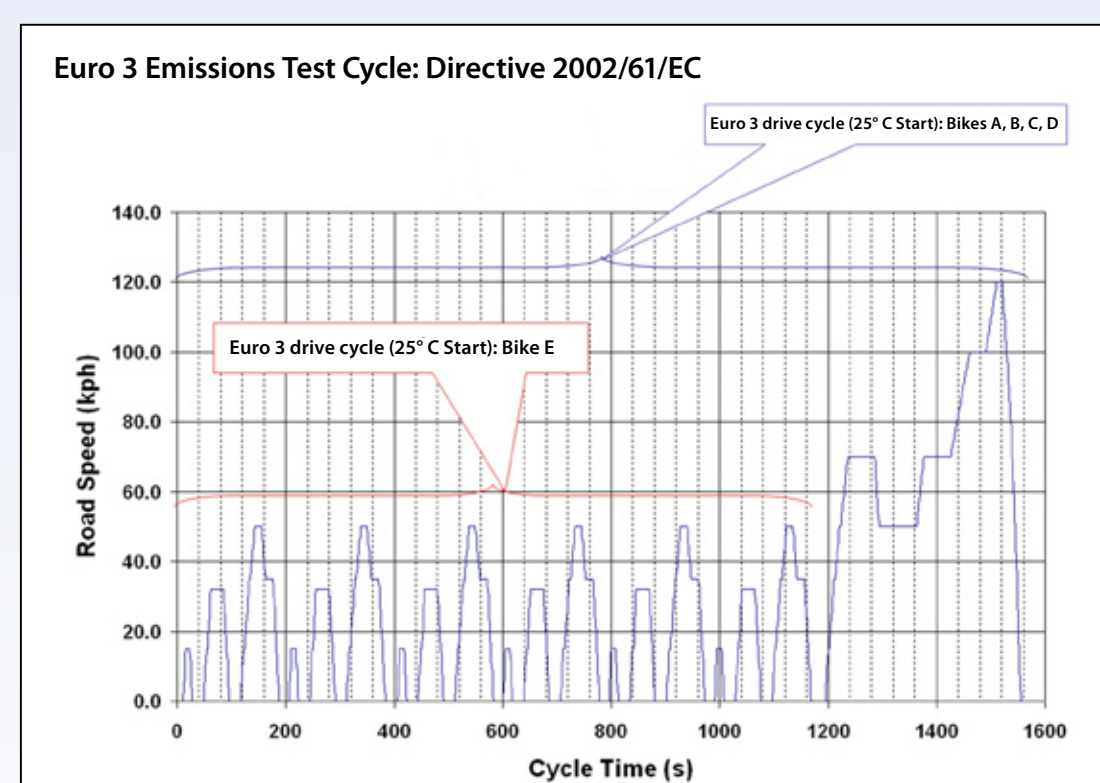
Bike	Engine	EFI	Open/Closed Loop Control	SAI	Catalyst	Spec
A	800cc V4	Y	Closed	Y	Y	Euro 3
B	800cc in line 2-cyl.	Y	Closed	N	Y	Euro 3
C	1300cc in line 4-cyl.	Y	Closed	Y	Y	Euro 3
D	500cc 1-cyl.	Y	Closed	Y	Y	Euro 3
E	149cc 1-cyl.	N	N/A	Y	Y	Indian Spec.

EFI = Electronic Fuel Injection SAI = Secondary Air Injection

Drive Cycles and Test Protocol

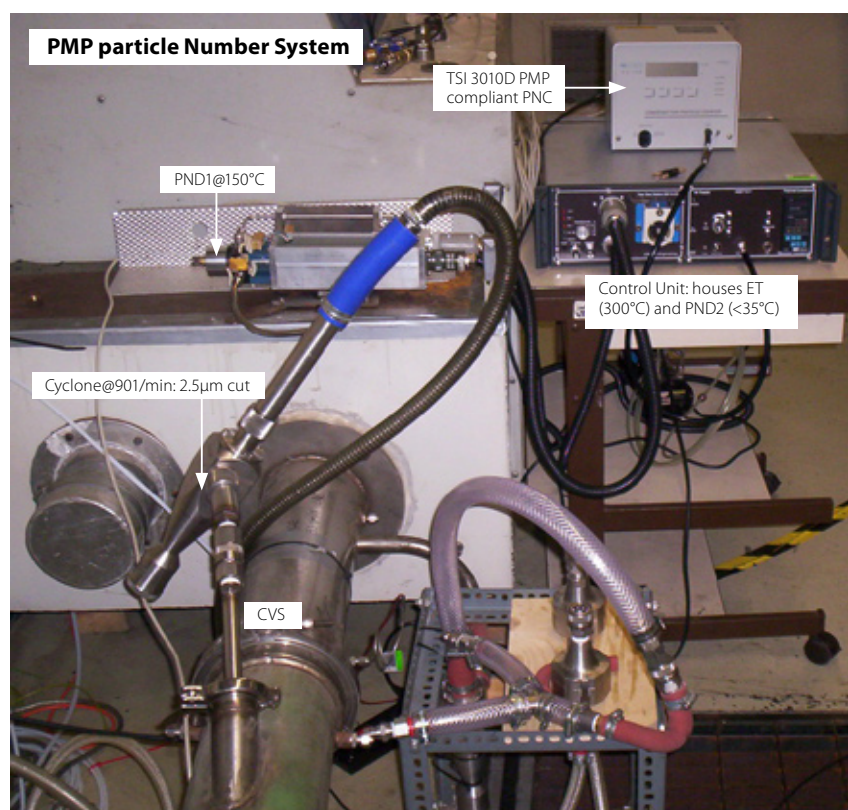
Test Protocol

- All motorcycles were preconditioned to the Euro 3 test cycle to allow any ECU adaptations to occur.
- Test conducted with a cold start, machines 'soaked' over night under test conditions as per regulations
- PM Filters preconditioned on the day prior to testing. Weighed on test day.
- All 3 tests conducted using TX40 filter papers for particulate mass measurement. 1 extra test conducted on glass fibre filter for chemical analysis of soot, anions and HCs
- All test fuel taken from a single batch of pump grade 95RON Unleaded.
- Continuous and bag data recorded.



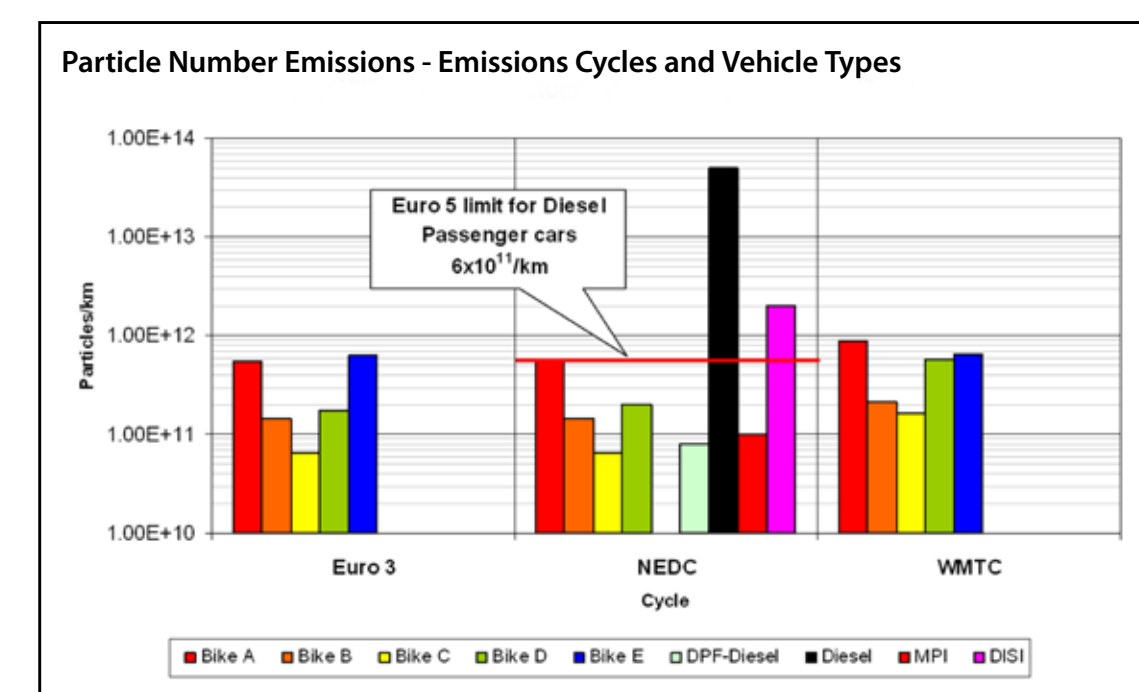
PN and PM sampling

- Particulate Mass**
 - Currently no approach in regulations for particulate emissions from spark-ignited vehicles
 - New approach proposed for emissions from Euro 5 GDI vehicles
 - Same approach as used for DPF equipped Diesels and developed in the PMP programme
- In this programme an approach broadly similar to the PMP Euro 5 method was employed
- Latest methodology for low emissions engines and vehicles
- Particle Number**
 - Particle numbers sampled from CVS as in light-duty and heavy-duty PMP procedures
 - Measurement equipment the same as used in AECC Euro VI programme
 - Dilution factors of 150 to 180
 - Sufficient to keep emissions from all bikes below 10,000/cm³
 - Cycle average data at ~ 200/cm³
 - Performed according to latest draft of R83 except
 - CVS dilution tunnel does not have HEPA filter
 - Coarse filter is in place
 - Background level elevated
 - Typical background levels 10 -20 /cm³
 - Light-duty levels <2/cm³
 - CVS and transfer tube purged of particles and low volatility HC, by high temperature operation (150kph) of lambda1 motorcycle, prior to testing



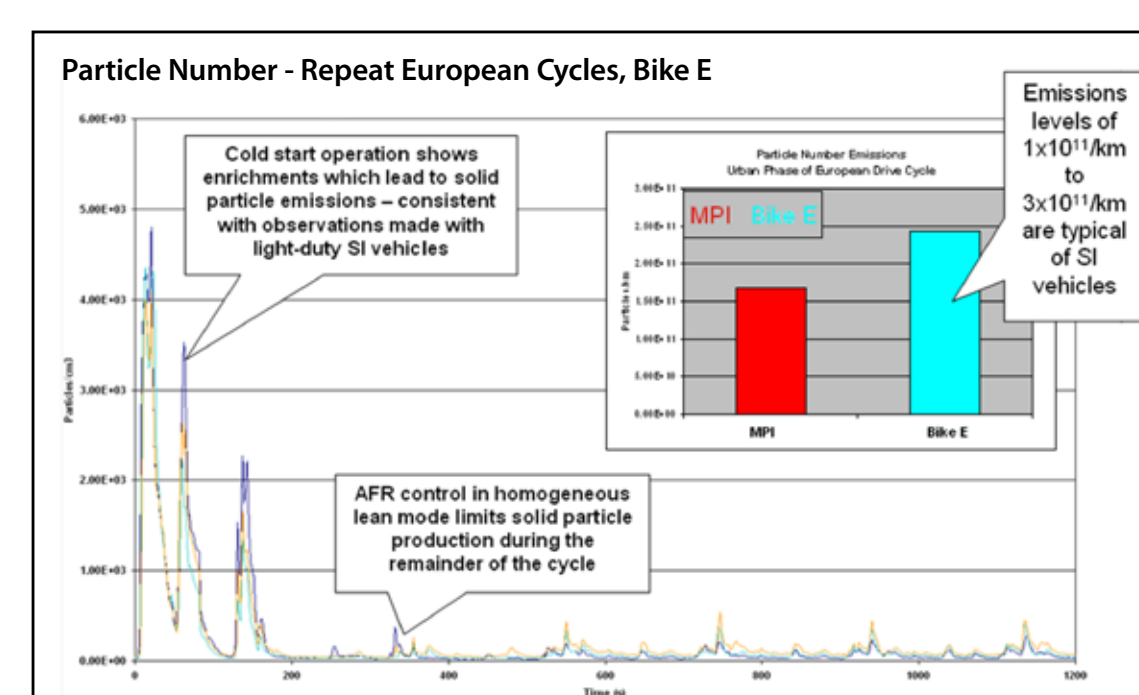
PN in Context

- All bikes show NEDC emissions levels of 6×10^{11}/km
- WMTC emissions did not exceed 10^{12} from any bike
- Motorcycles unlikely to be seen as imminent targets for particle number control



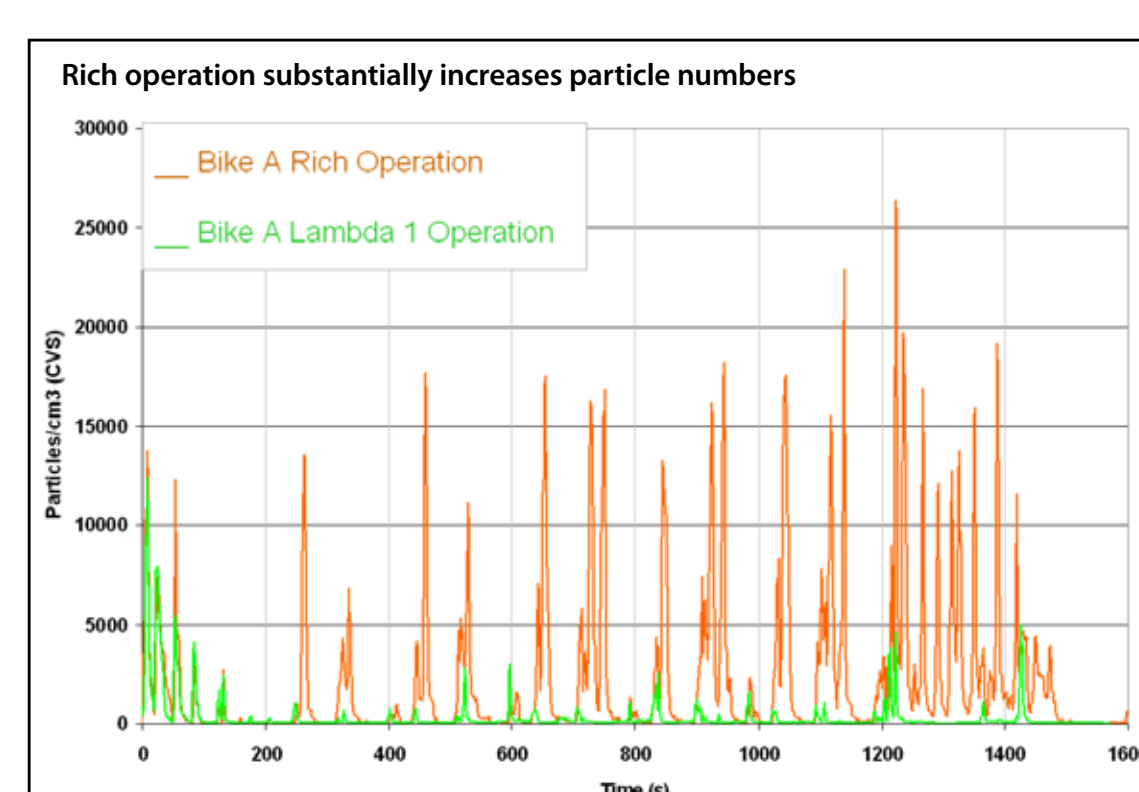
Euro 3 Cycle - Engine effects on Particle Emissions

- Lean operation gives particle numbers similar to stoichiometric SI vehicles



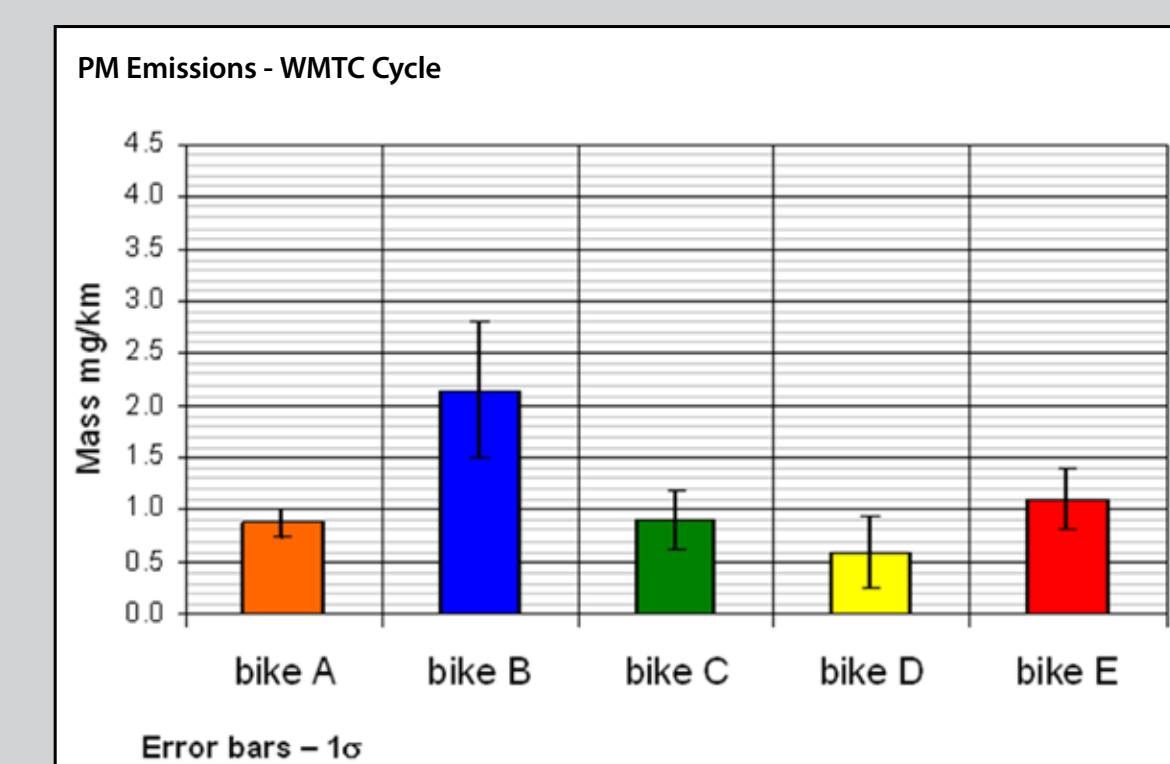
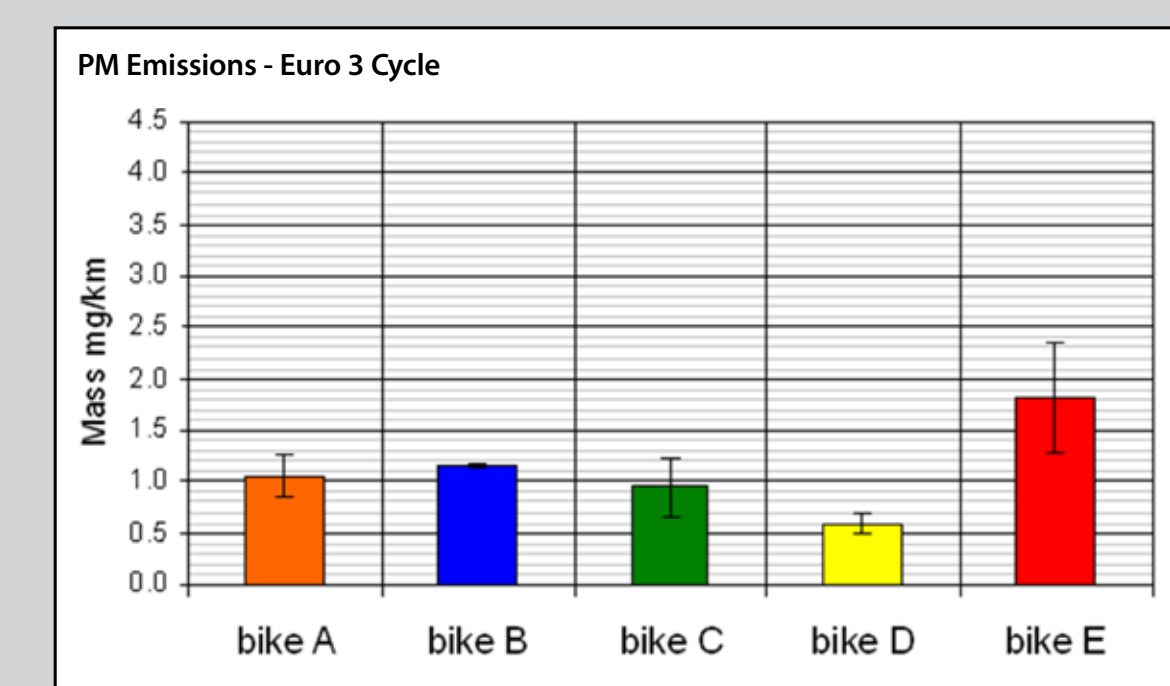
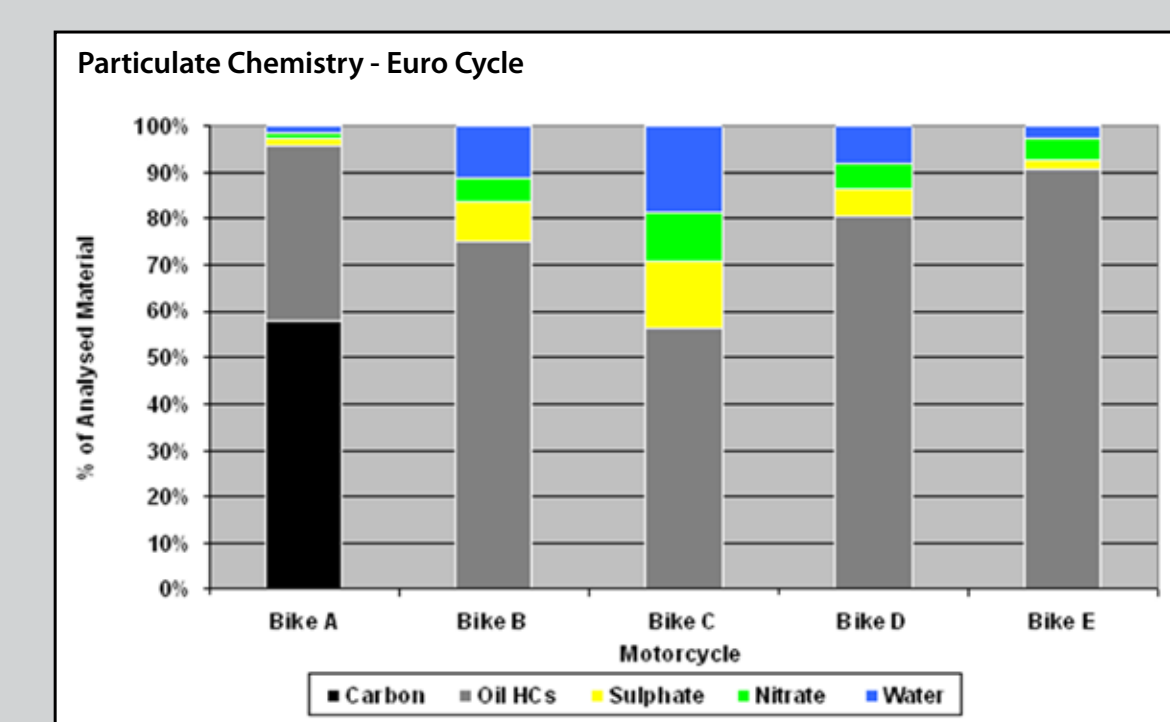
Particle Numbers Many Times Higher When Running Rich

- Bike A tests in rich and lambda 1 modes
- Particle number emissions from rich tests >math>10^{12}</math>/km
- Lambda 1 tests ~math>5 \times 10^{11}</math>/km



PM Results And PM Chemistry

- Generally similar mass levels from all motorcycles on both WMTC and Euro 3 cycles
- Mass emissions always <math><2.5</math>mg/km
- Emissions levels below 4.5mg/km level required for Euro 5 (DPF Diesel and GDI)
- Elemental carbon present at trace levels in PM from all bikes (<math><0.6</math>mg/km)
- Oil HCs are a major contributor (often >80%) and may contribute to particle numbers
- Trace levels of anions

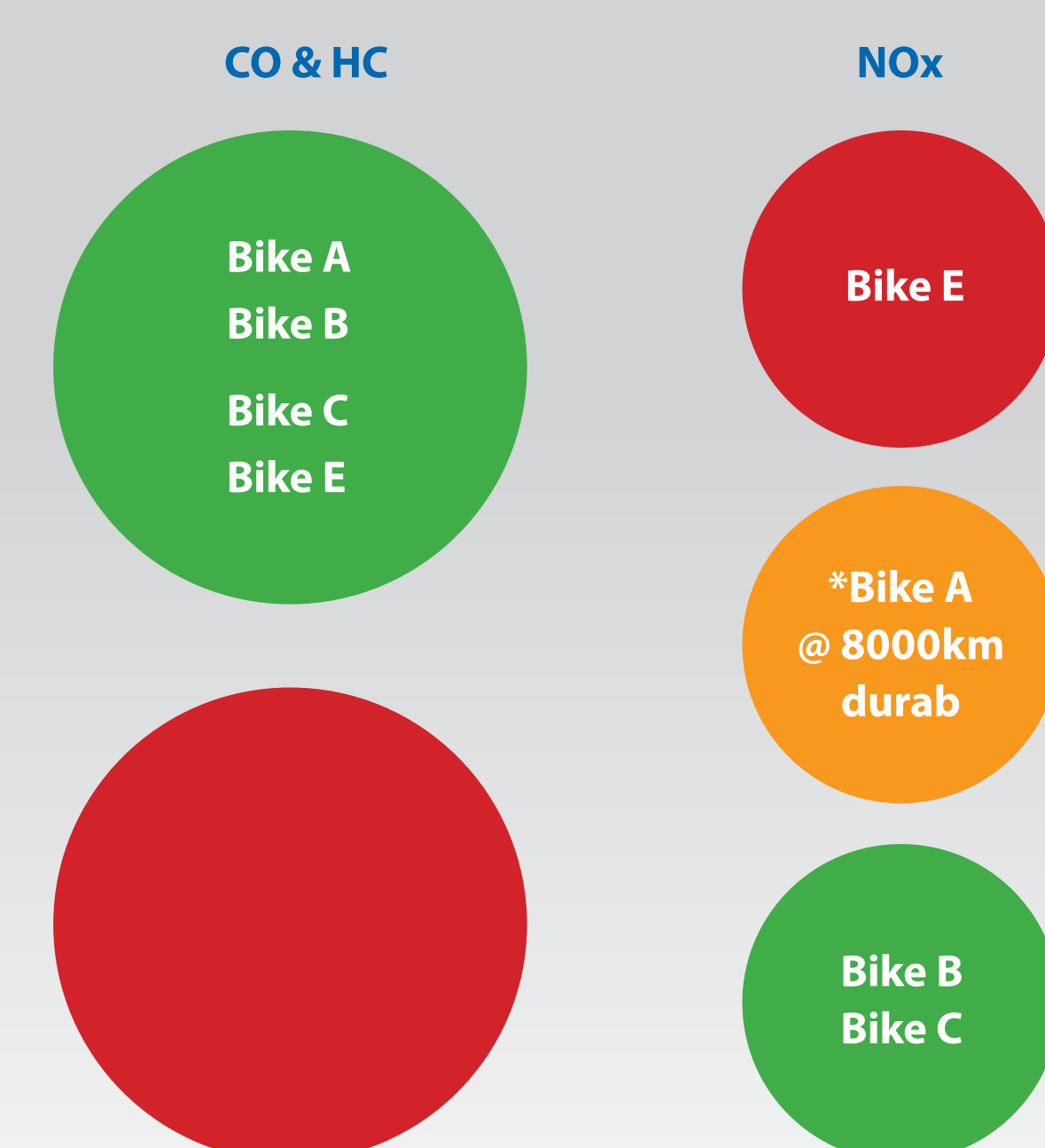


PM and Particle Number Conclusions

- All lambda 1 motorcycles produced particle number emissions from Euro 3 and WMTC that were below the 6×10^{11} /km level required for light-duty Diesels at Euro 5.
- Rich operation elevated particle numbers to >math>10^{12}</math>/km, similar to levels seen from lean-burn DI gasoline vehicles
- Particulate mass emissions were typically 2mg/km or less, well inside the 4.5mg/km limits required for Diesel vehicles at Euro 5

Regulated Emissions Conclusions

- Compliance with limits on Euro 3 and WMTC Cycles after 1000 km durability



- Bike D showed unpredictable behaviour and results varied widely from test-to-test from this motorcycle