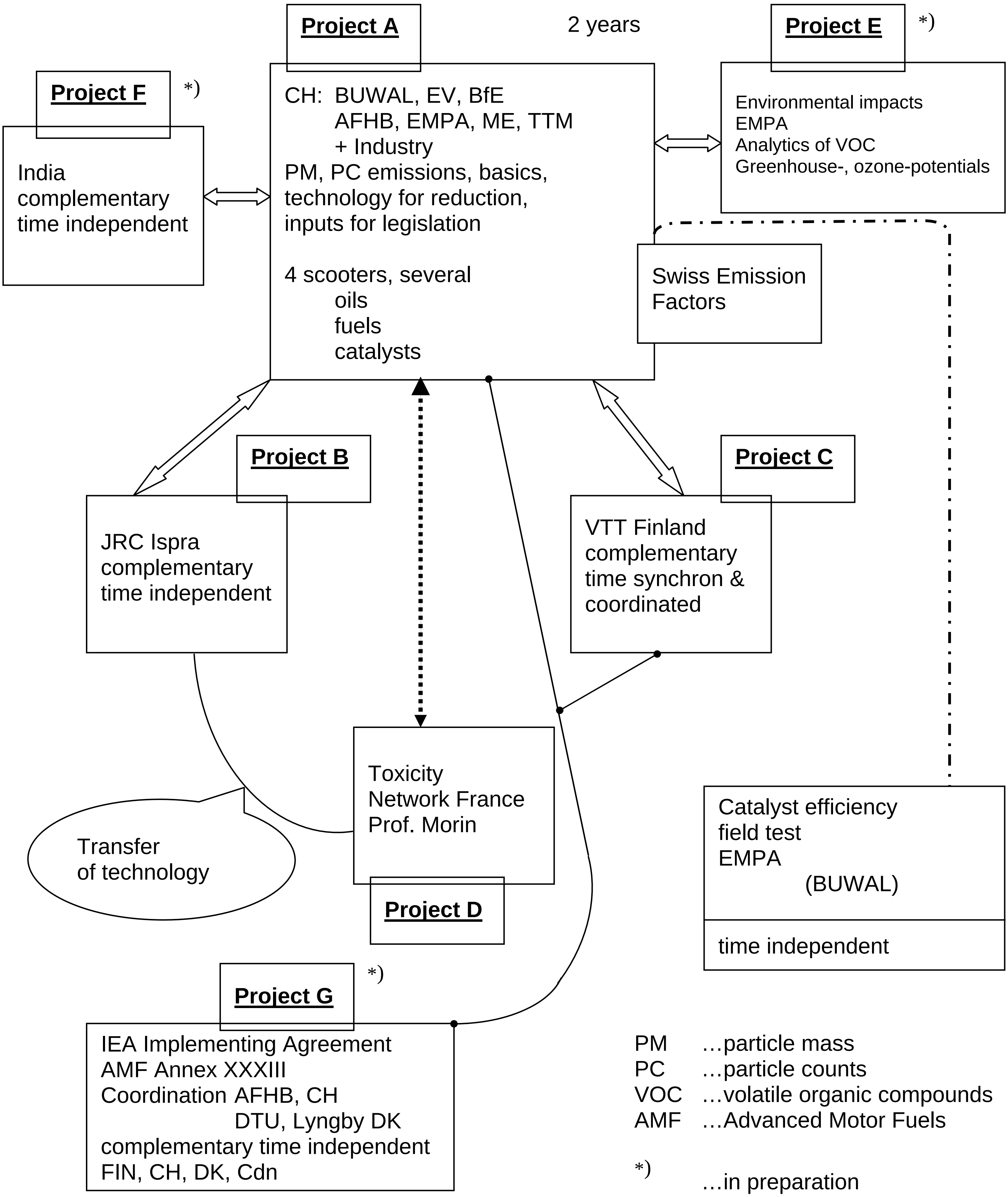
2-S Scooters International Projects Network: Particle emissions, toxicology & environmental impacts

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

Catalyst Ageing and Effects on Particle Emissions of 2-S Scooters

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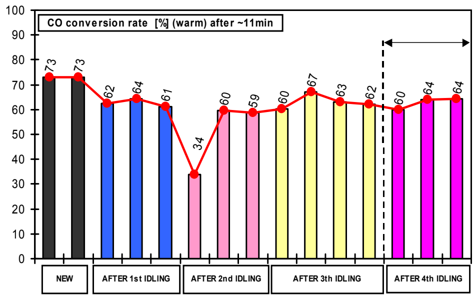
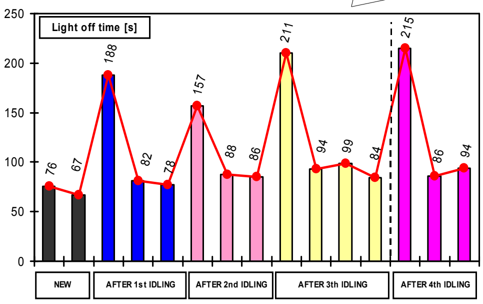
Catalyst ageing

- ► **thermal oven-ageing** (by manufacturer)
- ► **physico-chemical ageing** (on vehicle, oil overdosing)
- ► **pollution & cleaning** (disassembled muffler)

Phase 1 : Pollution of the catalyst in long run tests & idling

►Catalyst polluted after 4h idling & ~ 4% oil





► CO conversion rate (warm) and light off time after cold starts pollution of catalyst by oil overtreatement (4%) and 4h idling

Peugeot Looxor carb.; lube oil: Panolin TS

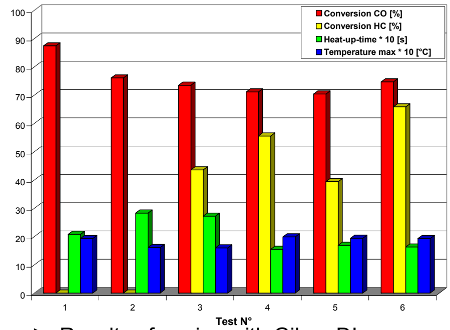
Phase 2 : ageing procedure

- ►Oil overdosing (summary approx. 4%)
- ►2h idling - 10 min FL* - 2h idling - 10 min FL - 2h idling - 10 min FL - 2h idling

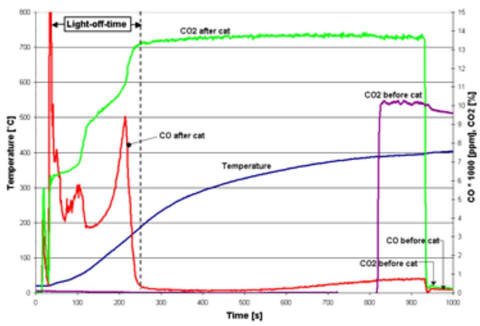
* FL ...full load

- ►Cooling down with blower (minimum 30 min)
- ►Cold start with acceleration to FL (10 min gas measurement after cat)
- ►Gas measurement before cat nondiluted
- ►Gas measurement before cat diluted
- ►Gas measurement after cat diluted

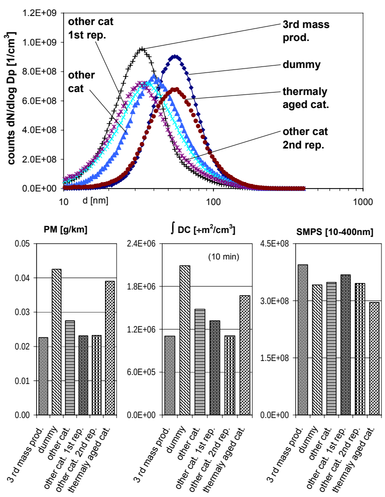
Sationary warm



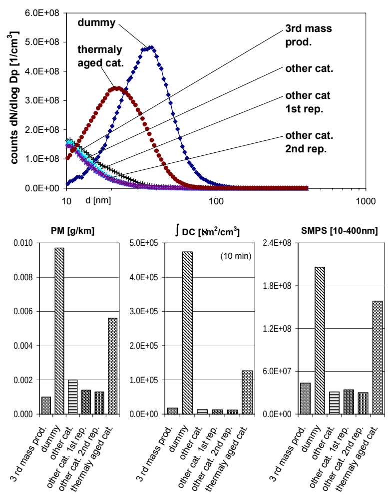
► Results of ageing with Gilera DI



► Definition of light-off-time of Typhoon Carb.



Gilera DI



Typhoon Carb.

Phase 3 : Catalyst screening at 40 km/h

► lower PM-oxidation with dummy, or with aged catalyst

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IC-Engines and Exhaust Gas Control

Potentials of Particle Emission Reduction of 2-S Scooters with Combinations of Technical Measures.

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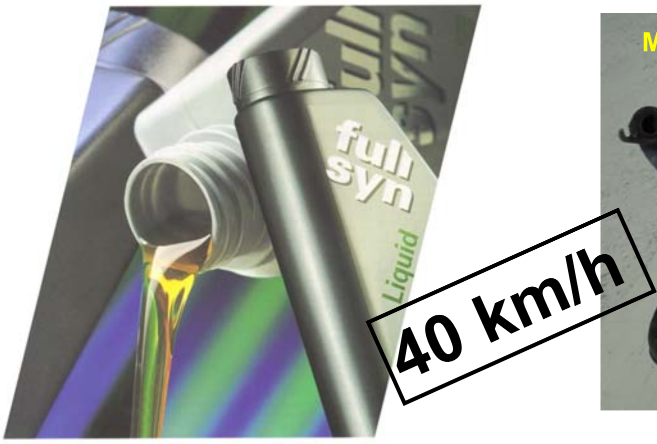
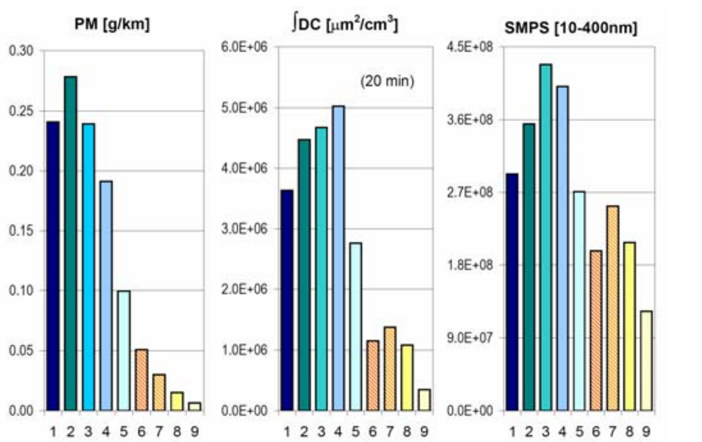
Investigated Combinations

- no catalyst (dummy), lower tier oil, overdosing, gasoline
- no catalyst (dummy), lower tier oil, 100% dosing, gasoline
- no catalyst (dummy), higher tier oil, 100% dosing, gasoline
- no catalyst (dummy), higher tier oil, 50% dosing, gasoline
- ox. catalyst (series), higher tier oil, 50% dosing, gasoline
- ox. cat. + WFC, higher tier oil, 50% dosing, gasoline
- ox. cat. + WFC, higher tier oil, 50% dosing, Aspen

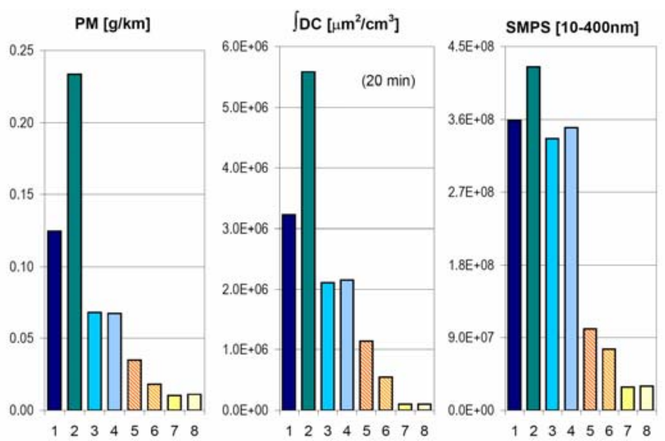


Particle Mass & Nanoparticle Emissions



Peugeot TSDI

1: dummy, lower oil, 100%, gas. 4: dummy, higher oil, 100%, gas. 7: oxi cat+WFC, higher oil, 50%, gas.
2: dummy, lower oil, 150%, gas. 5: dummy, higher oil, 50%, gas. 8: oxi cat+WFC, higher oil, 50%, gas.
3: dummy, lower oil, 200%, gas. 6: oxi cat, higher oil, 50%, gas. 9: oxi cat+WFC, higher oil, 50%, Aspen.



Peugeot Carb.

1: dummy, lower oil, 100%, gas. 4: dummy, higher oil, 50%, gas. 7: oxi cat+WFC, higher oil, 50%, gas.
2: dummy, lower oil, 200%, gas. 5: oxi cat, higher oil, 50%, gas. 8: oxi cat+WFC, higher oil, 50%, Aspen.
3: dummy, higher oil, 100%, gas. 6: oxi cat, higher oil, 50%, gas.

► PM-Reduction from standard to the best case <u>95%</u>

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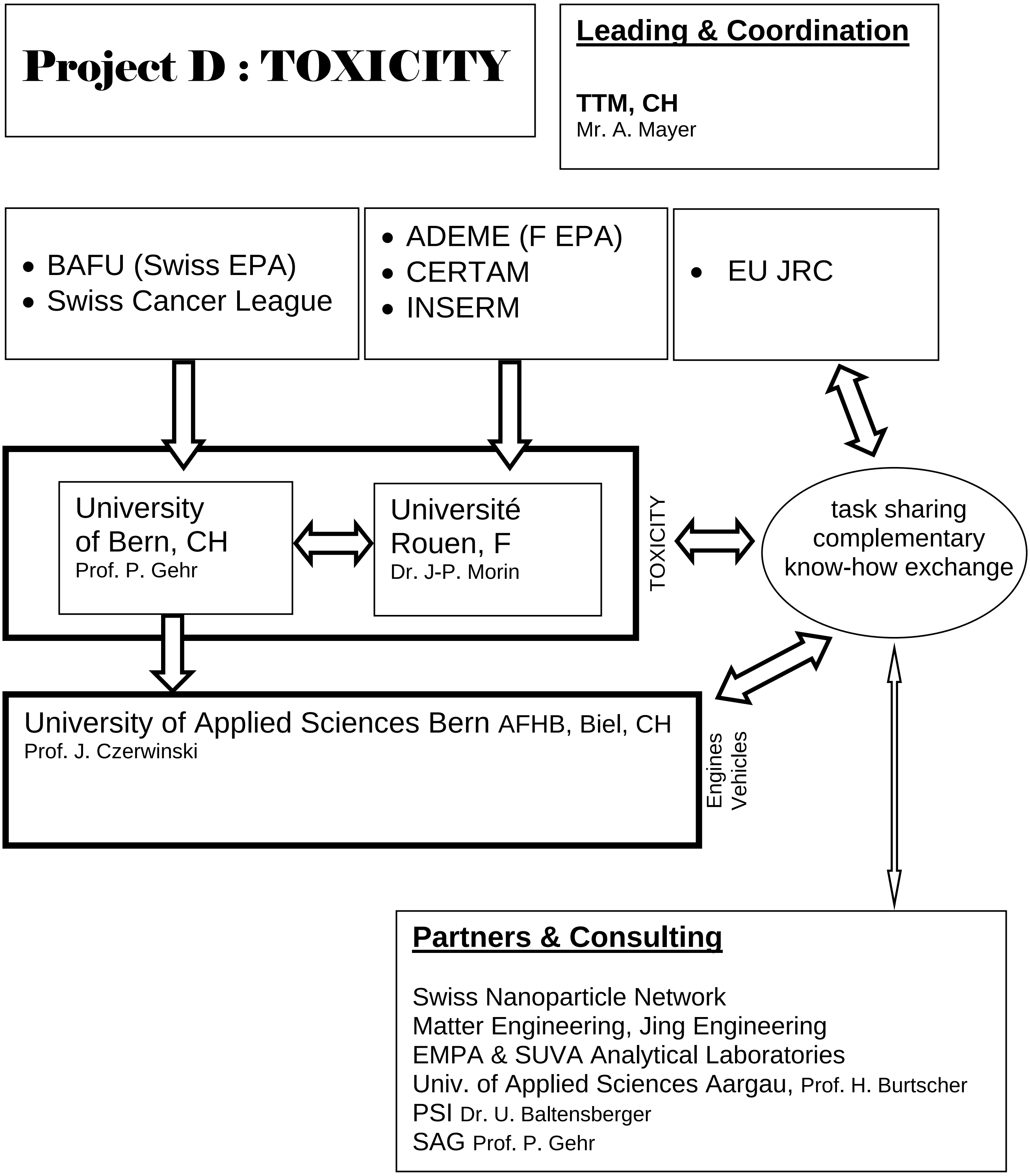
2-S Scooters Internatinal Projects Network :
Particle emissions, toxicology & environmental impacts

Nov. 2007



BAFU	…	Bundesamt für Umwelt
ADEME	…	Agence de l'Environnement et de la Maîtrise de l'Energie
CERTAM	…	Centre D' Etudes et de Recherche Technologique en Aérothermique et Moteur
INSERM	…	Institut National de la Santé et de la Recherche Médicale
JRC	…	Joint Reserch Center
AFHB	…	University of Applied Sciences Bern, Abgasprüfstelle FH Biel
TTM	...	Technik Thermische Maschinen
EMPA	...	Matrials Science and Technology
SUVA	...	Schweizerischer Unfall Versicherungsanstalt
PSI	...	Paul Scherrer Institut
SAG	...	Swiss Aerosol Group (medical)

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Particle-phase Polycyclic Aromatic Hydrocarbon Emissions from Non-catalysed, In-use Four-stroke Scooters

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Abstract The emissions of particle-phase polycyclic aromatic hydrocarbons (PAHs) were evaluated in the exhaust of four (two EURO-0 and two EURO-1) four-stroke engine, in-use scooters with displacement of 150 cc, which were not equipped with catalytic converters. Non-catalysed motorcycles still represent a large proportion of circulating two-wheelers in Italy and, possibly, also in other countries. Tests were performed on a dynamometer bench, using the ECE-40 test cycle procedure. Particulate matter into the exhaust emissions was collected both during the "hot" phase of the ECE-40 driving cycle and including the first two elementary cycles of engine warming-up heating (whole cycle). Fourteen PAHs were quantified and total PAH emission factors (Σ PAH) ranged from 7 to 169 μg km^{-1}. Expressed in benzo(a)pyrene equivalent (BaP_{eq}), emission factors ranged from 0.6 to 18 μg km^{-1}. Results from the tested scooters show that despite their small engine size, non-catalysed motorcycles can emit amounts of particulate PAHs that can be comparable or even higher than emissions reported elsewhere from gasoline- and diesel-powered passenger cars and light- and heavy-duty vehicles. In countries where a large number of non-catalysed motorcycles are circulating, PAH emissions in urban areas from this class of vehicles might be of the same order of magnitude of emissions from diesel passenger cars.

Keywords Dynamometer bench · Emission factors · Exhaust emission · Motorcycle · Particulate matter · Polycyclic aromatic hydrocarbons

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1 Introduction

Polycyclic aromatic hydrocarbons (PAHs) are formed as a complex mixture of compounds during incomplete combustion of organic matter. The presence of PAHs in the atmosphere has received increased attention because the possible effects on human health. For some PAHs, carcinogenic and mutagenic properties have been documented (IARC, 1983; 2003).

Motor vehicles have been recognised to be major contributors to the atmospheric burden of PAHs in urban areas (Baek et al., 1991; Caricchia, Chiavarini,

Table IV Particulate matter (PM, mg km^{-1}) and particle-phase PAHs (μg km^{-1}) emission factors

	M1		M2		M3		M4		TEF*
	Whole	Hot	Whole	Hot	Whole	Hot	Whole	Hot	
PM	1.3	1.7	2.3	2.5	7.7	7.3	1.9	1.9	
PHE	0.04	0.04	0.07	0.10	0.80	0.63	0.12	0.12	0.001
AN	0.00	0.00	0.00	0.00	0.32	0.21	0.00	0.00	0.01
FLA	0.46	0.51	1.42	1.66	7.79	6.87	0.34	0.41	0.001
PY	0.90	1.02	2.68	3.01	14.0	12.7	0.60	0.81	0.001
BaA	0.93	1.31	3.85	4.48	16.8	15.7	0.68	1.16	0.1
CHR	0.74	1.02	2.98	3.58	12.7	12.0	0.61	0.96	0.01
CPP	0.87	1.19	3.96	4.07	28.4	25.9	0.99	1.69	–
BF	0.73	1.02	4.32	5.58	19.6	20.1	0.85	1.43	0.1
BeP	0.68	0.93	3.58	4.46	11.6	12.1	0.81	1.41	–
BaP	0.40	0.59	2.82	3.42	12.5	12.9	0.59	1.02	1
IP	0.19	0.28	1.63	2.12	9.05	9.85	0.24	0.47	0.1
DBahA	0.03	0.03	0.18	0.23	1.08	1.19	0.05	0.09	0.1
BghiP	0.59	0.87	4.62	5.35	19.7	22.6	0.82	2.01	0.01
COR	0.20	0.30	2.51	2.65	14.3	16.1	0.64	1.34	–
∑ PAH	6.74	9.10	34.6	40.7	169	169	7.34	12.9	
BaPeq	0.61	0.87	3.90	4.76	17.5	17.9	0.78	1.36	

* Source: Nisbet & LaGoy, 1992.

TEF values for the PAHs are reported in last column.

Figure 2 Correlation between emission factors of ΣPAH (sum of 14 compounds) and PM emission factors.

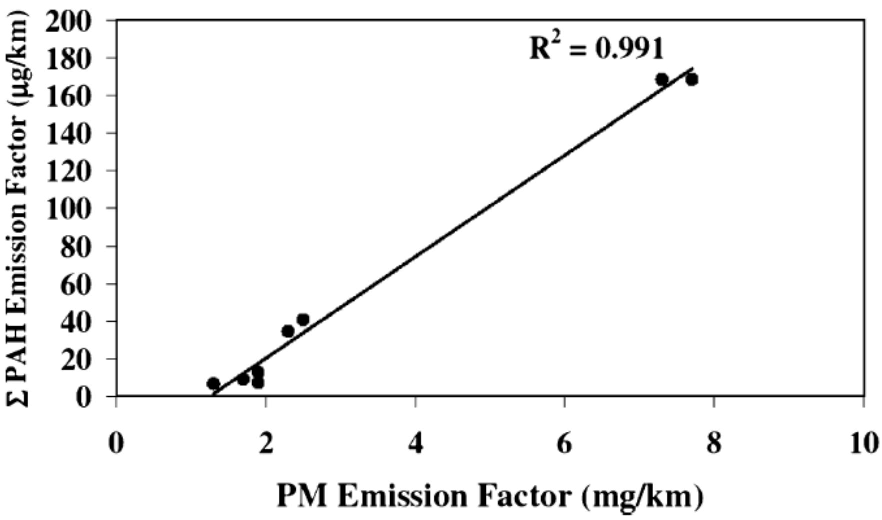
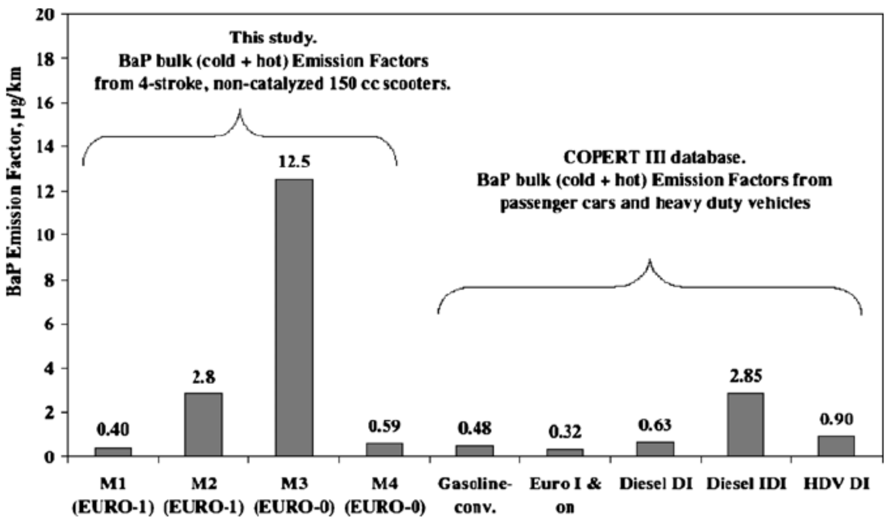


Figure 3 Comparison of BaP bulk (cold + hot) emission factors.



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Potential of high technology 50cm³ two stroke and four stroke engines

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Future exhaust emission targets and increasing customer demands call for the implementation of enhanced engine technologies, as well known from automotive applications, into small capacity engine categories. Especially the applied engineering solutions in the market of motor vehicles driven by engines up to 50 cm³ displacement have been significantly changed in the last years. Beside low cost technologies (air cooled two stroke or four stroke engines with carburetor), enhanced mixture preparation and exhaust gas after treatment systems come to use.

Highly technological two stroke engines are equipped with direct fuel injection systems in combination with efficient exhaust gas after treatment methods; in four stroke engine applications intake port fuel injection systems in combination with oxidation catalysts or 3-way catalytic conversion are established on the market. Several applications of new and innovative technologies have already been worked out in research programs and presented at several SETC conferences (please refer to the following papers: SETC 2006-32-0065 [1], SETC 2005-32-0098 [2] and [3] for the two stroke engines and SETC 2006-01-0404 [4], 2004-01-2105 [5] for four stroke engines). These technologies are now available in a pre-serial production status or as prototype engines.

Keywords: 4-stroke, 2-stroke, emissions, pollutant, costs, oil consumption, efficiency

1. INTRODUCTION

The present paper treats a comparison of the potential of highly technological 50 cm³ two stroke and four stroke engines as drive units for two wheeler motor vehicles.

In the following, four engine technologies will be analysed in detail and compared according to their relevance on the market, their technical behaviour and finally to the thermodynamic behaviour especially regarding engine losses.

Four stroke naturally aspirated engine (4S-NA):

First engine is a 50 cm³ four stroke engine with overhead cam shaft (OHC), 4 valve cylinder head, equipped with fuel injection and a 3-way catalyst exhaust gas after treatment. More technical details can be found in Table 1.

Four stroke supercharged engine (4S-SC):

The second engine in our comparison is a 50 cm³ crankcase supercharged engine with an OHC 2 valve cylinder head. The working principle of the supercharged engine is displayed in Figure 1. The intake air (1) is aspirated through a reed valve (2) into the crankcase (3). The oil for the lubrication of the crank train is pumped via the oil induction pipe (12) into the crankcase. After being pre-compressed in the crankcase the air-oil mixture flows through the outlet reed valve (4) into the oil separating volume (5). In this volume the oil will be isolated from the air. The intake air is then mixed with fuel in the intake port (6) (or in the case of DGI in the combustion chamber). The gas exchange is controlled by the intake valves (8) and the exhaust valves (9) as common in conventional four stroke engines. The isolated oil flows through the oil back flow system (10) into the oil tank (11). The oil tank can be used as an additional lubrication system of the engine. From the oil tank an oil pump (13) forces the oil through lubrication holes (12) into the crankcase. The oil circle consists of the oil tank, an oil dosing pump, the crankcase, a separating volume and the oil back flow system. The oil tank is used for the second lubrication cycle of the engine too. For the lubrication of the cylinder head or other parts the oil is forced to the lubrication spots by an additional oil pump. In Table 1 the technical data of this supercharged engine can be found.

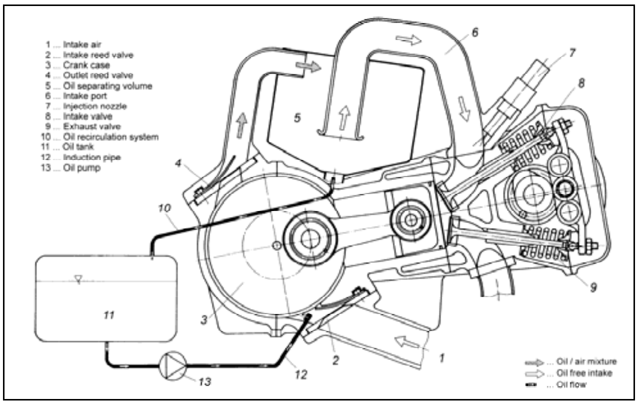

Figure 1: Functional description of a crankcase supercharged four stroke engine with oil separating system [13]

As a counter part to the four stroke engines two types of two stroke engines are added to the comparison approach. Engine three and four are 50 cm³ two stroke engines. One engine with intake port injection, as example for external mixture preparation systems, and one applied with low pressure direct injection, representative for internal mixture preparation system.

Two stroke intake port injection engine (2S-PI):

The 2S-PI is a 50 cm³ two stroke engine with external mixture preparation. This engine works with a homogeneous air-fuel-oil mixture preparation in the crankcase and in the scavenge process. To allow a perfect adjustment of the air fuel ratio in this engine configuration the carburettor was displaced by a fuel injection system and a throttle body (Figure 2) (1). The injector (2) is oriented towards the reed valves (3).

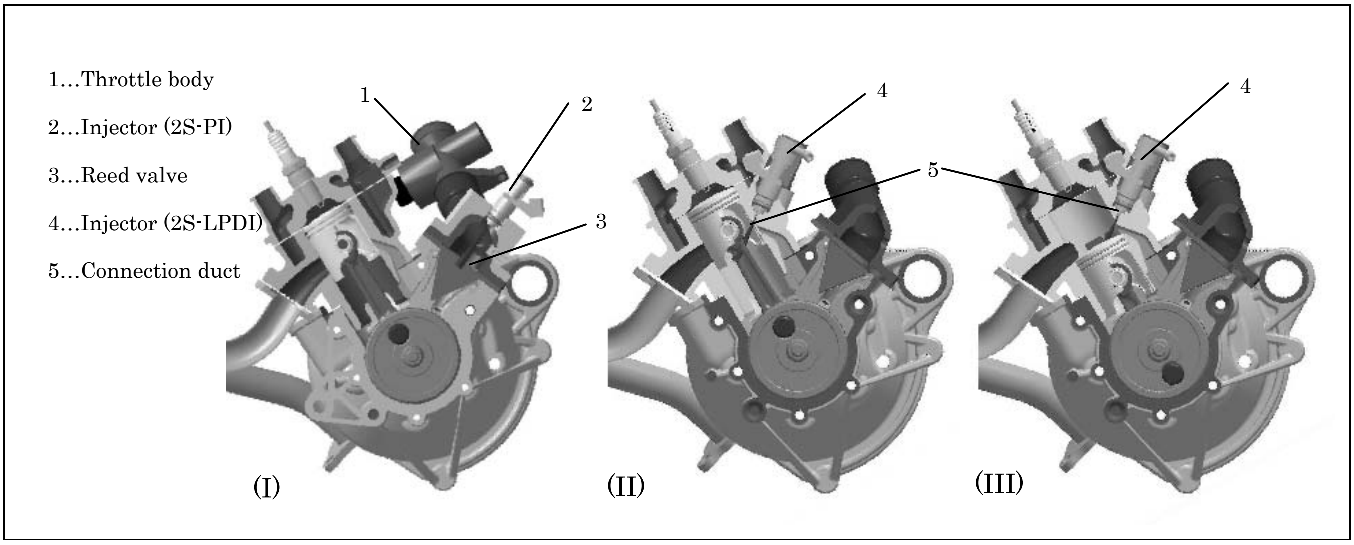

Figure 2: Functional principal of the two stroke engines, (I) 2S-PI, (II) 2S-LPDI homogenous mode, and (III) 2S-LPDI DI-mode

Two stroke low pressure direct injection engine (2S-LPDI):

Finally a higher sophisticated 50 cm³ two stroke engine is included in this program.

In principle this system is capable of effecting two different mixture preparation systems (Figure 2). The fuel can either be directly applied to the cylinder (direct injection) or can be injected into the crankcase through a window in the piston (homogenous mode). The injection nozzle is located in the cylinder wall opposite to the exhaust port (4) and is connected to the cylinder via a small connection duct (5). The injection can be effected as long as the cylinder pressure is lower than the injection pressure and, respectively, as long as the connecting duct is not covered by the piston. The injection spray is directed to the piston surface and thereby has to penetrate the strong flow field of the scavenge ports. The technical data of the above mentioned 4 engine types are summarized in the Table 1.

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GEO2 has created a novel ceramic PM filter

High porosity and permeability → 67%

Low backpressure → Less than half backpressure of leading ceramics (Cordierite and Silicon Carbide)

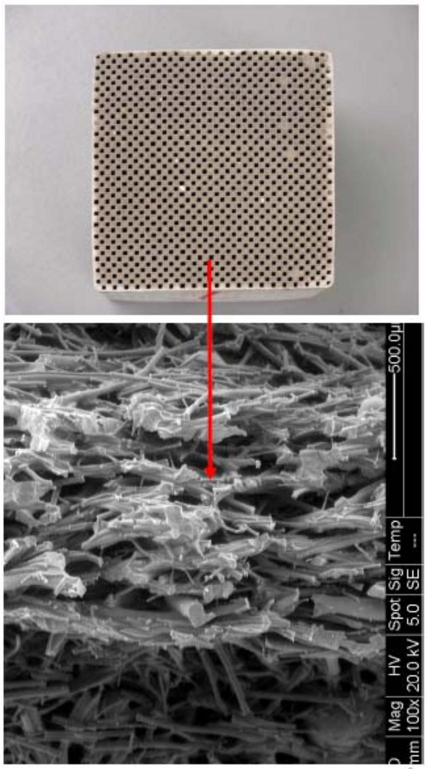
High trapping efficiency → 98%+ (particle number concentration based)

High temperature → 1500 C maximum operating temperature

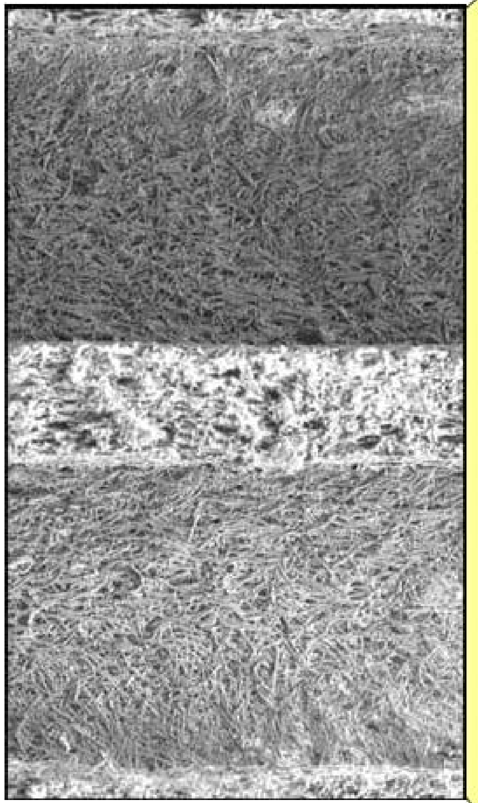
Multiple material chemistries

- Mullite
- Silicon Carbide
- Cordierite
- Others

Low cost of production

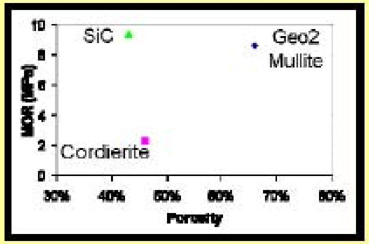


GEO2 has an advantaged cross-linked microstructure for efficient nano-particle filtration

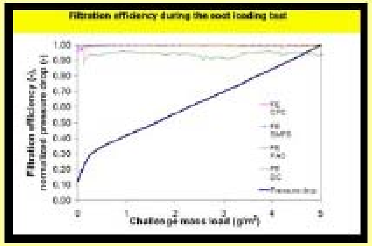


Microstructure can enable:
- Filter size reduction
- Low backpressure
- Less precious metal required

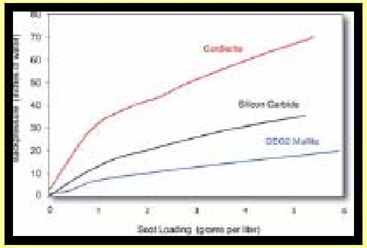
High strength at high porosity



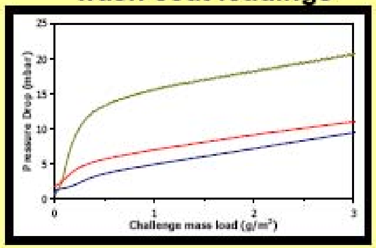
High trapping efficiency



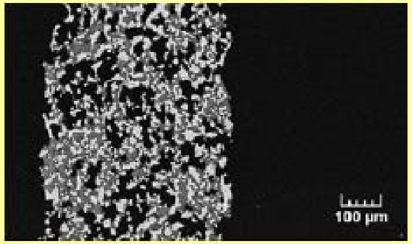
Low uncoated backpressure



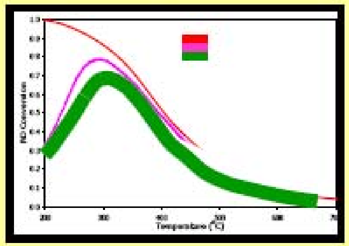
Low backpressure with wash coat loadings



Better dispersion of catalyst

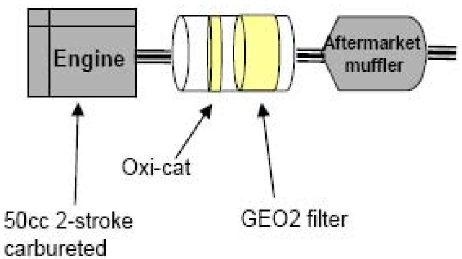


Higher catalyst reactivity

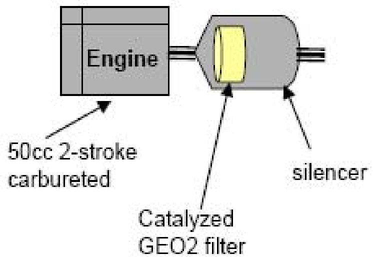


Scooter test set up: Technical details

Current test configuration



Future test: integrated cat + filter



Piaggio 2-stroke 50 cc engine

66mm x 50.8 automotive catalyst for temperature increase. Stock catalyst is 66mm x 25.4mm

71mm x 71mm x 70mm square filter. 200 cpsi, 18 mil walls

16,000 km on steady state durability test (~280 Hours) and dyno full throttle accelerations performed on Dayton MC Dyno

Temperature (C):
- 380 - 400 into catalyst
- 700 - 900 into filter
- 475 - 675 out

Particle emissions measurement system: TSI Model 3070A EAD (linearly calibrated with a TSI CPC) equipped with Matter Engineering MD19-2E Rotating Disk Diluter (heated lines)

Oil used: Mobile 1 Racing 2T (API TC, JASO FC)

AECC NEWSLETTER
September – October 2007

India to move to 10% Biofuels by 2017

Speaking at the International Symposium on Biofuels in New Delhi, the Indian Petroleum Secretary announced that India plans to replace 10% of its transport fuels by biofuels in the next 10 years. Currently India uses a 5% ethanol/petrol blend.

Beijing adopts Low Sulfur Fuel and restricts Manganese

Beijing's new fuels specifications, to be put into use from 1 January 2008, have been approved by the State Council. The key parameters are a maximum sulfur content of 0.005% for both diesel and gasoline and a maximum manganese concentration of 0.006g/litre for gasoline.

MIDDLE EAST

Israeli Ministers approve Plan to Reduce Pollution by Vehicles

Israel's Ministerial Committee on the Environment and Hazardous Materials has approved a plan to reduce vehicle pollution. It is intended to significantly decrease dangerous levels of air pollution as well as decreasing fuel consumption and reducing traffic. The plan includes new, severe standards for automobile exhaust gases. It includes rules limiting pollutants from diesel vehicles as well as carbon dioxide emissions levels for gasoline-powered cars.

The green police will be allowed to remove from the roads vehicles that exceed the limits. In addition, all government and public transport will gradually switch to fuel-saving and environmentally friendly vehicles. Starting in January 2008 entry of diesel vehicles more than five-years old to Tel Aviv city centre will be restricted unless they have emissions controls installed. Also included in the plan is the disposal of old cars in return for payments to their owners. Roadside emissions tests will also be reinstated. Employees will be encouraged to travel to work on public transport. Vehicle taxes will take into account an environmental rating. Also, financial incentives for non-petroleum alternative fuels will be set.

GENERAL

ICCT Report on Emissions Impacts of Two- and Three-Wheel Vehicles

The International Council on Clean Transportation (ICCT) has released a new report that discusses the air quality impacts of two- and three-wheel vehicles that are a primary transportation mode in many cities throughout Asia. It includes a summary of the current regulatory environment for these types of vehicles and a summary of available control measures.

China, India, Indonesia, Thailand, Taiwan and Vietnam all have substantial population of bikes and many have annual growth rates in excess of 10% for motorcycles. In cities like Delhi, Bangkok, and Ho Chi Minh City, motorcycles are estimated to produce 70% or more of the total transportation related volatile organic compound (VOC) emissions.

The report is available at: www.theicct.org/reports_live.cfm

Mercedes launches BlueTec® in Europe

Mercedes staged a major effort on 'environmental' products at the Frankfurt International Motor Show, including the launch of BlueTec for the European market. Most of the main floor in DaimlerChrysler's hall was taken up with a display of green technologies, including the E300 BlueTec due for European launch this year, R320 BlueTec and C-class versions including a BlueTec hybrid, and an S-300 Hybrid intended for launch by 2010.

Researchers identify Diesel Exhaust Links to Heart Attacks and Blood Clots

A study conducted by researchers at the University of Edinburgh in Scotland and Umea University in Sweden has indicated how air pollution may be associated with heart attacks. In the test work, 20 men with stable coronary heart disease inhaled dilute diesel exhaust or filtered air whilst riding a bicycle in the laboratory. The researchers found that inhaling the exhaust reduced the amount of oxygen available to the heart during exercise and resulted in a three-fold increase in stress on the heart by altering its electrical activity. The risk of blood clots was also increased. Whilst it was not possible to determine from the tests which constituents of diesel exhaust were responsible for the observed effects, the researchers suggest that the effect may be linked to particle emissions and they plan to repeat the test with a particulate filter installed.

Source: Mills et al, Ischemic and Thrombotic Effects of Dilute Diesel-Exhaust Inhalation in Men with Coronary Heart Disease; The New England Journal of Medicine, Vol. 356, 1075-1082, 13 September 2007.

A second study, from researchers at Northwestern University, the University of Illinois and the US Environmental Protection Agency identifies a mechanism by which PM10 can trigger clotting in the blood, thus helping to explain how air pollution causes heart attacks and strokes. The researchers found higher levels of several proteins linked to blood

Air Emissions Issues Related to Two- and Three-Wheeled Motor Vehicles

An Initial Assessment of Current Conditions and Options for Control

July 2007

Meszler
Engineering Services

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usage change, some fraction of operators will curtail usage. As discussed above, the cost-effectiveness of such measures is highly dependent on local conditions and available transportation alternatives, but in general behavioral-type controls tend to be less cost-effective than technology-based controls. At the same time, behavioral controls have the benefit of being able to affect emissions from all in-use motorcycles. As was the case with outright bans on motorcycle use, the impacts of behavioral controls are likely to disproportionately affect the lower income segments of society, who depend on comparatively inexpensive motorcycles for their transportation needs. This does not mean that such controls should not be considered, but rather that they should be fully evaluated in the context of local conditions -- including in comparison to the cost of other control options such as more stringent emission standards for new motorcycles -- and implemented only in cases where they are justified from both socioeconomic and environmental viewpoints.

6. Summary of Issues and Options

Emissions from motorcycles can be significant contributors to air quality problems, especially in urban areas where they can serve as a primary transportation option due to both their relative affordability and their ability to maneuver in heavy traffic. As a result, control of motorcycle emissions is becoming an important element of an effective air quality control plan. Due to a continuing evolution in the knowledge database related to motorcycle emissions, there are a number of issues that merit further research and potential regulatory attention. At the same time, there are a number of currently recognized control options that can be implemented to control motorcycle emissions. While these options will also undoubtedly continue to expand and evolve, there is ample evidence that adoption of currently available control options would lead to dramatic and cost-effective emission reductions, while simultaneously promoting the continued development of next-generation controls.

Among the areas where additional research or support activity would be advantageous to the effective development of motorcycle emissions control programs are:

- Continuing efforts to recruit and test existing in-use motorcycles. Such efforts facilitate a better understanding of the current emissions burden associated with motorcycles, as well as allow for comparison of in-use performance to certification emission standards. As indicated by the emission factors used in this report, it is strongly suspected that in-use emissions are substantially greater than certification emissions and while the reasons for this are somewhat obvious, it is important that reliable estimates be established.

- Further confirmation that existing particulate matter emissions measurement techniques are (or are not) adequate for two-stroke motorcycle particulate that is dominated by lubricating oil emissions. Some existing research implies that the standard dilution tunnel methods associated with automotive emissions testing are adequate -- indicating that while there may be measurement differences between analytical methods, it does not appear that the differences are due to liquid sample loss (condensation on sample lines, etc.). [21] Emission measurements across methods appear to vary linearly with particulate mass so that correction factors could be developed if appropriate. Although this is encouraging, other research has reached differing conclusions and it is important that any issues be resolved and a reliable test method established.

- Further work on globally harmonized emission standards and associated emission testing protocols. While most countries currently rely on EU test methods and standards, there are several that have developed and implemented alternative protocols. In addition, the current EU protocols are evolving. The WMTC effort to derive a global test cycle is an important first step, but it is critical that it adequately allow for effective emission testing in all major motorcycle markets. Given that only a handful of manufacturers control the bulk of global motorcycle production (either through direct manufacturing or partnerships with smaller local manufacturers), it seems reasonable to institute one global standard of acceptability. Ideally this standard will be technology neutral to allow manufacturers to implement least cost solutions, but this requires a robust protocol to ensure that differing technologies are equally effective throughout the full useful life of a motorcycle.

- Expansion of emissions testing protocols to include evaporative emissions. As exhaust emissions continue to decline, evaporative emissions will gain in importance. Cost-effective control options are available, so effective emission reduction standards can be established.

- Expansion of emissions testing protocols to include standards for HC, CO, NO_x, and PM. Current standards apply either to HC and CO or HC+NO_x and CO. While research related to a definitive PM test regimen remains to be conducted, existing motorcycle PM emissions testing programs have demonstrated emission rates that are substantially greater than gasoline-powered automobile emissions.

- Consideration of the need for GHG emission standards. Several of the control options investigated in this report have the potential to cost-effectively reduce overall GHG emissions from motorcycles.

- Expansion of emissions testing protocols to include real-world durability requirements. Although many countries have established durability criteria, those criteria are far less stringent than actual useful life would dictate. The net effect is that this allows nondurable emissions control strategies to meet certification requirements while providing only limited in-use emission reductions. It is critical that certification durability requirements be expanded to ensure that compliance strategies actually produce expected in-use benefits.

- Where necessary, expansion of efforts to ensure that fuel quality is adequate to allow emission control catalysts to function effectively in-use. In-use fuel should approach certification fuel quality to ensure effective in-use emissions control.

- Development of effective in-use enforcement protocols. Current certification programs rely too heavily on initial certifications and production line testing. To ensure adequate in-use durability, regulators should conduct random in-use testing programs and require manufacturer recall when emission control equipment is not performing in accordance with certification requirements. While such programs are resource intensive, it is possible for global cooperation and efficiencies if globally consistent certification requirements are established.

- Development of effective I/M test protocols and standards, with appropriate demonstration that those protocols and standards accurately detect high-emitting motorcycles without erroneously flagging normal emitters.

- Development of comprehensive educational and instructional programs for both citizens and repair personnel. An adequate understanding of emissions issues could help to reduce detrimental in-use behavior (such as the use of incorrect lubricating oil), and there is no question that controlling in-use emissions requires an informed and effective repair industry.

Although there are obviously a number of issues where existing research is important to the efficient evolution of motorcycle emissions control, there are currently available control options that are effective on both a mass emissions reduction and cost basis. Moreover, many of these control options would substantially improve emissions durability and contribute to a much improved in-use motorcycle fleet. Table 9 provides a summary of the cost and emission reduction effectiveness of various emission control options evaluated in this report, while Table 10 presents corresponding cost-effectiveness estimates. As indicated, there are a number of technology options that provide consumer savings and could therefore be used to set stringent global emission standards for the near term. Such an approach will ensure that effective emission reduction technology is introduced into the existing fleet while the various issues highlighted above are evaluated and resolved.