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Recent research activities on particle emissions from two-stroke mopeds performed at ENEA, Italy

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Introduction

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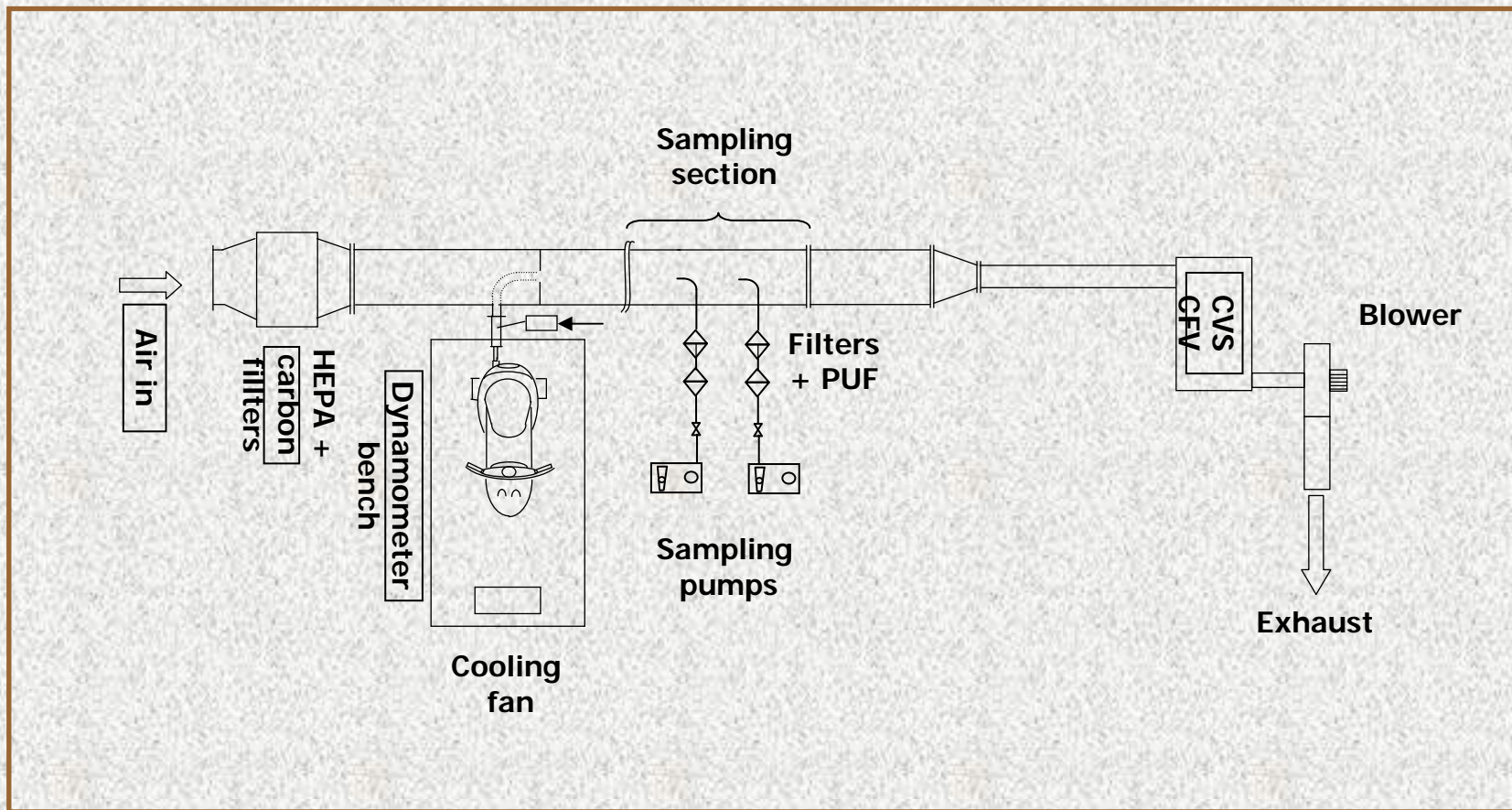
In recent years, the problem of particle emissions from in-use two-stroke mopeds was addressed by ENEA, the Italian National Agency for New Technologies, Energy and Environment, on request of the Municipality of Rome, Italy.

Further studies were undertaken in order to measure polycyclic aromatic hydrocarbon (PAHs) emissions as well as to characterize the emitted particles in terms of soluble organic fraction (SOF). The contribution of unburned lubricant oil and fuel components to the emitted particulate was also evaluated.

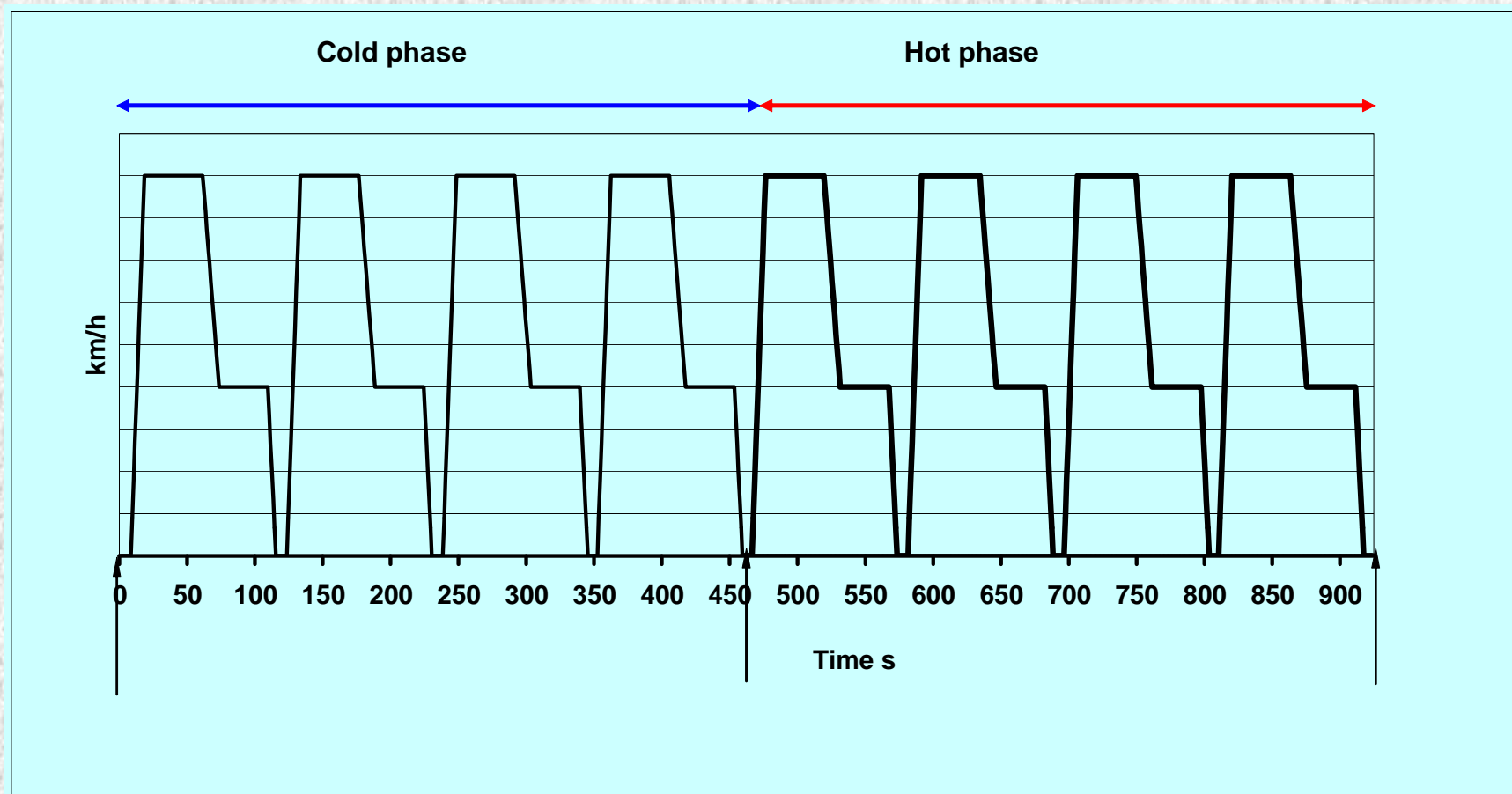
Main characteristics of tested 50-cm³, two-stroke mopeds

Code	Type approval	Model year	Catalyst	Fuelling	Mileage (km)
M1	EURO-0	1998	NO	Carburettor	11900
M2	EURO-0	1995	NO	Carburettor	13800
M3	EURO-0	1994	NO	Carburettor	16800
M4	EURO-0	1995	NO	Carburettor	19930
M5	EURO-I	2000	YES	Carburettor	22660
M6	EURO-I	2001	YES	Carburettor	6500
M7	EURO-I	1999	YES	Carburettor	8500
M8	EURO-I	1999	YES	Carburettor	11640
M9	EURO-II	2004	YES + SAI	Carburettor	1380
M10	EURO-II	2004	YES	Direct injection	1500

DIAGRAM OF THE TEST EQUIPMENT



The ECE-47 driving cycle



PM and PAHs measurements

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Particulate matter was collected on 47 mm Pallflex T60A20 filters. Gas-phase PAHs were collected on polyurethane foam (PUF) plugs placed behind the filters.

The filters were equilibrated at constant relative humidity and temperature before and after sampling. Filters were weighed on a micro balance in a controlled environment.

Filters and PUF plugs were extracted in an accelerated solvent extractor. Extracts were cleaned-up by using silica gel columns. PAHs were identified and quantified by gas chromatography/mass spectrometry (GC/MS) operated in selected ion monitoring (SIM) mode.

PAHs measurements

The concentrations of the following PAHs were determined:

Naphthalene (NAP)

Acenaphthylene (ACPy)

Acenaphthene (ACP)

Fluorene (FLU)

Phenanthrene (PHE)

Anthracene (AN)

Fluoranthene (FA)

Pyrene (PY)

Benzo(*a*)anthracene (BaA)

Chrysene/Triphenylene (CHR)

Cyclopenta(*c,d*)pyrene (CPP)

Benzo(*b+k*)fluoranthene (BF)

Benzo(*e*)pyrene (BeP)

Benzo(*a*)pyrene (BaP)

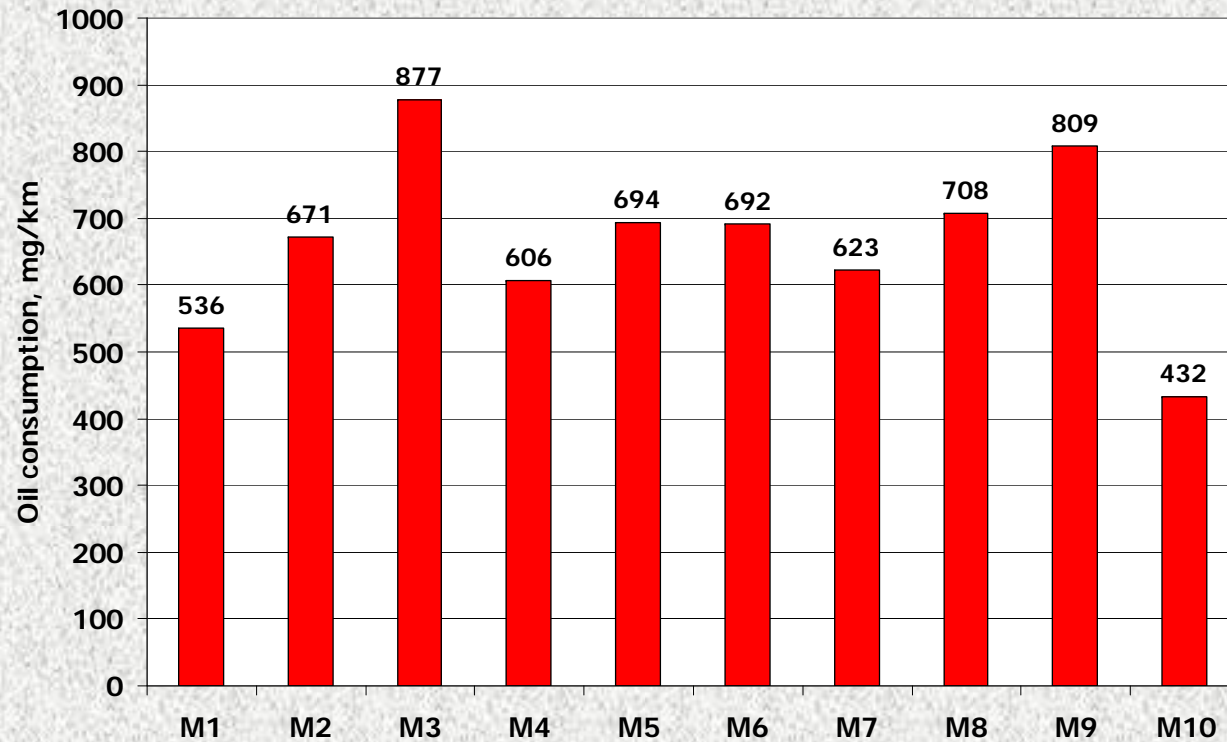
Indeno(1,2,3,-*cd*)pyrene (IP)

Dibenz(*a,h*)anthracene (DBahA)

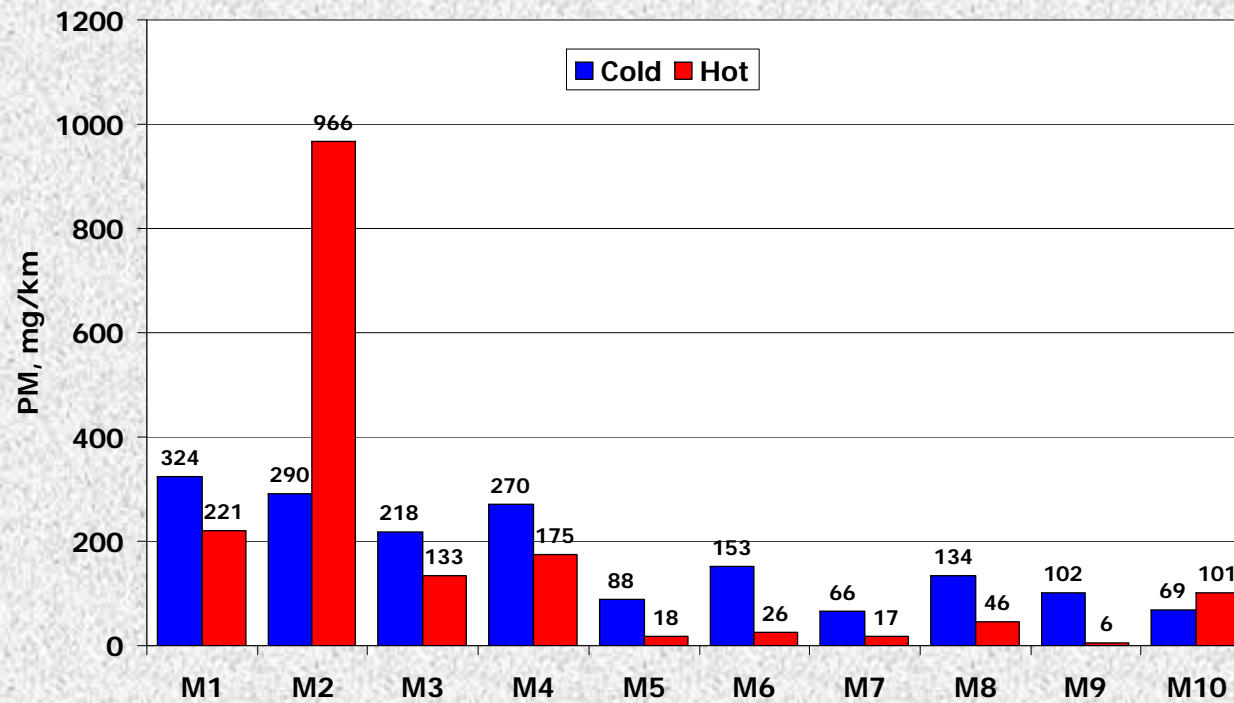
Benzo(*g,h,i*)perylene (BghiP)

Coronene (COR)

Lubricant oil consumption - hot phase



Emission factors: particulate matter (mg/km)





Comparison between diesel passenger cars and mopeds PM emissions in Italy, year 2003

PM emission scenario related to Italian 2003 fleet, excluding the Euro II mopeds (no sure data were obtained), showed that in urban areas moped contribution to particulate matter hot emissions is 1.6×10^6 kg and diesel passenger car contribution is 2.0×10^6 kg.

Diesel passenger cars emission factors used for the comparison are the hot stabilized urban emission factors for an average speed of 25 km/h (from COPERT III database); mopeds emission factors are the hot emission factors obtained in this study.

Mopeds, urban annual activity rate:

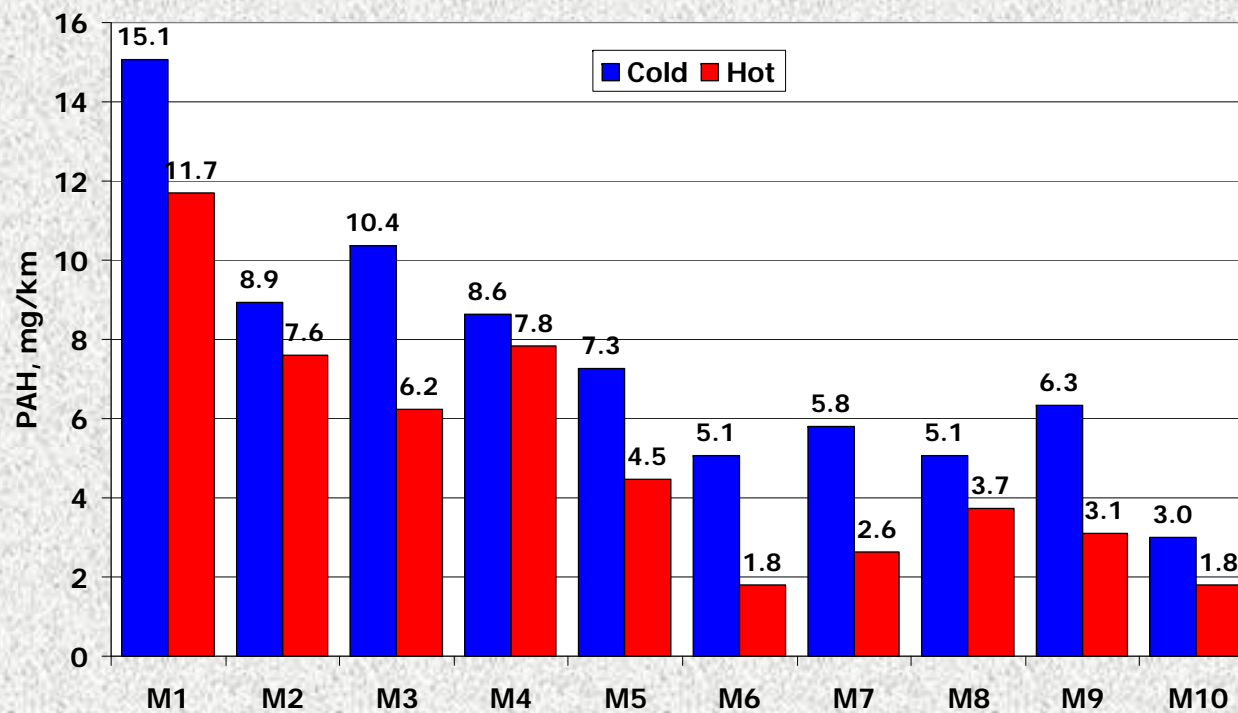
Euro 0 ($8,826 \times 10^6$ veh.km); Euro I ($2,483 \times 10^6$ veh.km); Euro II (638×10^6 veh.km).

Diesel passenger cars, urban annual activity rate:

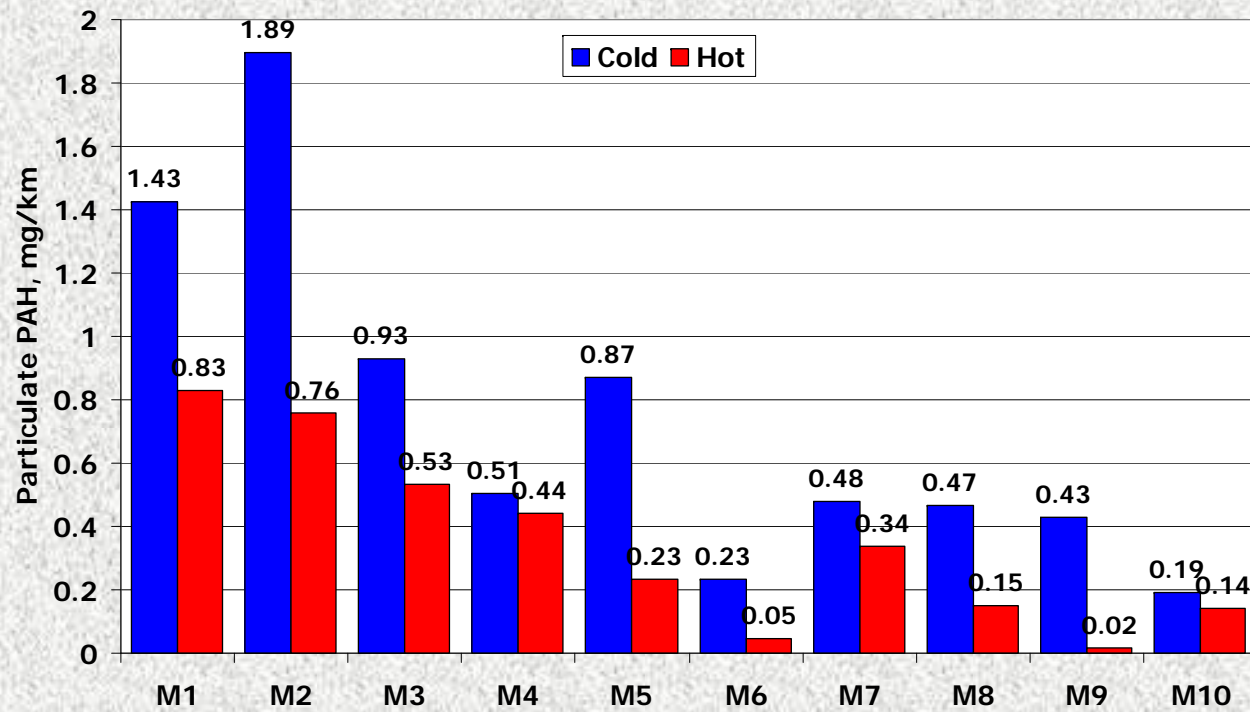
Euro 0 ($2,928 \times 10^6$ veh.km); Euro I ($1,107 \times 10^6$ veh.km); Euro II ($6,440 \times 10^6$ veh.km); Euro III ($8,287 \times 10^6$ veh.km).



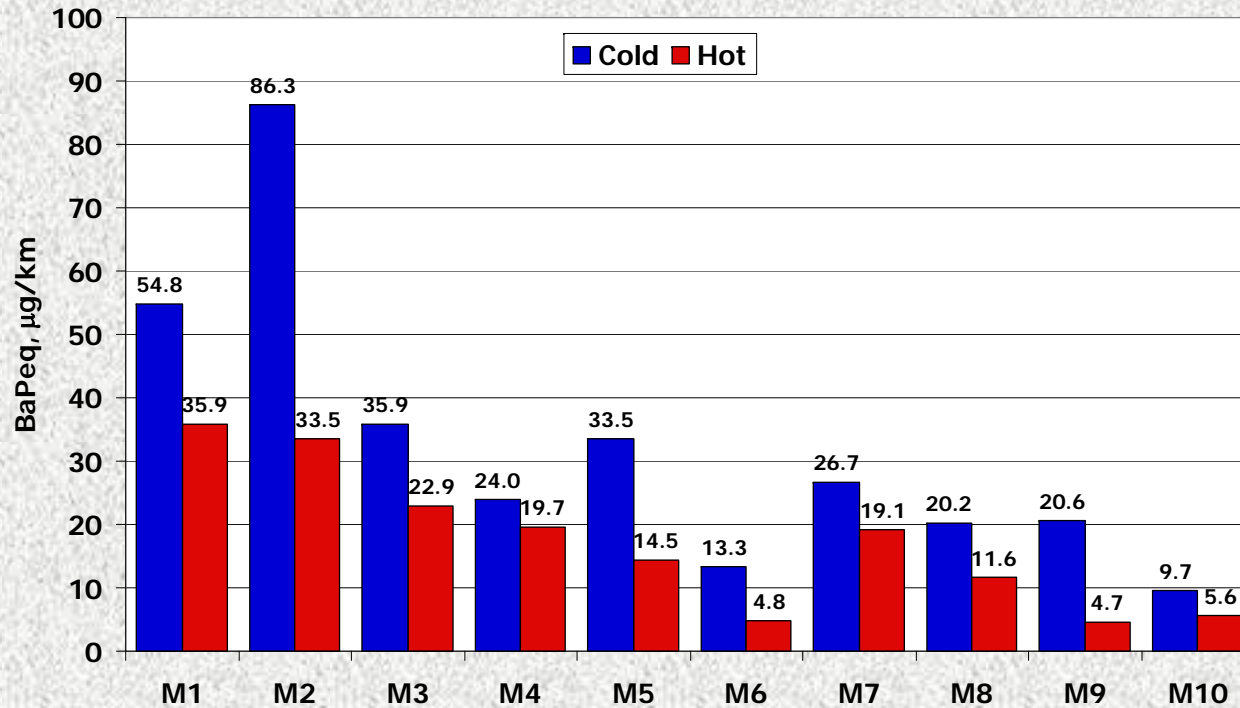
Emission factors: total (gas- and particle phase) PAHs (mg/km)



Emission factors: particle phase PAHs (mg/km)



Emission factors: Benzo(a)pyrene equivalent (BaP_{eq}), (μg/km)





Comparison between diesel passenger cars and mopeds BaP_{eq} emissions in Italy, year 2003

Mopeds (urban cycle)

Urban annual activity rate: Euro 0 ($8,826 \times 10^6$ veh.km); Euro I ($2,483 \times 10^6$ veh.km); Euro II (638×10^6 veh.km)

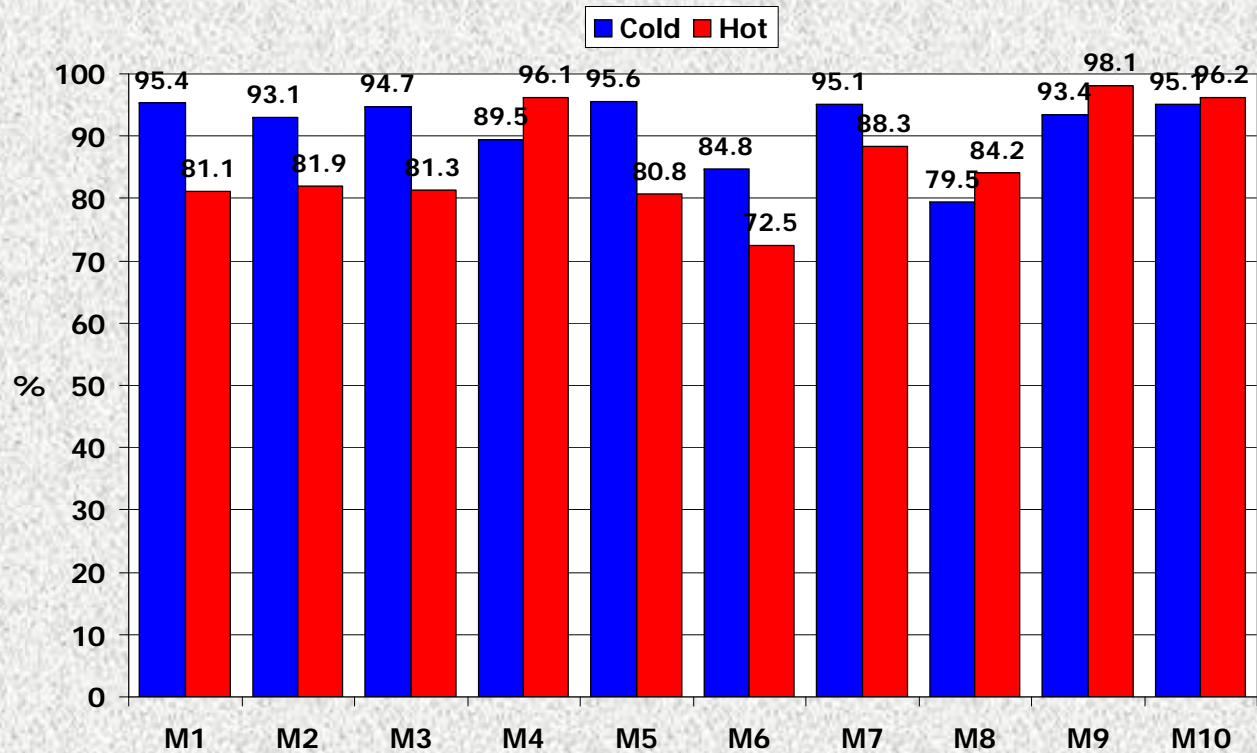
Emission = 281 - 511 kg BaP_{eq}

Diesel passenger cars (urban cycle)

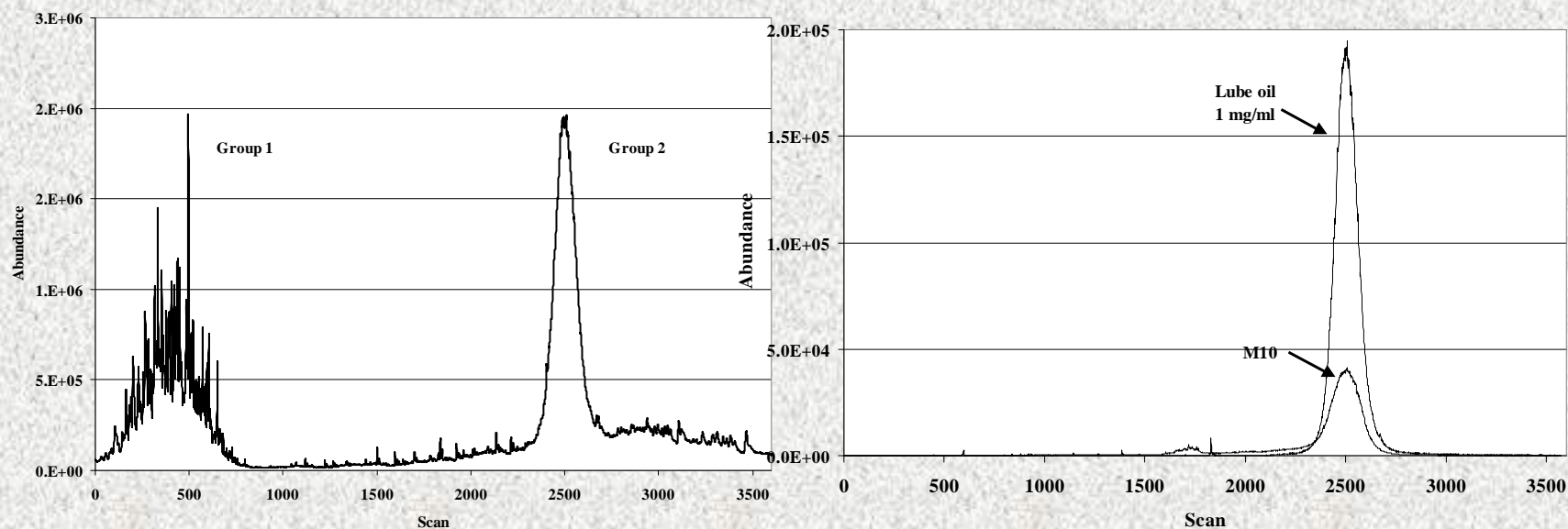
Urban annual activity rate (Euro 0, Euro I, Euro II, Euro III):
 $18,762 \times 10^6$ veh.km

Emission = 52 kg BaP_{eq}

Soluble organic fraction of moped particulates (% of PM)



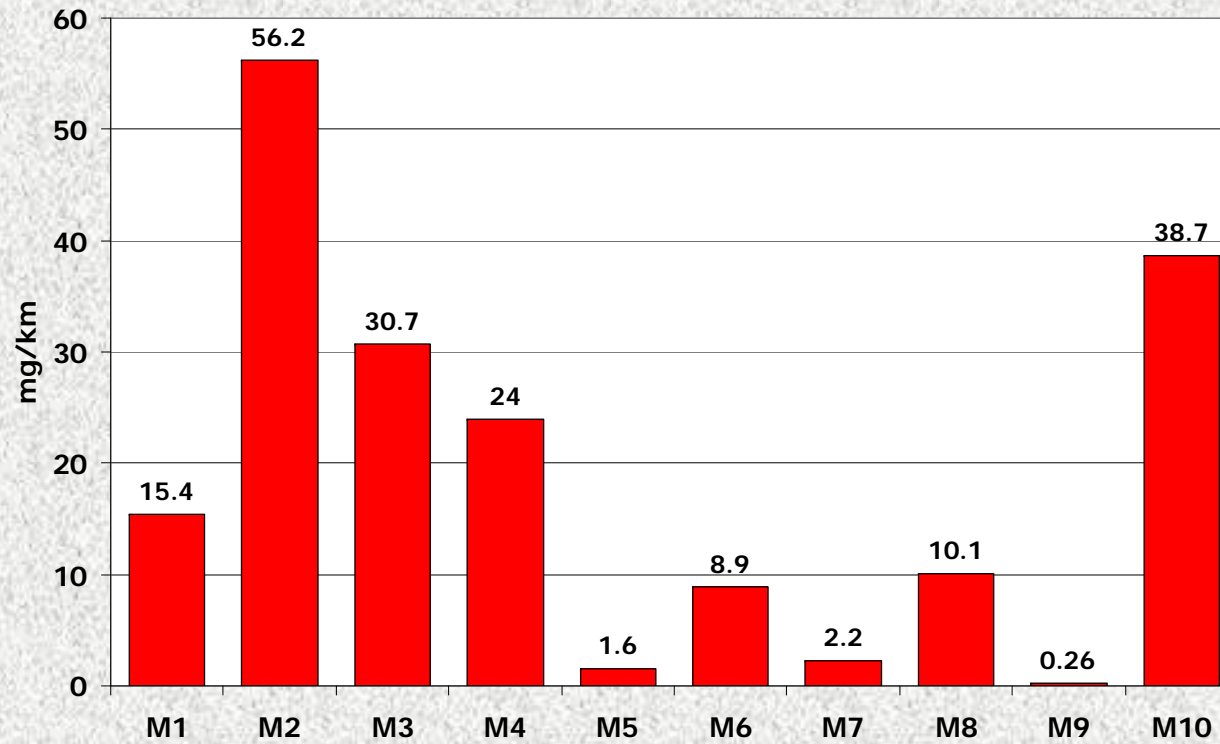
Contribution of unburned lubricating oil to particulate emission from two-stroke mopeds.



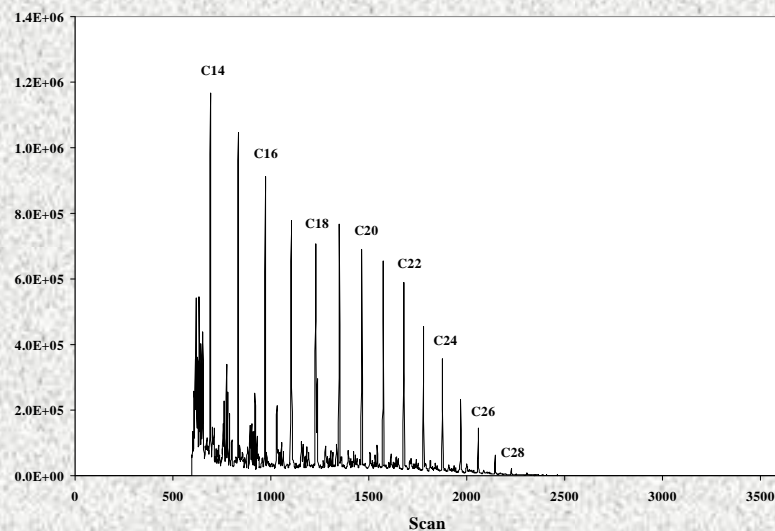
Total ion GC-MS chromatogram of the synthetic oil used during the tests.

Extracted ion GC-MS chromatograms (m/z 129) of the synthetic oil and extracted M10 moped particulate.

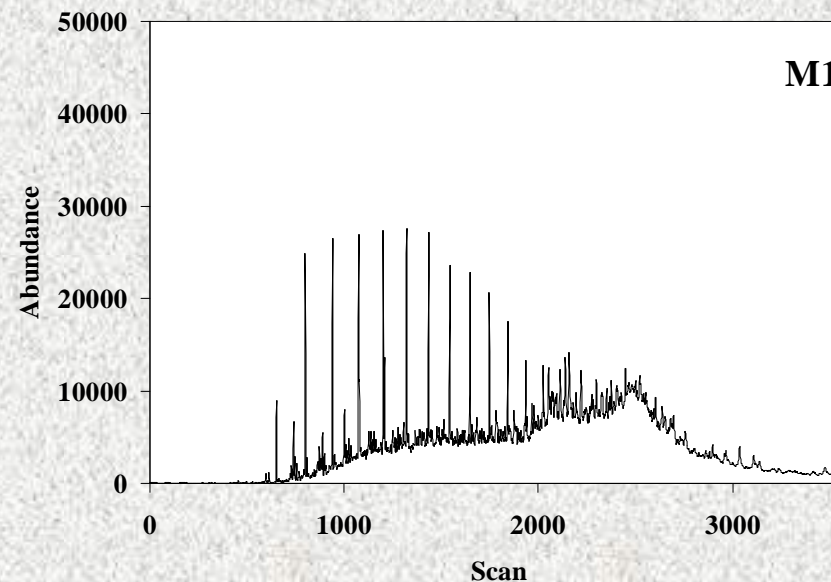
Unburned lubricating oil emission rate (mg/km)



Contribution of gasoline-derived n-alkanes (C14-C26) to particulate emissions from two-stroke mopeds.

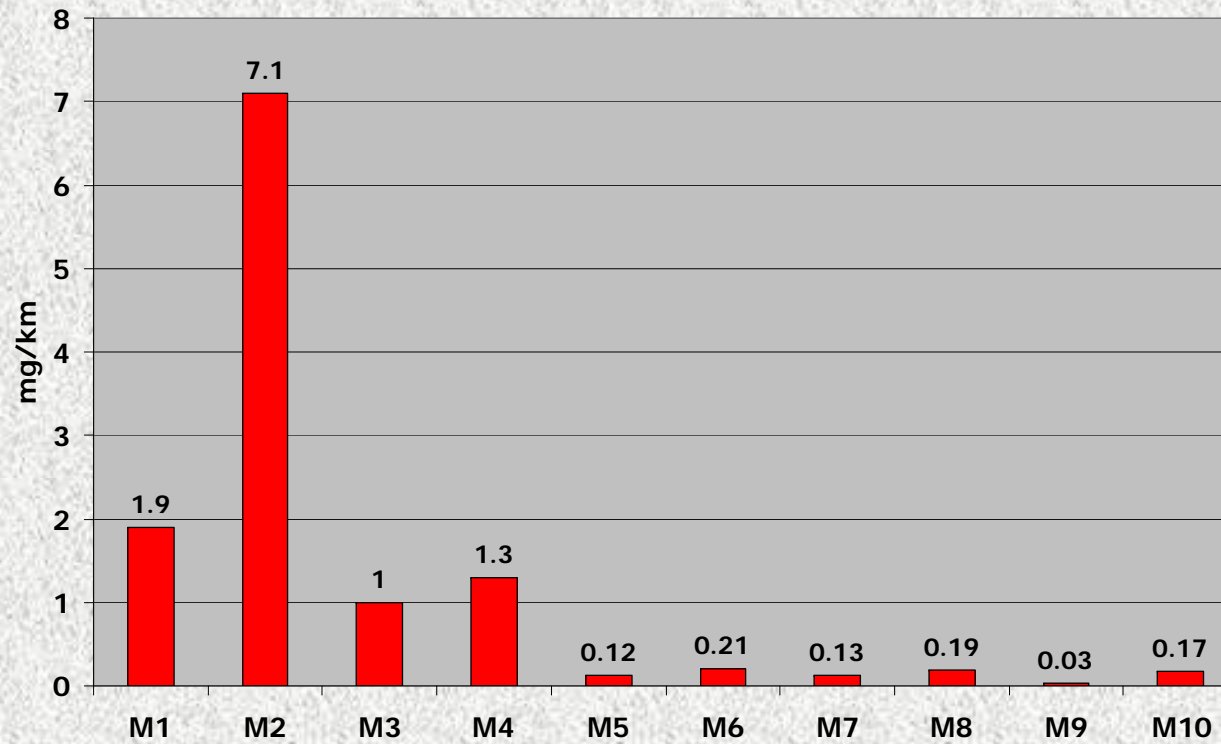


Extracted ion GC-MS chromatogram (m/z 85) for n-alkanes distribution (C14-C26) for the commercial gasoline used during the tests.

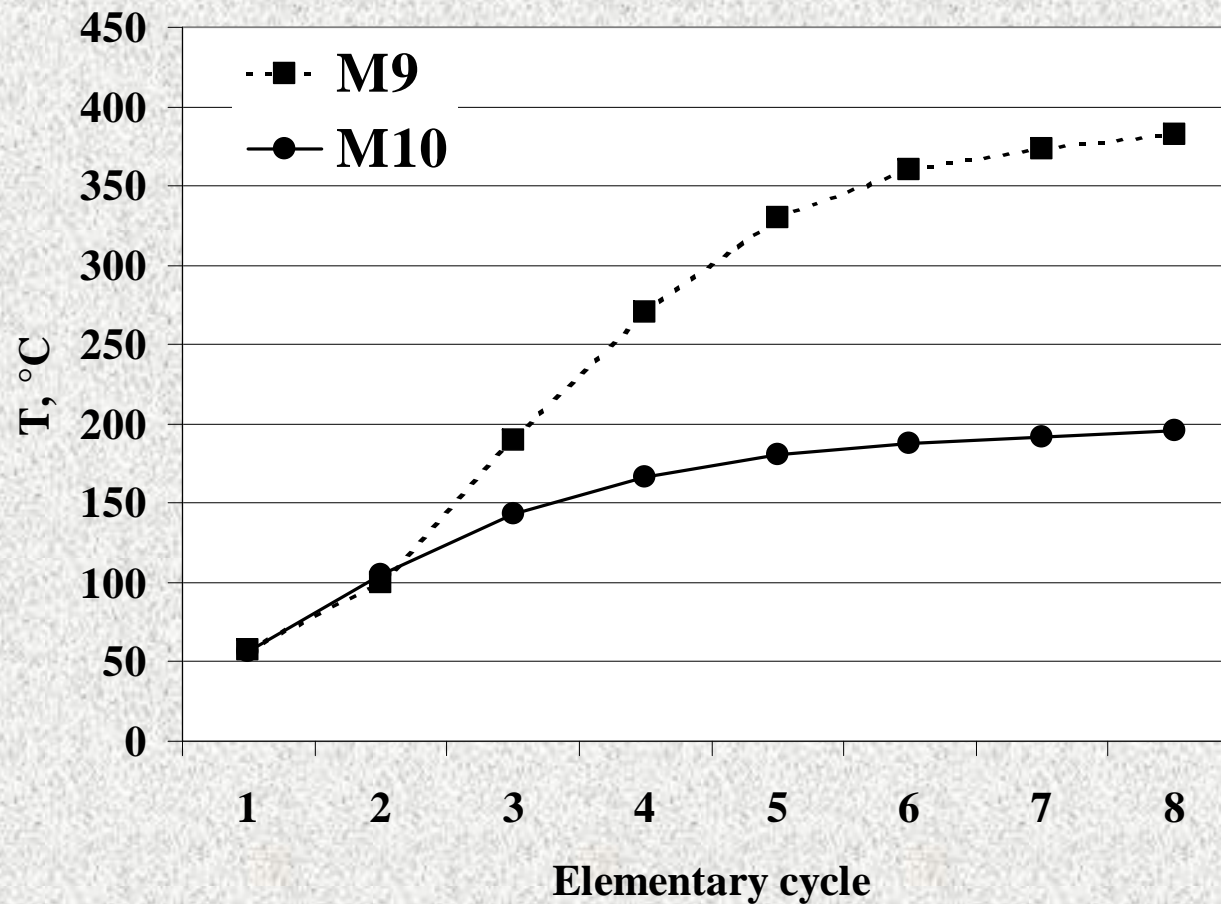


Extracted ion GC-MS chromatograms (m/z 85) for n-alkanes distribution (C14-C26) for the extracted M1 moped particulate.

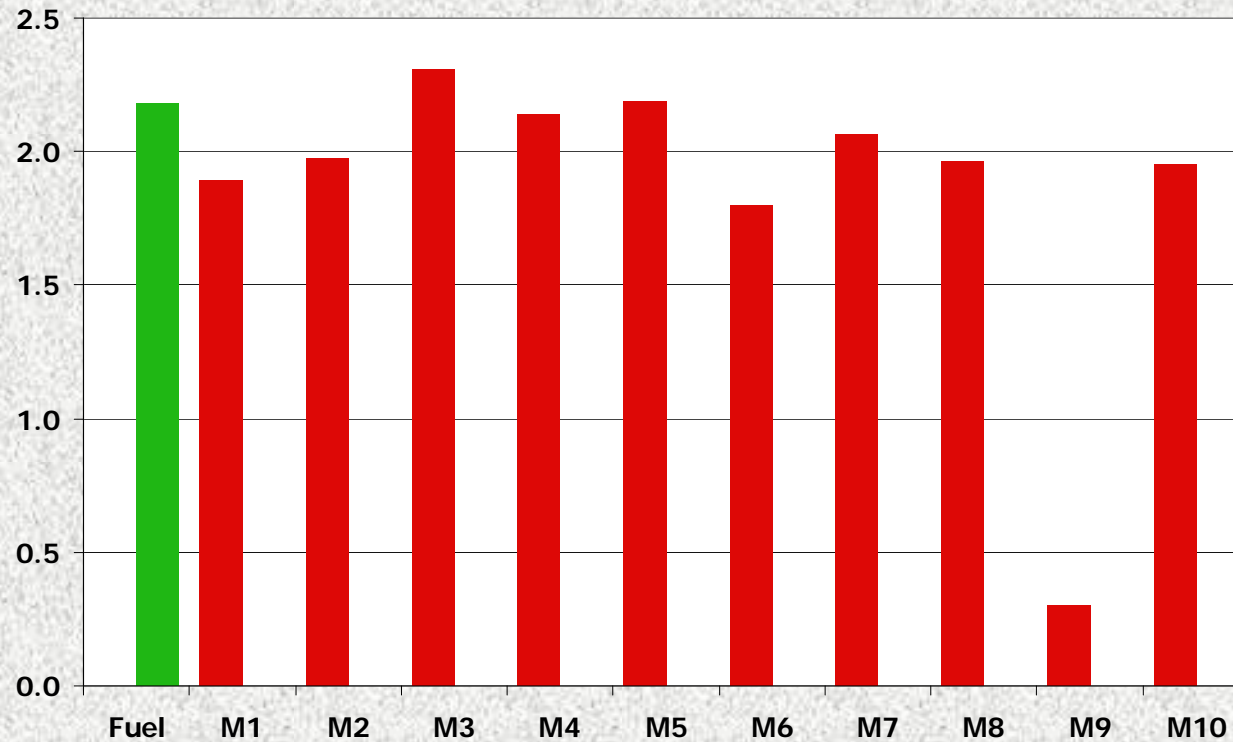
N-alkanes (C14-C26) emission rate (mg/km)



Average temperatures of the gases measured approximately 30 cm downstream the exit of the exhaust system.



Methyl-phenanthrenes/phenanthrene ratios in unburned gasoline and emitted particulate matter



Main conclusions - 1

PM emissions from non-catalyst 2-S mopeds is strongly related to lubricant oil consumption.

The soluble organic fraction (SOF) of the PM range 72-98 %.

Unburned lubricating oil was quantified in PM by GC-MS analysis and accounted for a significant fraction of PM emitted from 2-S mopeds.

PAHs emissions from 2-S mopeds are comparable or even higher than PAHs emissions reported elsewhere from gasoline- and diesel-powered passenger cars and light- and heavy-duty vehicles.

In countries such as Italy where a large number of 2-S mopeds are circulating PM and PAHs emissions from this kind of vehicles cannot be neglected in urban emission inventories.

Main conclusions - 2

Catalyst mopeds (Euro I) reduce PM, unburned oil and PAHs emissions of approximately 80 %, 75 % and 45-60 %, respectively.

Tested catalyst Euro II mopeds showed a constraint behavior regarding to PM, unburned oil and PAHs emission reduction and related to the different engine design (carburetor + secondary air injection and direct injection).

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