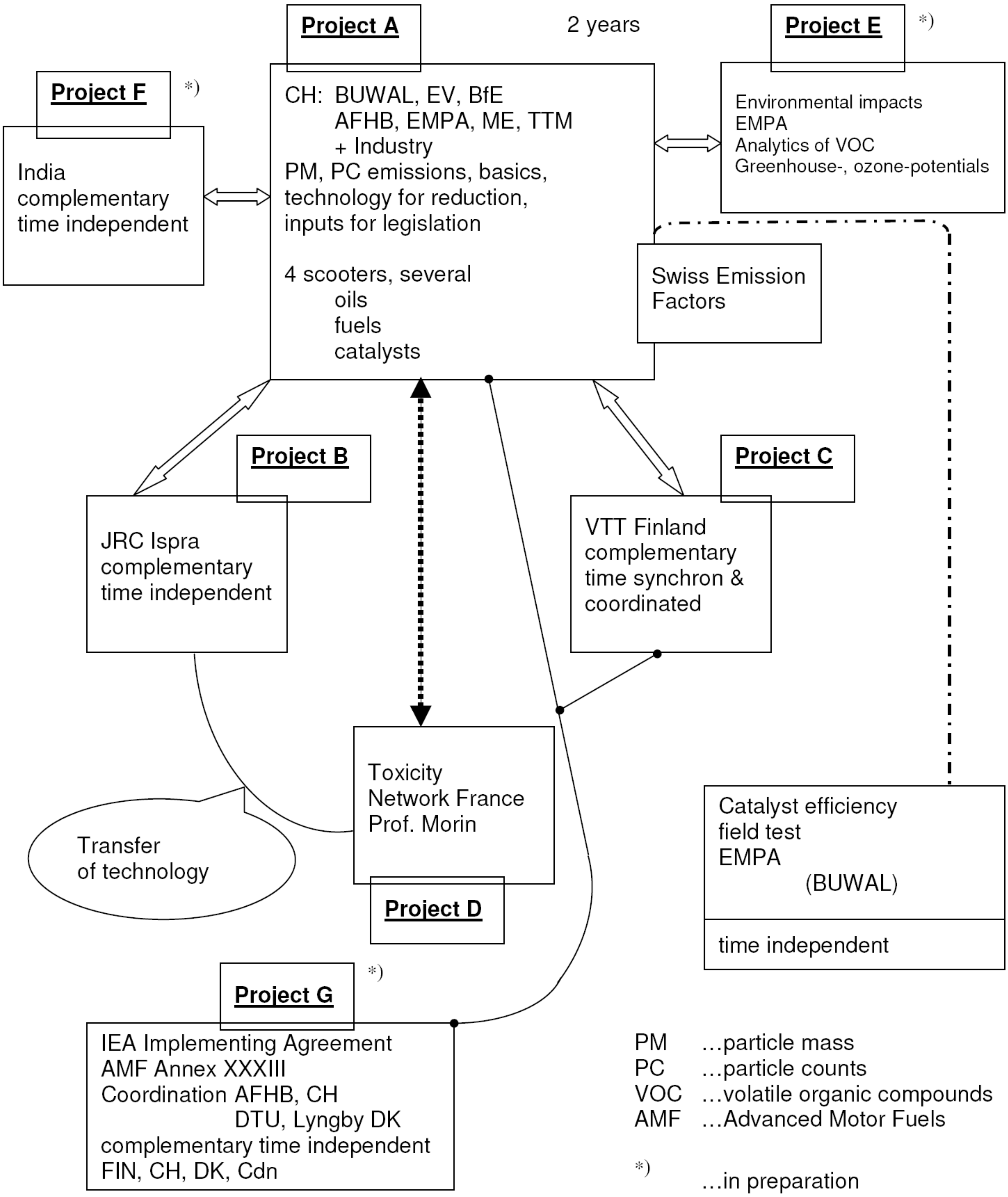
2-S Scooters International Projects Network: Particle emissions, toxicology & environmental impacts

November 2004



PM …particle mass
PC …particle counts
VOC …volatile organic compounds
AMF …Advanced Motor Fuels

*) …in preparation

University of Applied Sciences
Biel-Bienne, Switzerland
IC-Engines and Exhaust Gas Control

Influencing (Nano) Particle Emissions of 2-Stroke Scooters

Transport & Air Pollution 14th Intern. Symp. Graz, June '05
13th Intern. Pacific Conference, Korea, Aug.'05

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Measuring procedure on the chassis-dyno;

1. cold start
2. acceleration to 40 km/h
3. constant speed

		Peugeot	Peugeot
vehicle identification		Looxor TSDI	Looxor
model year		2002	2004
transmission no. of gears		variomat	variomat
km at beginning		1400	0
engine: type displacement cm^3 number of cylinders		 2 stroke 49.1 1	 2 stroke 49.1 1
cooling		Air forced	Air forced
rated power	kW	3.6	3.72
rated speed	rpm	7800	8100
idling speed	rpm	1700	1800
max vehicle speed	km/h	45	45
weight empty	kg	94	94
mixture preparation		direct injection with automatic oil pump	carburetor with automatic oil pump
catalyst		yes	yes + SAS (secondary air system)
catalyst data		Pt/Rh 5/1 50 g/ft³ 200 cpsi metal support Ø 60,5 / L 40	Pt/Pd/Rh 1/28/1 50 g/ft³ 100 cpsi metal support Ø 60,5 / L 40

Data of the 2 scooters

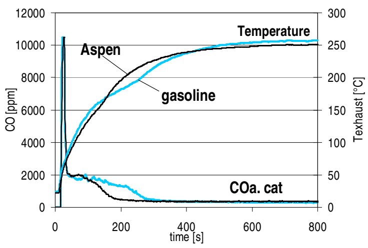
Property	Unit	Panolin TS	Panolin 2-S Synth.	Panolin Synth. Aqua	Nycolube
Viscosity kin 40°C	mm^2/s	90	103	95	
Viscosity kin 100°C	mm^2/s	11.2	8.2	6.3	7.9
Density 15°C	kg/m^3	882	925	946	
Pourpoint	°C	-27	-40	-28	
Flamepoint	°C	> 150	> 150	> 150	
Total Base Number TBN	mg KOH/g	3	3	2.5	
Sulfur	ppm	6250	450	0	350
Fe	ppm	0	5	2	1
Mo	ppm	1	0	0	0
Mg	ppm	2	3	1	2
Zn	ppm	105	18	0	0
Ca	ppm	617	458	11	322
P	ppm	90	36	16	6

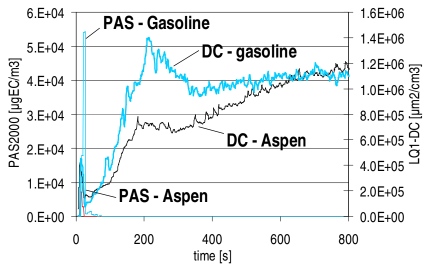
Datas of the used lube oils

Different Scooters Oils & Fuels

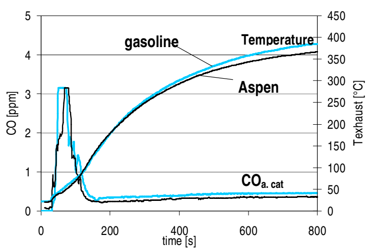
Time plots: **Gasoline – Aspen** (oil: Panolin TS)

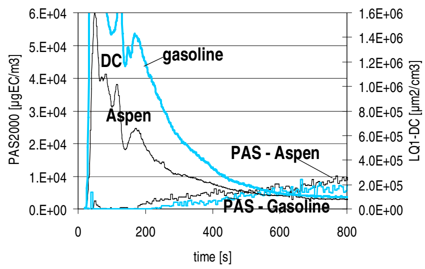
Peugeot TSDI



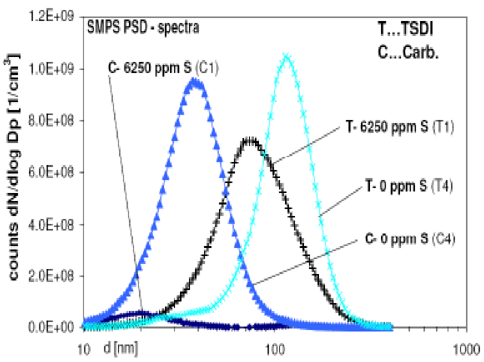


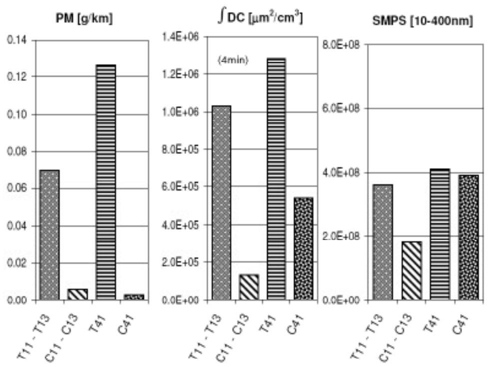
Peugeot Carburator





Comparison : TSDI – Carb. with two oils





Conclusions ;

- the composition of emitted aerosol depends on engine technology (DI-Carb.), exhaust gas aftertreatment (texh, SAS) and the used oil and fuel. The differences of the aerosol are visible by thermoconditioning of the sample,
- the influences of lube oils on the particle emissions from previous works could be confirmed on the scooter with DI and gasoline and they are slightly modified on the Carb. scooter,
- changing the fuel quality (Aspen) may increase the condensates with one oil and lower the condensates with another oil,
- due to an intense oxidation in the exhaust of the Carb. scooter the particle mass emission PM is very little and it is almost independent on lube oil quality,
- due to a high exhaust temperature of the Carb. scooter there are sulfates as condensates in the nuclei mode of the PSD-spectra,
- there is a clear evidence of coinfluences of oil & fuel on the spontaneous condensation and on the particle emission parameters,
- the sampling procedure: conditioning of the sample gas probe, dilution and sampling position have influence on the measured aerosol characteristics (PM, PSD, PAS, DC).

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Catalyst behaviour and emissions of 50 ccm two stroke scooters over the first 1000 km

Martin WEILENMANN, Claudio RUEDY & Philippe NOVAK

Introduction

The vehicle class of 50 cm^3 scooters is booming in central Europe. Possibly, this has to do with the increasingly stuck traffic in urban areas, where scooters are faster than cars. Scooters sold today have to fulfil the Euro-2 emission regulations. Most two stroke scooters are equipped with an oxidation catalyst (oxi-cat) to reach the desired emission quality.
Even though the fleet size of scooters is small compared to passenger cars, their contribution to urban air quality is relevant, especially for HC emissions, since their emission factors are much higher than those of cars (Chen 2003, Gense 2003, Vasic 2004).
In contrast to passenger cars which have to fulfil the emission legislation for a mileage of 80'000 km, two wheelers have no such durability requirements. So, production cost minimization may shorten the life span of the after treatment systems used.
To monitor the real emissions and emission deterioration of such vehicles, six 50 cm^3 two stroke scooter were tested during their first 1000 km.
The following test sequence was repeated three times for the new vehicles (~0 km) and once after 200 km, 500 km and 1000 km:

- The legislative ECE 40m test. Here the emissions were collected separately for the warm up phase and for the legislative phase.
- The first phase of WMTC. See paper for details.
- Constant speed driving at 30 km/h, 45 km/h and full speed, allowing to measure the emissions upstream and downstream of the catalyst.

Between the test series the vehicles were used by employees for their way home, thus in normal traffic.

Results of new vehicles

As shown in Figure 1, two vehicles fail the legislative value of CO; four scooters fail for HC and one for NO_x. In total only vehicles 01 and 05 satisfy the legislation, vehicle 3 exceeds the HC value by 1%.
In Figure 2, the constant speed results are given as catalyst efficiencies at three different load points.
Considering HC, vehicles 01 and 06 show a reasonable catalyst efficiency of more than 60 %, while the efficiencies of vehicles 03 and 04 lie between 30 % and 60 %. The catalyst of vehicle 02 with HC-efficiencies of less than 20 % is more or less inactive, while the catalyst of vehicle 05 shows a low conversion rate except at full load. It must be assumed that this cat has a high light-off temperature not reached at the lower loads.

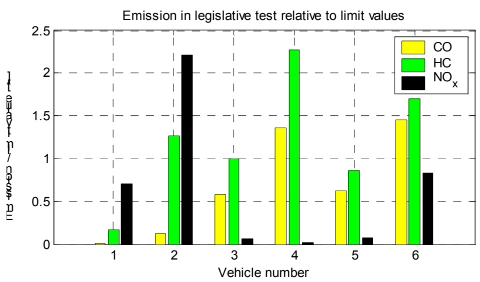

Figure 1: *CO, HC and NO_x emissions of ECE40m test, relative to legislation level.*

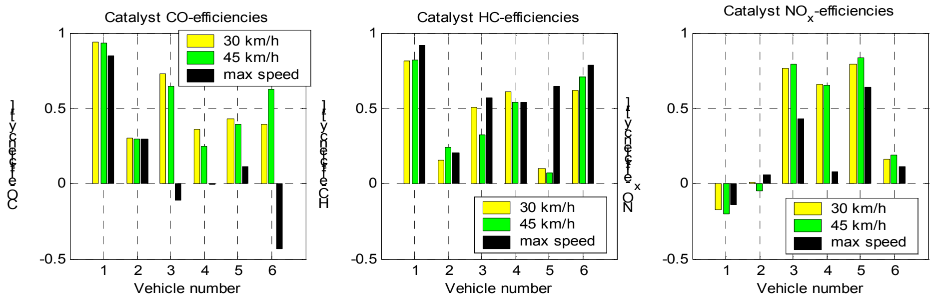

Figure 2: Catalyst efficiencies at different constant load points for new vehicles.

The CO efficiencies are similar to the HC observations except for two cases at full load where they become negative, i.e. the CO concentration is higher downstream the catalyst than upstream. A possible reason is that the engine is running very rich and in the catalyst the HC is oxidized into water and CO but obviously there is not enough oxygen to completely transform the unburned fuel to CO_2.

Emission evolution over 1000 km

As Figures 3 shows, the emissions do not rise over the first 1000 km for warm engines.
However, the cold start HC and CO emissions, measured in the warm up part of the legislative cycle, are rising fairly for some of the scooters (Figure 4). Possibly the "ageing" or "running in" raises somewhat the catalyst light off temperatures.
For those vehicles of the test fleet that showed bad catalyst efficiencies from the beginning, it is not clear if they were designed like that or if their catalysts were destroyed during the few minutes they were driven by the manufacturer or the seller before they came to the laboratory.

Conclusions

- Four of six scooters failed the legislative test as they came from the seller.
- The HC conversion rates of the catalysts range from 80 to 10 %. But the absolute values of the emissions do not correlate to the catalyst efficiencies.
- For some driving conditions and vehicles, the post catalyst CO and NO_x concentrations are higher than before the catalyst.
- The performance of the catalysts did not deteriorate during the first 1000 km, starting with 3-7 km mileage. It can not be excluded that some catalyst broke already before delivery.

References

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Gense R., Elst D., (2003) Towards meaningful real-world emission factors for motorcycles: An evaluation of several recent TNO projects, 12th TAP symposium, pp. 161 - 168, INRETS, Lyon, France.
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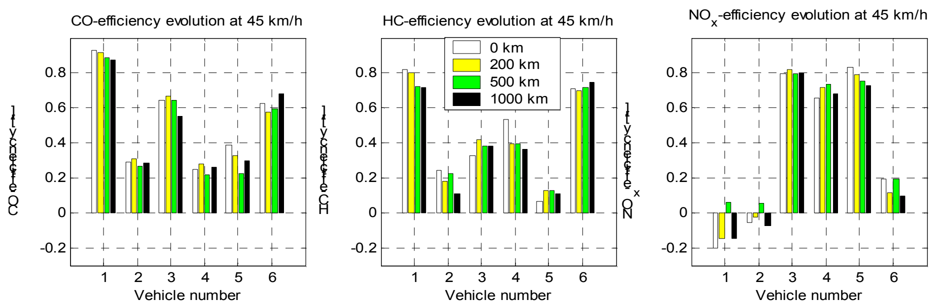


Figure 3: Trend of catalyst efficiencies at 45 km/h over mileage.

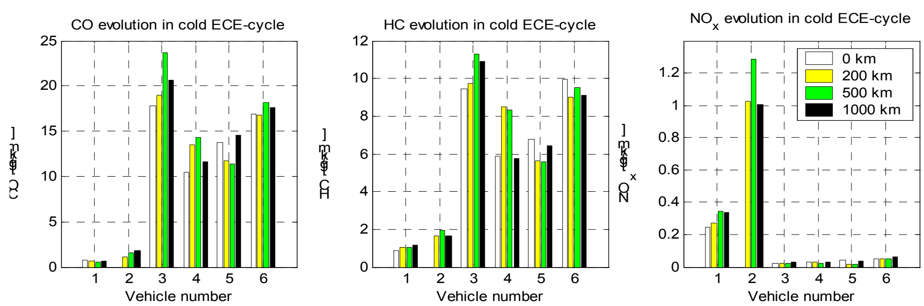


Figure 4: Trend of cold start emissions over mileage.

Acknowledgements: This work was done within the DACH+NL (German, Austrian, Swiss and Dutch) cooperation on vehicle emission monitoring. The authors wish to thank SAFEL and all co-founders.

TWO STROKE MOPEDS and FOUR STROKE SCOOTERS: COLD AND HOT TOTAL MASS PARTICULATE EMISSIONS. PM_{10}; $PM_{2,5}$; PM_1 EMISSIONS.

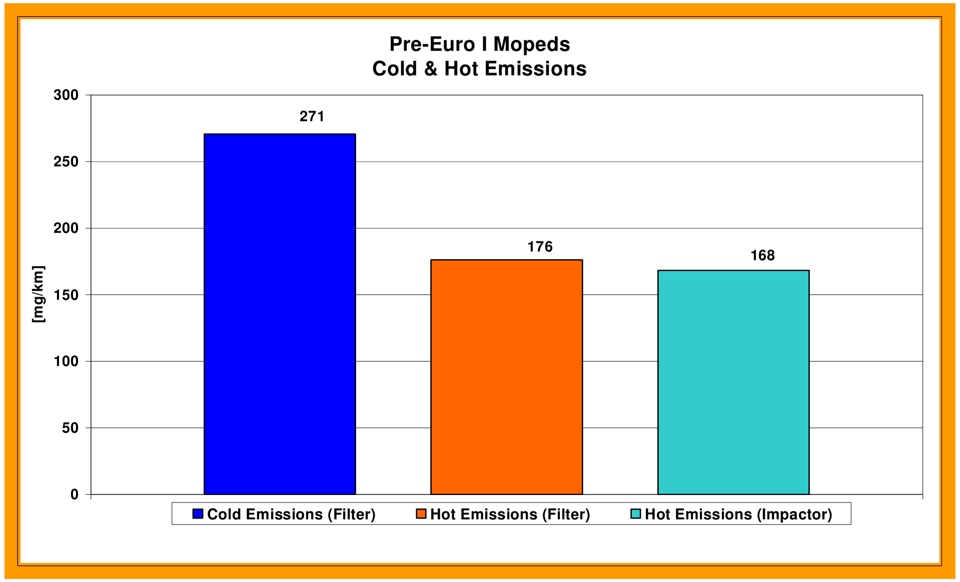
In Rome there are about 277.500 four stroke motorcycles and 312.500 two stroke mopeds.
The PM urban air concentration is the major pollution issue in several Italian big cities.
ENEA in cooperation with the Municipality of Rome carried out an experimental activity to estimate the amount of PM emissions due to two wheel powered vehicles in urban areas. The two wheel vehicles tested were:

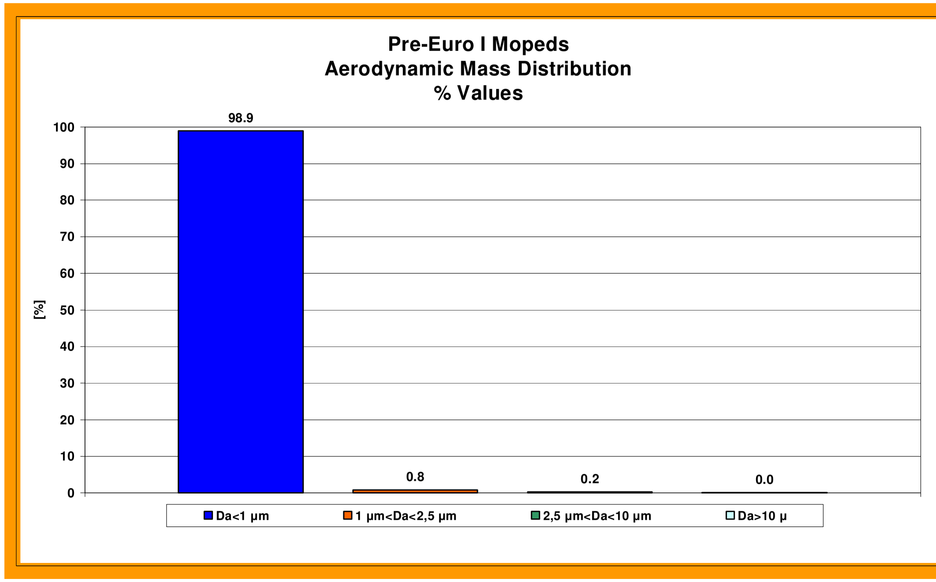
8 in use two stroke mopeds: 3 conventional; 3 Euro I and 2 Euro II ;
4 in use four stroke scooters: 2 conventional and 2 Euro I.

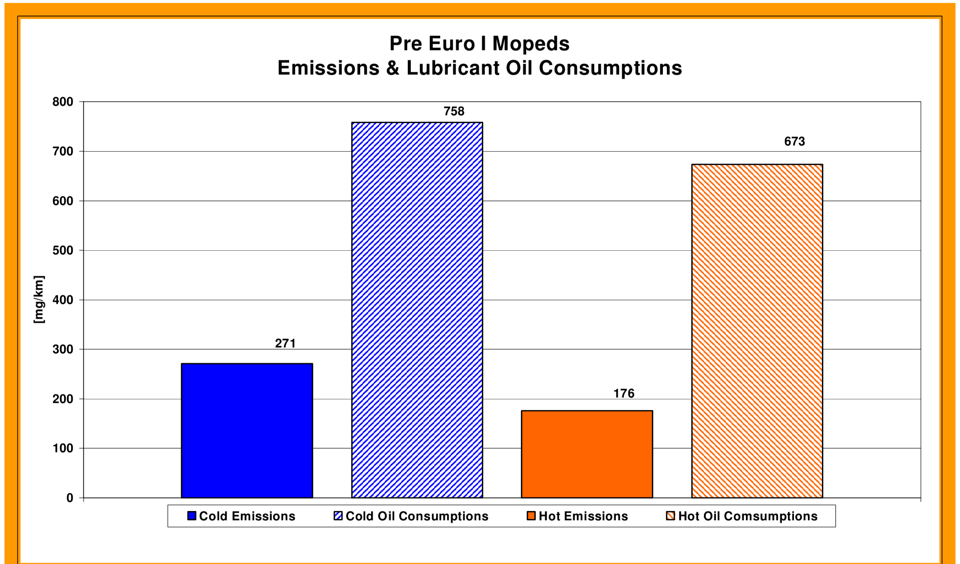
Both mopeds and scooters had continuum variable speed drive.

A bench dynamometer for two vheel vehicles with power up to 35 kW was used. Dynamic tests were performed according to ECE 47 driving cycle for the mopeds and ECE 40 driving cycle for the scooters.
Dilution and sampling procedures were the same used for diesel vehicles. Scooters PM emissions were measured during the whole ECE 40 cycle and during the hot phase, moped emissions during cold and hot phase. Aerodynamic diameter mass distribution was determined only during the hot phase.
The same type of fully synthetic lubricant oil was used for all mopeds.

MAIN CHARACTERISTICS OF TWO WHEELS TESTED							
	VEHICLE CODE	ENGINE DISPLACEMENT (cc)	COOLING SYSTEM	MILEAGE (km)	TECHNOLOGY	CAT	FUELLING
MOPEDS	CM 1	50	Air	16.800	PRE-EURO I	NO	CARBURETTOR
	CM 2	50	Air	19.930	PRE-EURO I	NO	CARBURETTOR
	CM 3	50	Air	11.900	PRE-EURO I	NO	CARBURETTOR
	CM 4	50	Air	6.500	EURO I	YES	CARBURETTOR
	CM 5	50	Air	22.660	EURO I	YES	CARBURETTOR
	CM 6	50	Air	11.640	EURO I	YES	CARBURETTOR
	CM 7	50	Air	1.380	EURO II	YES+SAI	CARBURETTOR
	CM 8	50	Liquid	1.500	EURO II	YES	DIRECT INJECT.
SCOOTERS	MT 1	150	Liquid	5.700	EURO I	NO	CARBURETTOR
	MT 2	150	Liquid	35.000	EURO I	NO	CARBURETTOR
	MT3	150	Liquid	36.000	PRE-EURO I	NO	CARBURETTOR
	MT 4	150	Liquid	33.000	PRE-EURO I	NO	CARBURETTOR

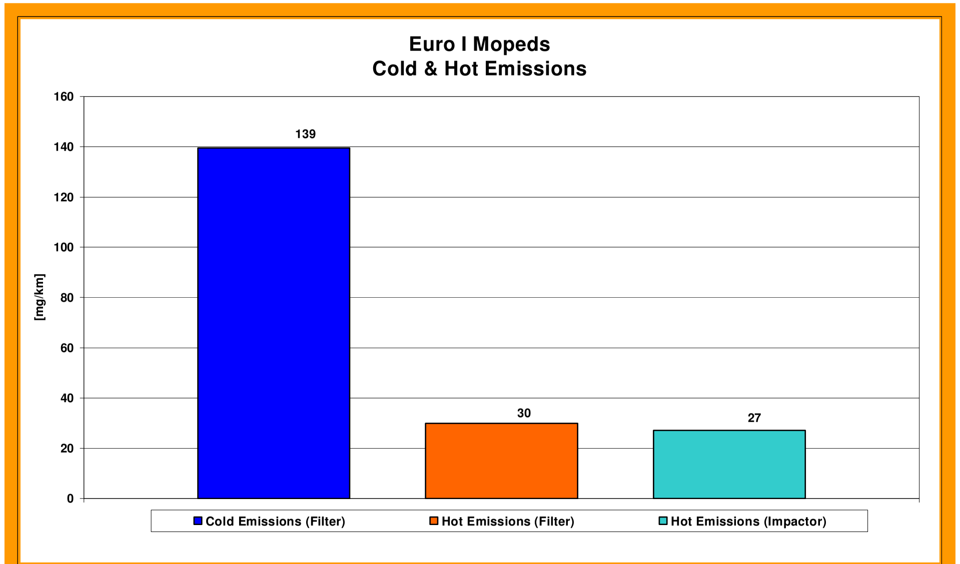


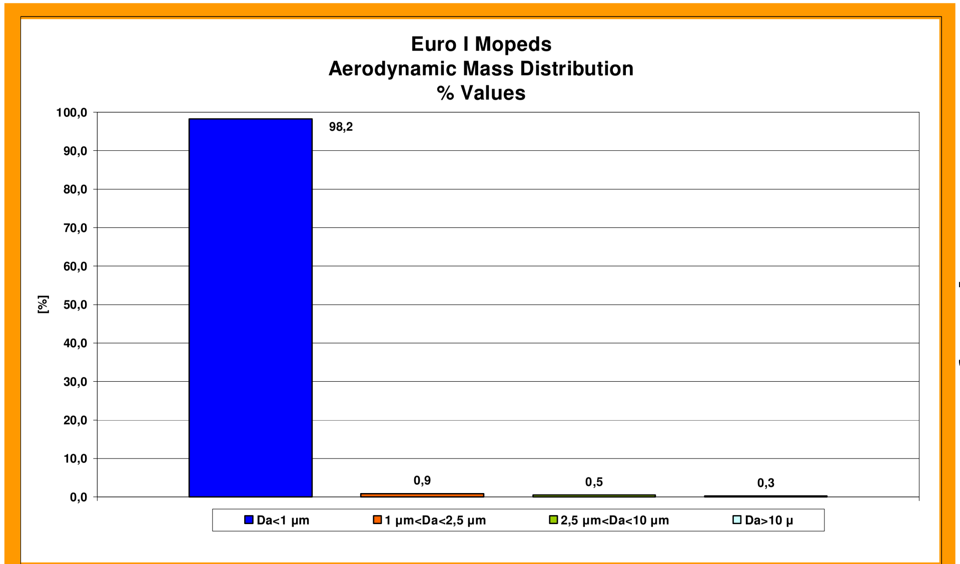


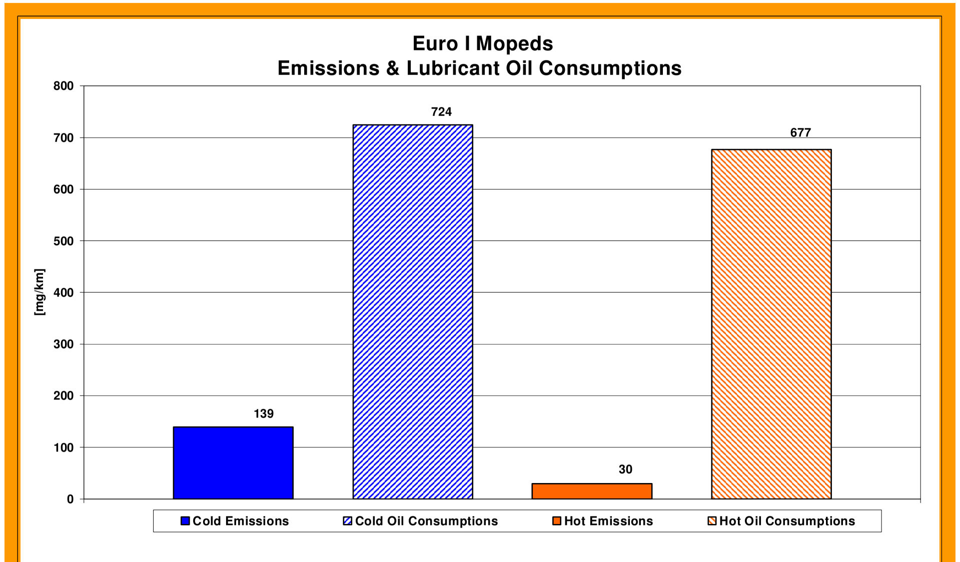


PRE–EURO I MOPEDS

Test results of Pre-Euro I mopeds are in line with the measurements existing in literature.
Emissions are related to lube oil consumption.
Referring to aerodynamic diameter mass distribution, 99% of total collected mass was found to have an aerodynamic diameter less than 1 µm.

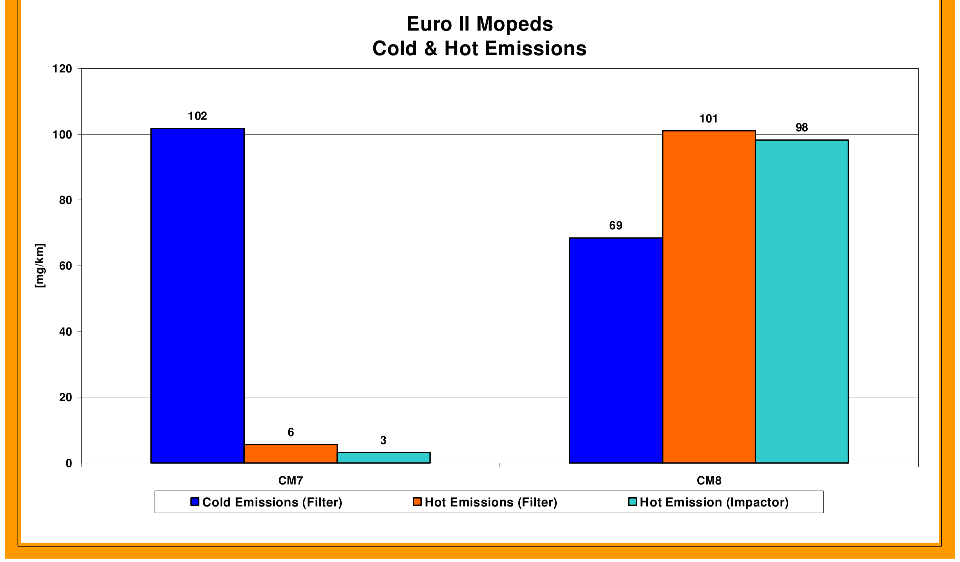


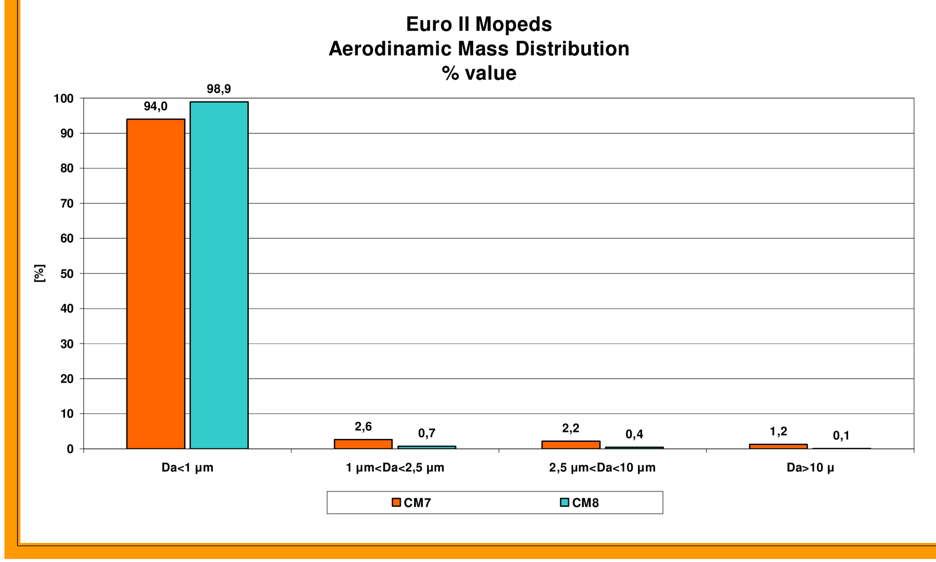


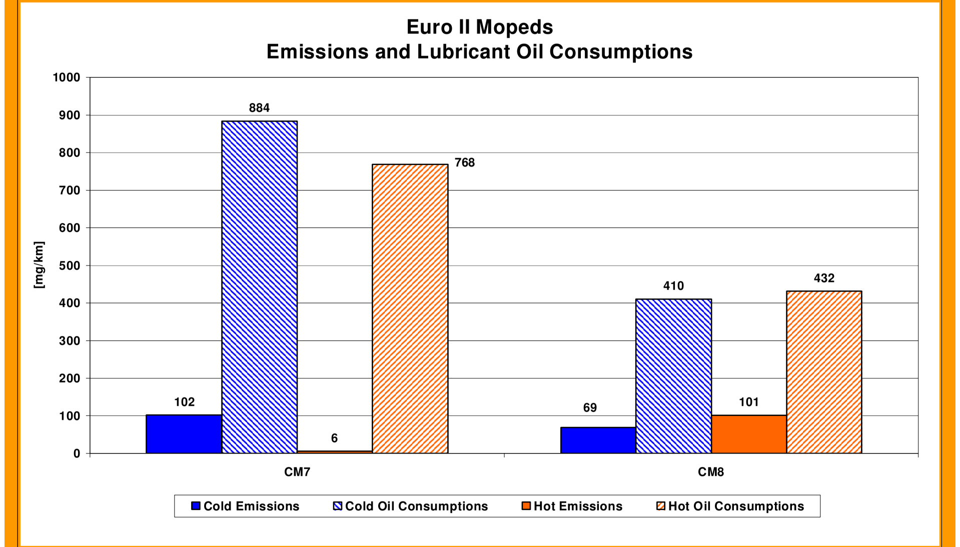


EURO I MOPEDS

Also for Euro I mopeds results were similar to those obtained in other experimental works. Oil consumption during hot phase is close to that measured during cold phase but the oxy-cat reduced emissions by about 80%. Aerodynamic diameter mass distribution showed almost the same pattern as pre-Euro I mopeds.







EURO II MOPEDS

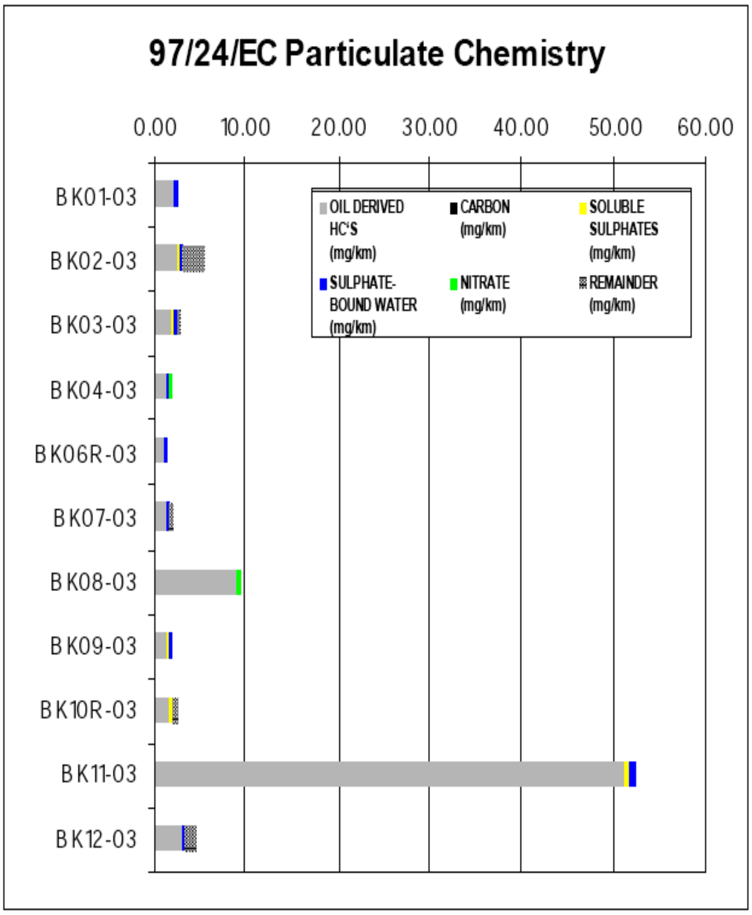
The tests carried out on the two Euro II mopeds showed different cold and hot emissions. Oil consumption and cold emissions of the CM7 moped were pretty close to those of the Euro I mopeds but its hot emissions were very low. On the contrary CM8 moped in spite of lower oil consumption had hot emissions higher than expected. Moreover cold emissions were lower than hot emissions. The results discrepancy suggest further investigations. Regarding to aerodynamic diameters mass distribution CM 7 moped showed slight differences from the others.

Paper JSAE 20030335

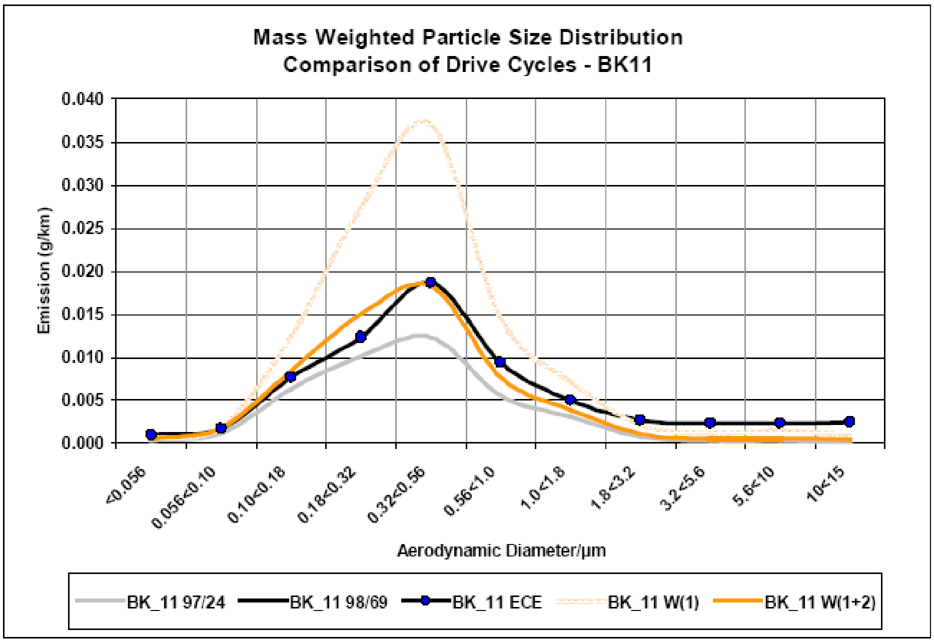
DfT Motorcycle Emissions Measurement Programmes : Unregulated Emissions Results

Ricardo Consulting Engineers

Motor Cycle	Approximate Capacity	2 or 4 stroke	Fuelling	SAI	Catalyst
BK01	180	4s	Carburettor	N	N
BK02	150	4s	Carburettor	Y	N
BK03	950	4s	EFi	N	Y
BK04	800	4s	Carburettor	Y	Y
BK05	650	4s	EFi	N	Y
BK06	500	4s	Carburettor	N	N
BK07	400	4s	Carburettor	Y	N
BK08	50	2s	EFi	N	N
BK09	1300	4s	EFi	N	Y
BK10	250	4s	Carburettor	Y	N
BK11	50	2s	Carburettor	N	Y
BK12	650	4s	Carburettor	Y	N

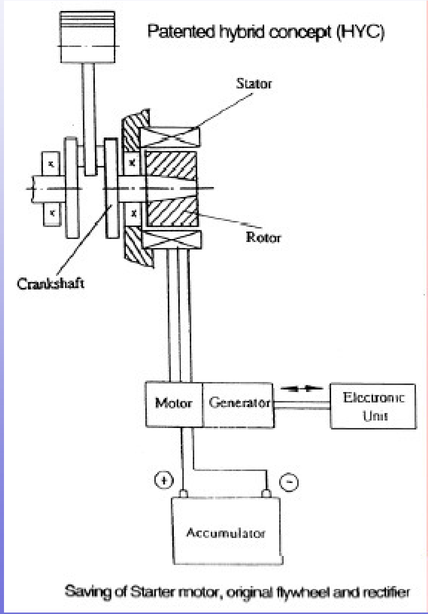


Stage	Test Cycle	Motorcycle	Notes
1	2 * Vehicle Pre-conditioning (UDC+EUDC+EUDC)	1&2	Both motorcycles in test pair
2	98/69 Cold Start Test	1	After cold soak
3	Warm-up/Stabilization	1	
4	Idle	1	10min
5	3 * Hot EUDC Cycles	1	
6	Idle	1	5min
7	Hot EUDC Cycle	1	
8	Idle	1	5min
9	Hot EUDC Cycle	1	
10	Forced Cool Down	1	30min
11	97/24 Emissions Test	1	
12	Forced Cool Down	1	30min
13	97/24 Emissions Test	1	
14	Forced Cool Down	1	30min
15	97/24 Emissions Test	1	
16	WMTC (Phases 1,2&3) Cold Start Test	2	After cold soak
17	Warm-up/Stabilization	2	10min
18	3 * Phase 2 of WMTC Cycle	2	
19	Warm-up/Stabilization	2	10min
20	3 * Phase 3 of WMTC Cycle	2	



HYC

A New Hybrid Concept for Enhanced Performance and ULEV Level Emissions



Patent drawing of the HYC-concept

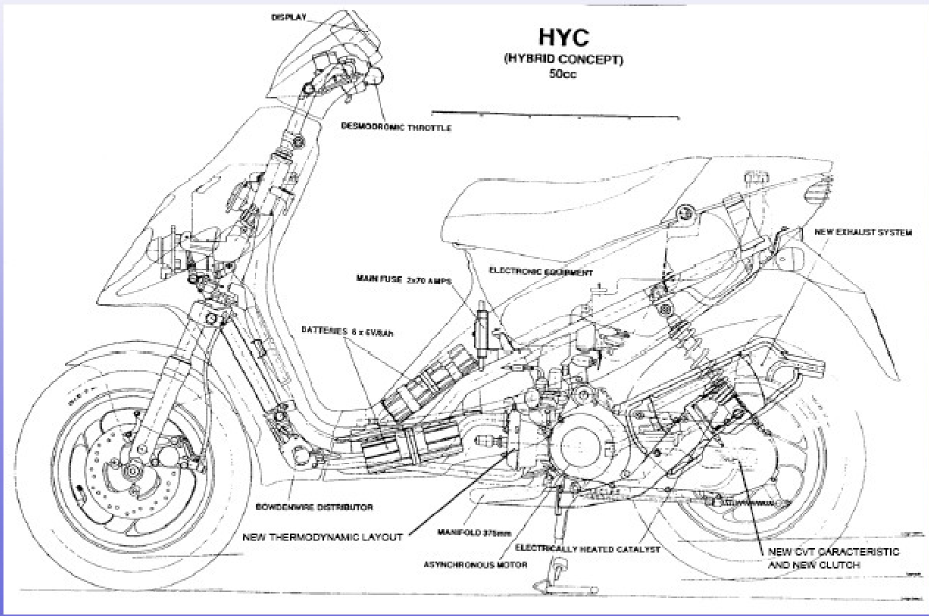
- Increased torque for acceleration
- Lower and stabilized engine idle speed
- Electric starter is replaced by the asynchronous motor (ASM) thus keeping additional weight caused by the ASM minimum
- ASM can work as speed limiter
- Energy recovery during deceleration ASM provides power for the electrically heated catalyst (EHC)

Development Objectives

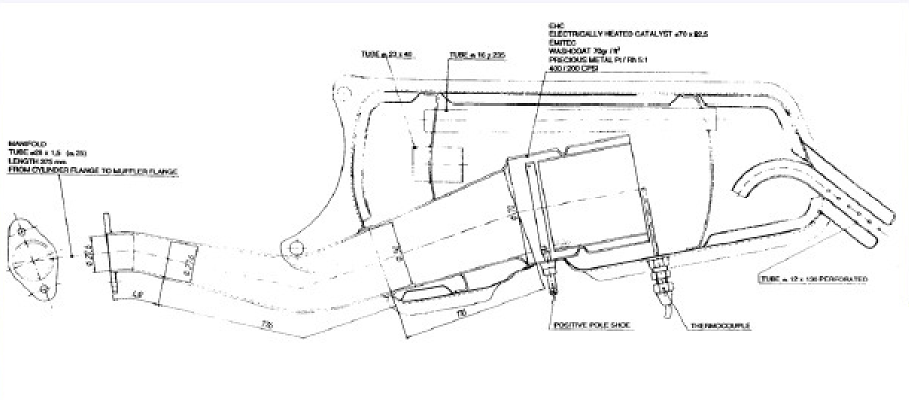
- Good throttle response of the lean burn engine especially under transient conditions
- Reduced and smooth idle at low noise emission
- 10% reduced fuel consumption in the ECE-R47 driving cycle compared to the original engine

Mechanical Development

HYC vehicle modifications, general view



Electrically heated catalyst (EHC)



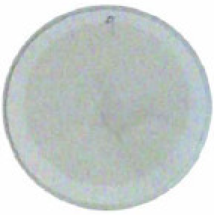
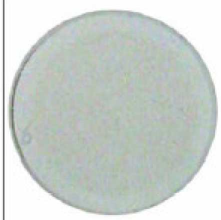
Electrically heated catalyst (EHC)

Emissions and Fuel Consumption

Acceptance Test Results	CO [g/km]	HC [g/km]	NO_x [g/km]	$HC+NO_x$ [g/km]	Particle Emissions [g/km]	Fuel Consumption [km/l]	Top Speed [km/h]	Acceleration 0-35km/h [s]
18.12.2001 EU Limits	1.0	Aggr. Limit $HC+NO_x$	Aggr. Limit $HC+NO_x$	1.2	No Limit	-	45	-
According ECE47 Regulation (4 warm up cycles followed by 4 measurement cycles)								
Standard MA50 Vehicle	17.2	6.90	0.010	6.910	Not Measured	32.8	47.5	9.0
Lean Burn with Catalyst	0.25	0.09	0.097	0.187	0.020	39.0 - 41.0	48.5	5.5
HYC with EHC	0.31	0.04	0.160	0.200	0.006	37.9 - 43.7	49.0	3.2
ECE47 Driving Cycle Including Cold Start (4 measurement cycles)								
Standard MA50 Vehicle	18.2	7.10	0.010	7.110	0.260	31.2	47.5	9.0
Lean Burn with Catalyst	0.60	1.5	0.070	1.570	Not Measured	38.2	48.5	5.5
HYC with EHC	0.43	0.39	0.085	0.499	0.005	37.6 - 40.0	49.0	3.2

Particle emissions

(photos of the particle filters for visualization)

	Standard MA50 engine, including cold start	Lean Burn, 4 warm up cycles and 4 measuring cycles	HYC including cold start	HYC 4 warm up cycles and 4 measuring cycles
Main filter				
Secondary filter				

Effect of motorcycle engine technology upon physical properties of nanoparticles

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Abstract
The purpose of the present exercise was to evaluate the effect of two-wheelers engine technology upon the physical properties of particles. The vehicle fleet included 11 motorcycles of different engine types (2 and 4-stroke), technologies (carburetor, direct injection, electronic fuel injection) and after-treatment systems. The dynamic tests were conducted on a chassis dynamometer following the regulated European test cycles (ECE R40 and 47). The sampling conditions were identical to those used for diesel passenger cars, i.e. a dilution tunnel whose flow rate was kept constant during the entire testing campaign. The total mass and the mass versus size distributions were measured using a Low Pressure Impactor (LPI). Some steady state measurements were also conducted with a Scanning Mobility Particle Sizer (SMPS) to investigate the effect of vehicle speed upon the particle concentration. The particulate matter emitted by motorcycles equipped with 4-stroke engines appeared to be of similar mass and size to that from the conventional gasoline passenger cars. The particulate emitted by two wheelers powered with two stroke engines were much higher in mass and strongly depend on the engine technology. Conventional 2-stroke engines exhibit mass-size distributions with peak towards 200-300 nanometers whereas the direct injection technology produced smaller diameters.

Introduction
The European institutions are preparing the amendment of the Directive 97/24/EC [1] on “Characteristics of two or three-wheel motor vehicles”. One of the objectives of the future legislation is to lower the particulate emissions from motorcycles, especially from the ones equipped with two-stroke engines. The main two objectives of the present study were to determine particulate mass emissions from 2-stroke engines and to assess particulate emissions for big four-stroke engines to check if they diverge significantly from passenger cars with similar engine sizes. The motorcycles considered for this study were chosen to best represent the wide range of engine and after treatment technologies existing for these vehicles. The effect of oil quality upon the results is discussed in a companion paper [2].

Test fleet and test conditions
The test motorcycles have been selected to best represent the variety of engine and after treatment technologies existing on the market. The fleet included 3 mopeds with 2-stroke engines and several motorcycles with 4-stroke engines. Amongst the mopeds, one was “pre-Euro1”, i.e. with no reduction system, whereas the second one was equipped with a catalytic converter and the third one with a direct injection engine. Within the 4-stroke family, the technology was ranging from the conventional engine with a carburetor to the most advanced one with electronic fuel injection and a three-way catalytic converter. Various engine capacities, ranging from 125cc to 1200 cc, were also considered.

The dilution of the exhaust gas was carried out using a constant volume sampler (CVS) whose flow rate was set to 7.5 m^3/min for the entire testing campaign. The dilution air, taken from the test cell was maintained at constant temperature and humidity (22.5°C, 50%rH) throughout a test. Mass measurements have been conducted under dynamic conditions (different driving cycles) following the standard procedure for diesel passenger cars. The number size distributions have been obtained using a Scanning Mobility Particle Sizer (SMPS) at constant speeds (from 20 kph to 60 kph when possible).

Results
In terms of mass, the pre-Euro1 moped equipped with a 2-stroke engine emits a significant amount of particulate matter. The more advanced vehicles exhibit better results, close to the Euro4 limit for diesel passenger cars (0,025 g/km). The chemical composition of these particles is obviously very different

from the one emitted by diesel engines [3]. As far as 4-stroke engines are concerned, the particulate emission levels were very low and do not significantly diverge from those of modern gasoline passenger cars. The total masses collected with the Low Pressure Impactor were in good agreement with the filter results.

The engine technology has a strong influence on the properties of the particulate emissions from 2-stroke mopeds. The mass/size distribution of particulates emitted by these vehicles exhibit a peak in the range of about 200-300 nm (aerodynamic diameter). For the moped equipped with a direct injection engine, the distribution is shifted towards smaller diameters. The latter observation is consistent with the measurements of the number/size distributions performed with the SMPS.

Finally, the day-to-day repeatability of the latter type of measurements was proven to be excellent, as evidenced by the good agreement between the curves obtained for five consecutive days, each curve being the average of 5 consecutive scans with the apparatus.

Conclusions

The physical properties of particulate from motorcycles have been characterized using the pre-defined existing test procedures and “state of the art” instruments. The conclusions are that Pre-Euro1 conventional 2-stroke engines emit high masses and numbers of particulate matter and that there is some technological potential to reduce these levels using 2-stroke engines with direct injection and/or catalytic converters. All 4 stroke engines, even the less modern ones, emit masses of particulate matter comparable to those observed for gasoline passenger cars, at least in terms of mass per distance, which is the parameter considered by the policy maker.

Acknowledgements

These tests have been conducted with the essential contribution from the Vehicle and Engine Laboratory (VELA) staff. The authors also the European association of motorcycle manufacturers (ACEM) for providing test motorcycles.

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Chemical Characterization of Emissions from 2-stroke and 4-stroke Motorcycle Engines

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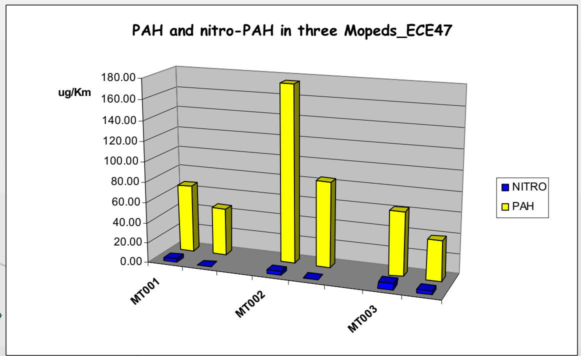
Objectives:
•Characterization of non-regulated Polyaromatic compounds, PAC (*i.e.* PAH, nitro-PAH & Azaarenes) present in PM emissions from motorcycles.
•Evaluation of links between emissions and health effects.

Motorcycle fleet

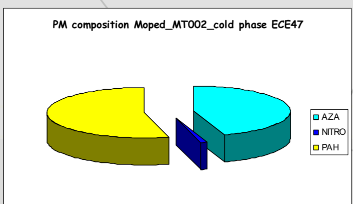
Category	Motorcycles	Eng. (cc)	2S	4S	Engine/After-treatment characteristics
Moped	MT001	50	X		Standard 2-stroke engine
Moped	MT002	50	X		Ditech Engine, Electronic injection
Moped	MT003	50	X		Moped, With Catalyst
>450cc	MT007	500		X	Catalyst
>1000cc	MT008	1150		X	Controlled TWC (Three Way Catalyst)
>1000cc	MT009	1200		X	Controlled TWC (Three Way Catalyst)

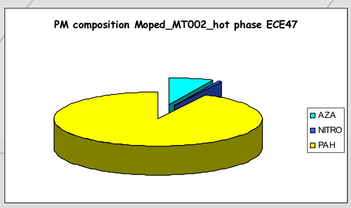
Sampling and analysis of PM collected from the motorcycles

- The test were performed on a chassis dynamometer following the ECE47 driving cycle for mopeds; ECE40 and WMTC test cycles were used for large motorcycles.
- PM was collected on Teflon coated filters after the dilution tunnel.
- Chemical analysis were performed by GC-MS (EI ionization mode and NICI for nitro-PAH) after soxhlet extraction and clean up (SPE).

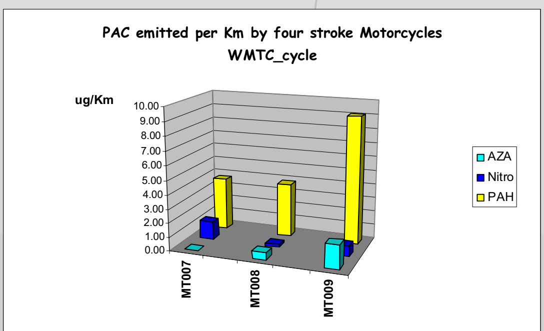


PAH concentration is much higher than nitro-PAH in all the moped PM emissions analyzed.





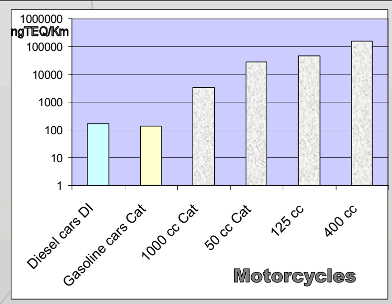
•Results from 8 different types of PM indicate that azaarenes are present in engine exhaust.
•The highest amount of this class of compounds was found in mopeds and it can change significantly depending on the after-treatment technology
•The chemical composition of the PM emitted is different for cold and hot phases.



Large motorcycles with advance after-treatment systems emit significantly lower amount of PAC than Mopeds and medium size motorcycles (125cc-450cc).

Conclusions:

- Links between emissions and health effects:
  - Motorbikes emit higher amount of toxic compounds than gasoline and diesel cars
  - Large motorcycles with TWC technology are cleaner than the small ones.
  - The toxicity equivalency system allows for meaningful data reduction/evaluation.
- Chemical composition :
  - The composition of the PM emitted is directly related to the engine and the after treatment technology.



TOXIC EQUIVALENCY FACTOR (TEF) is a measure of relative toxicological potency of a chemical compared to a well characterized reference compound (BaP). TEFs can be used to sum the toxicological potency of a mixture of chemicals which are all members of the same chemical class, having common structural, toxicological and biochemical properties. This concept has been proposed to facilitate both human and ecological risk assessment (*e.g.* U.S. EPA, 1991).

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"Emissions from a Moped Fuelled by Gasoline/Ethanol Mixtures"

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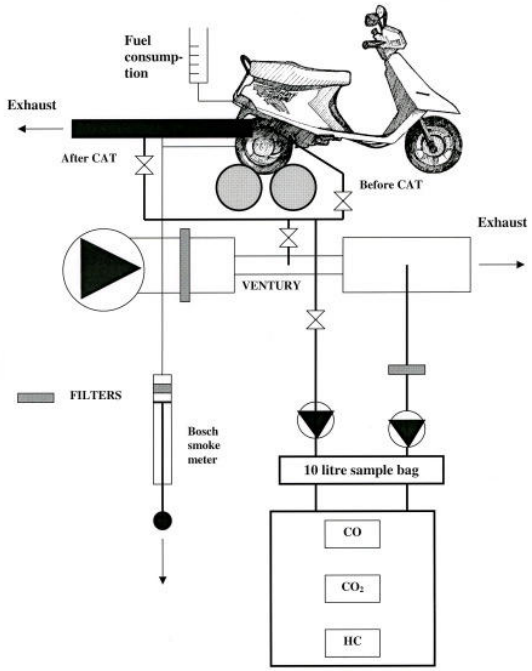

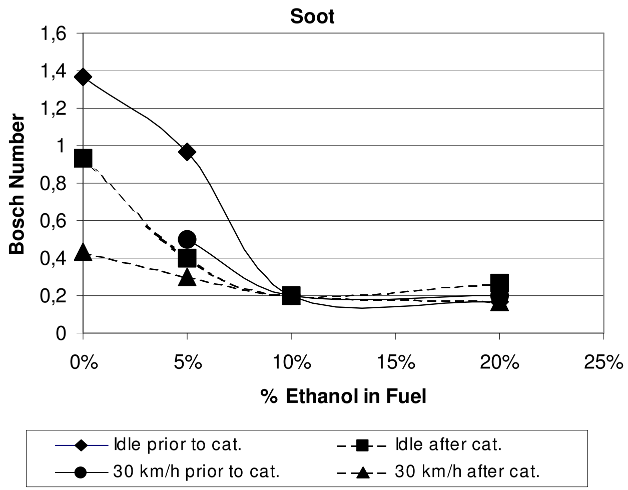

	Gasoline		*Gasoline with 10% Ethanol*	
	Prior to cat	After cat	Prior to cat	After cat
Total particulate matter	0,106	0,024	0,048	0,011
SOF[1] (% of total)	0,0943 (89)	0,0063 (26)	0,048 (100)	0,0030 (27)
Inorganic	0,012	0,018	0,000	0,008

Table 7. Particulate emissions in g/km at 30 km/h with hot engine. (measured by collection of the particulate matter on a filter after dilution)

[1] Soluble Organic Fraction of particulate matter

Vehicle Type	Gasoline Cars	Diesel Cars	2stroke-EFI	2stroke-Carb.	MC-4stroke EFI	MC-4stroke Carb.	
Catalyst	TWC	OX	-	-	TWC	TWC	-
CO[1]	0,6	0,2	0,7	4,0	4,5	10,5	13
CO (regulated)[2]	2,3	0,64	8	8	13	13	13
HC	0,11	0,05	1,0	4,0	0,6	0,4	0,9
HC (regulated)	0,2		4	4	3	3	3
NOx	0,1	0,5	0,6	0,03	0,25	0,11	0,23
NOx (regulated)	0,15	0,5	0,1	0,1	0,3	0,3	0,3
HC+NOx		0,55	1,6	4,0			
HC+NOx (regulated)		0,55					
Particulates	0,002	0,03	0,01	0,06	0,003	0,005	0,003
Particulates (regulated)	(0,025)[3]	0,05 (0,025)[3]					

Table 2. Measured and regulated emission factors (g/km) from cars and motorcycles.

1: Measured emissions. Car emissions were measured on EURO 3 cars at The Technical University of Denmark [5] and motorcycle emissions were measured on 97/24/EC regulated motorcycles in U.K. [6].
2: Regulated emissions in EU.
3: EURO 4, to be implemented in 2005.

Ratio:	2stroke EFI / Gasoline Cars	2stroke Carb. / Gasoline Cars	4stroke EFI, TWC / Gasoline Cars	4stroke Carb., TWC / Gasoline Cars	4stroke Carb. / Gasoline Cars
CO	1,2	6,7	7,5	17,5	21,7
HC	9,1	36	5,5	3,6	8,2
NOx	6	0,06	2,5	1,1	2,0
Particu-lates	5,0	30	1,5	2,5	1,5

Table 3. Ratio between measured moped/motorcycle emission factors and gasoline car emission factors.

Ratio:	2stroke EFI / Gasoline Cars	2stroke Carb. / Gasoline Cars	4stroke EFI, TWC / Gasoline Cars	4stroke Carb., TWC / Gasoline Cars	4stroke Carb. / Gasoline Cars
CO	3,5	3,5	5,7	5,7	5,7
HC	20	20	15	15	15
NOx	0,7	0,7	2	2	2
Particu-lates					

Table 4. Ratio between regulated moped/motorcycle emission factors and gasoline car emission factors.

	Mopeds (2stroke)	Motorcycles (4stroke)
CO	1-5 (3)	11-32 (8)
HC	7-28 (15)	5-12 (22)
NOx	0-5 (1)	2-4 (3)
Particu-lates	4-23 (-)	2-4 (-)

Table 5. Estimated emissions from motorcycles and mopeds in relation to gasoline car emissions in Denmark in 2002. In brackets are shown the same figures, calculated from emission regulation limits. Units are in percent.