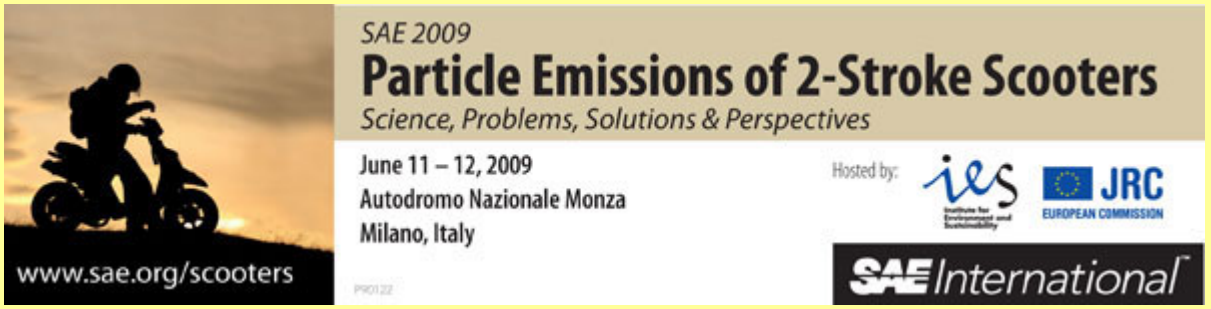


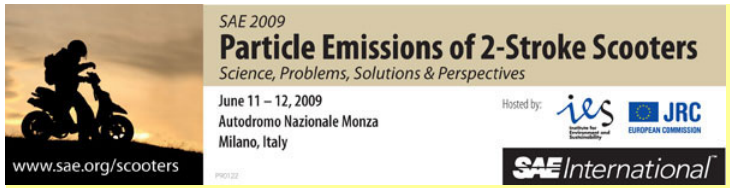
Regulated and unregulated emissions of mopeds

Andrea Unich[1], Maria Vittoria Prati[2], Maria Antonietta Costagliola[3]

1-Second University of Naples

2-Istituto Motori National Research Council

3-University of Naples Federico II

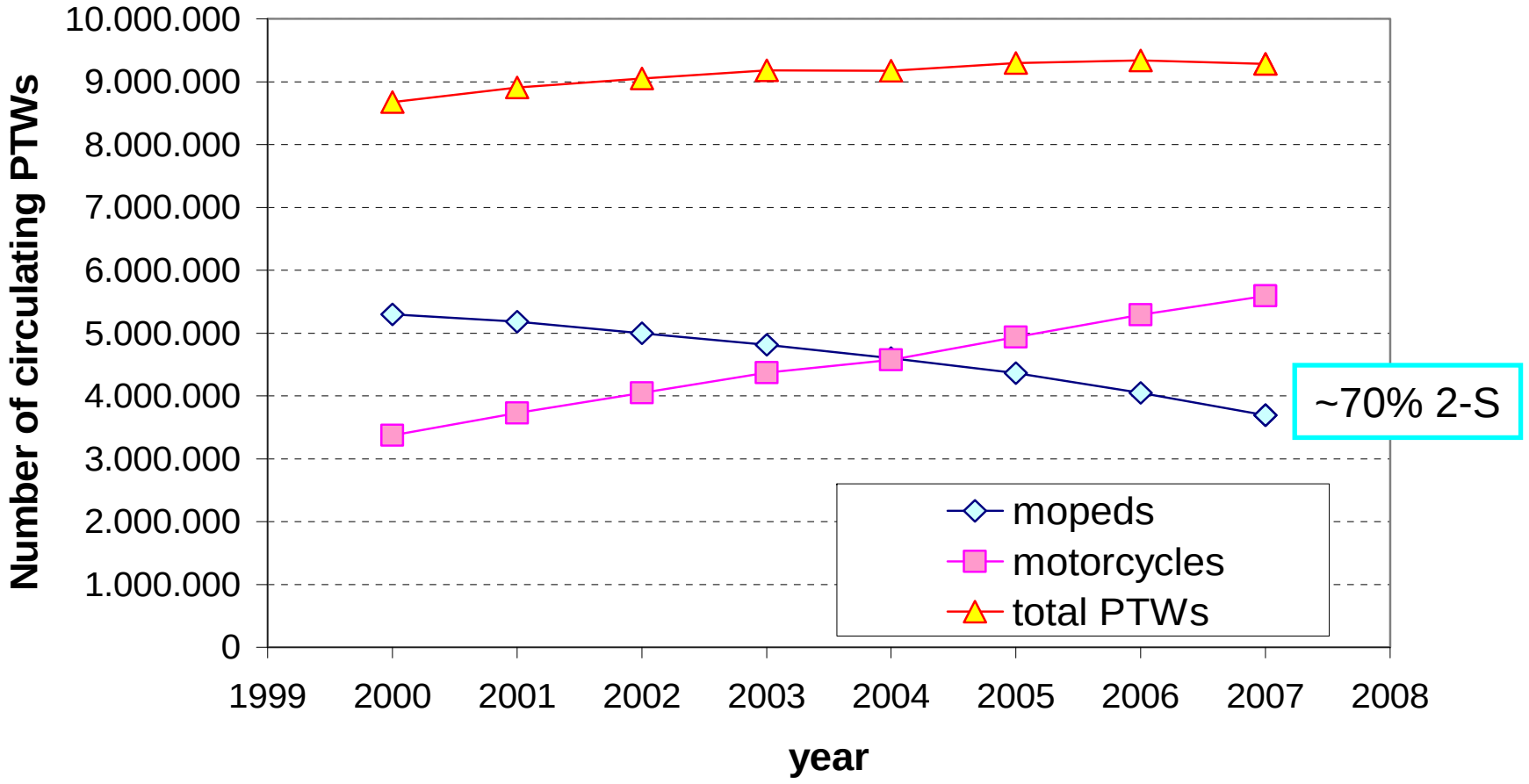


Summary

- **Regulated and unregulated emissions have been measured at the exhaust of in-use 2 Stroke and 4 Stroke mopeds.**

- **Vehicles were approved according to different emission standards, tests have been carried out on three different driving cycles.**

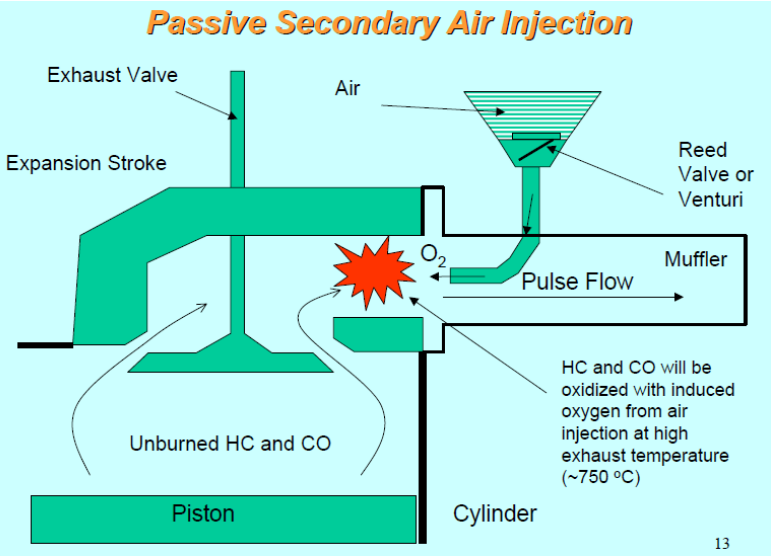
PTWs circulating in Italy 2000 - 2007



Source: 2007 ANCMA data http://www.ancma.it/common/file/articolo_202sezione_9.pdf

Tested vehicles

Q.ty	Type	Emission standards	Fuel system	Mileage [km]	Exhaust aftertreatment
3	2 S	Pre 97/24	carburetor	~ 20.000	N/A
1	2 S	97/24 Stage 1	carburetor	~ 20.000	oxycat
1	2 S	97/24 Stage 2	carburetor	~ 10.000	oxycat+secondary air inj.
1	4 S	97/24 Stage 1	carburetor	~ 20.000	N/A
1	4 S	97/24 Stage 2	carburetor	~ 1.000	oxycat+secondary air inj.



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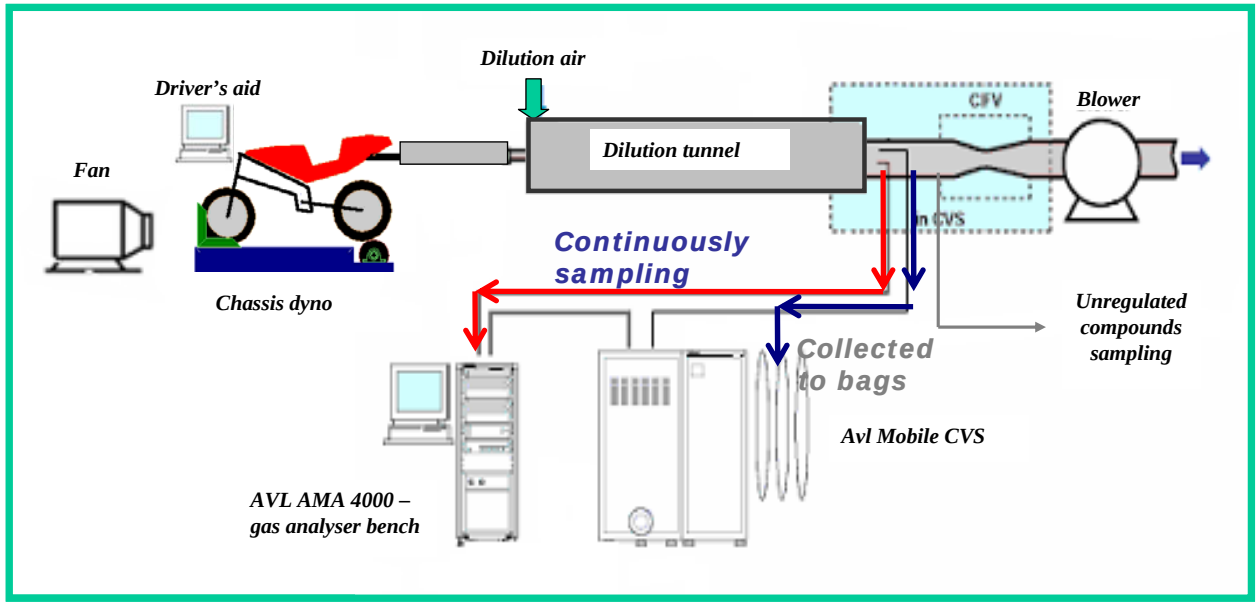
Experimental apparatus



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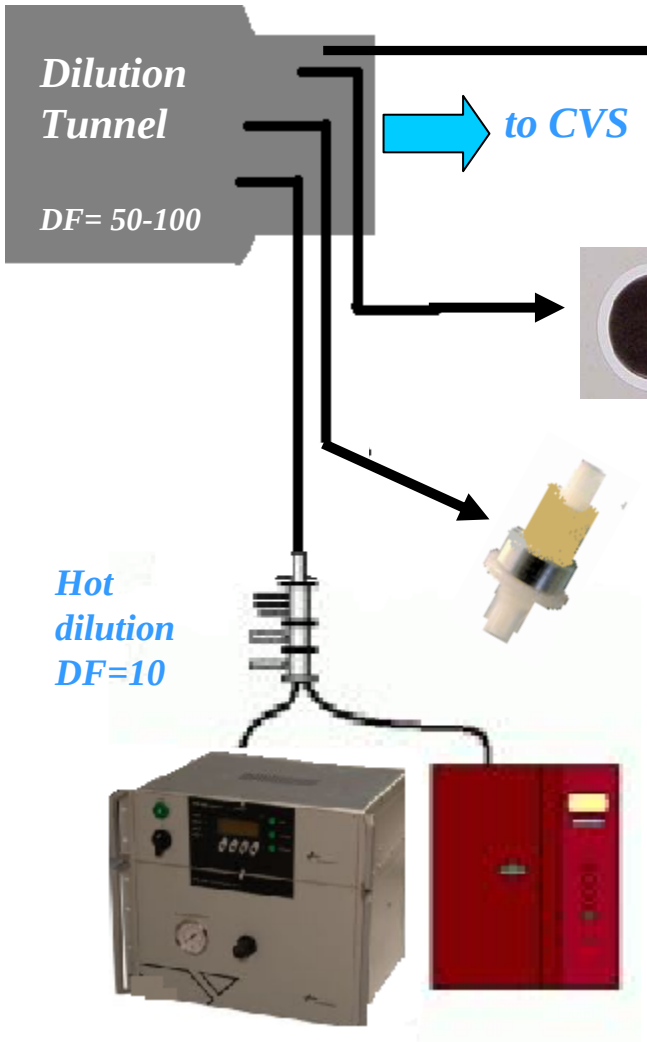
Unregulated emissions characterisation



Sampling bags for measurements of regulated compounds and some **Volatile Organic Compounds (VOC)** (*GC-FID analysis*)

Sampling fiberfilm filter for measurements of **total particulate mass** (*gravimetric analysis*) and adsorbed **Polycyclic Aromatic Hydrocarbons (PAHs)** (*GC-MS analysis*)

DNPH cartridge for measurements of **Carbonylic compounds** (*HPLC – UV detector analysis*)

Fine Particle Sampler - FPS and Electrical Low Pressure Impactor – ELPI for measurements of **Particles Number Distribution**

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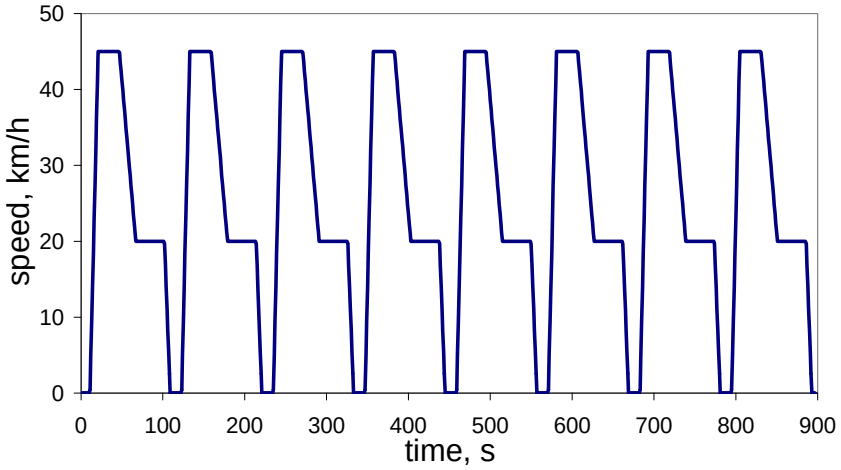
List of Unregulated Compounds

Compound	Group	IARC Class.(*)	Compound	Group	IARC Class. (*)
Phenanthrene	PAHs		**Acetaldehyde**	VOC	2B
Anthracene	PAHs		**Acetone+acrolein**	VOC	
Fluoranthene	PAHs		**Propionaldehyde**	VOC	
Pyrene	PAHs		**Crotonaldehyde**	VOC	
Benzo(a)anthracene	PAHs	2A	**Butanone**	VOC	
Crisene	PAHs		**Butiraldehyde**	VOC	
Benzo(b+k)fluoranthene	PAHs	2B	**Benzaldehyde**	VOC	
Benzo(e)pyrene	PAHs		**Isovaleraldehyde**	VOC	
Benzo(a)pyrene	PAHs	2A	**Valeraldehyde**	VOC	
Perylene	PAHs		**o+m+p Toluadehyde**	VOC	
Indeno(1,2,3,c,d)pyrene	PAHs	2B	**Hexaldehyde**	VOC	
Dibenzo(a,h)anthracene	PAHs	2A	**2,5 dimethylbenzaldehyde**	VOC	
Benzo(g,h,i)perylene	PAHs		**Benzene**	VOC	1
Coronene	PAHs		**1,3-butadiene**	VOC	2A
Formaldehyde	VOC	1			

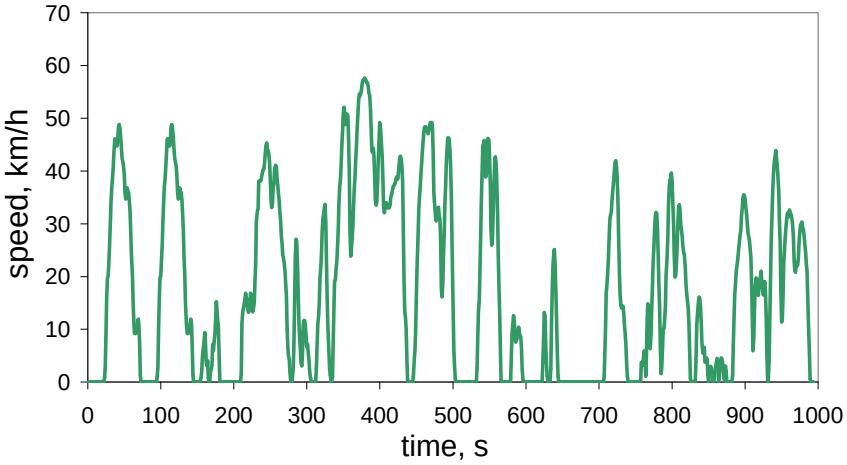
(*) 1: carcinogenic to humans; 2A: possibly carcinogenic to humans; 2B: probably carcinogenic to humans.

Driving cycles

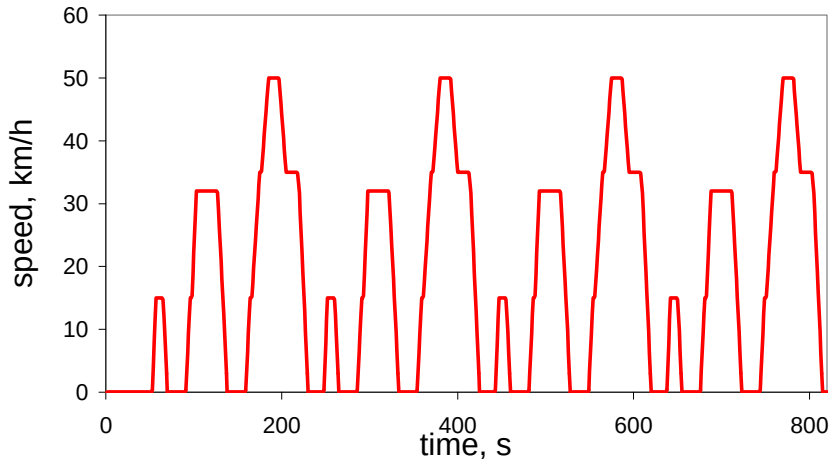
ECE R47



Artemis URBAN



ECE 40

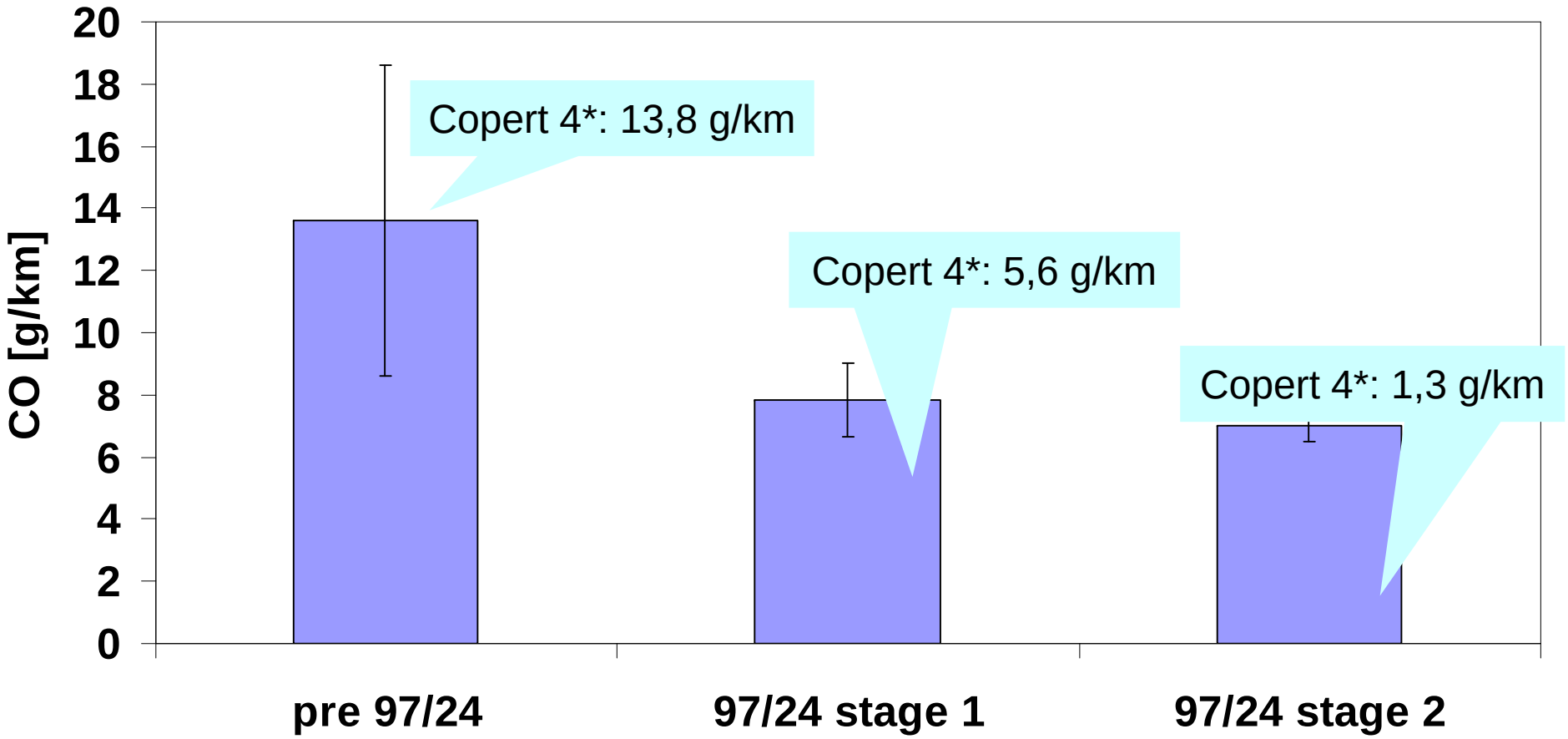


	ECE R47	ECE R40	Artemis URBAN
Duration, s	895	820	991
Distance, km	6,2	4,1	4,5
Average Speed, km/h	25,1	17,8	17,5
Maximum speed, km/h	45,0	50,0	57,1
T idle, %	12,5	34,1	26,0
T acc, %	9,8 →	20,5 →	39,6
T dec, %	25,9	19,5	35,6
T cruise, %	51,7 ←	25,7 ←	0,0

Regulated emissions results

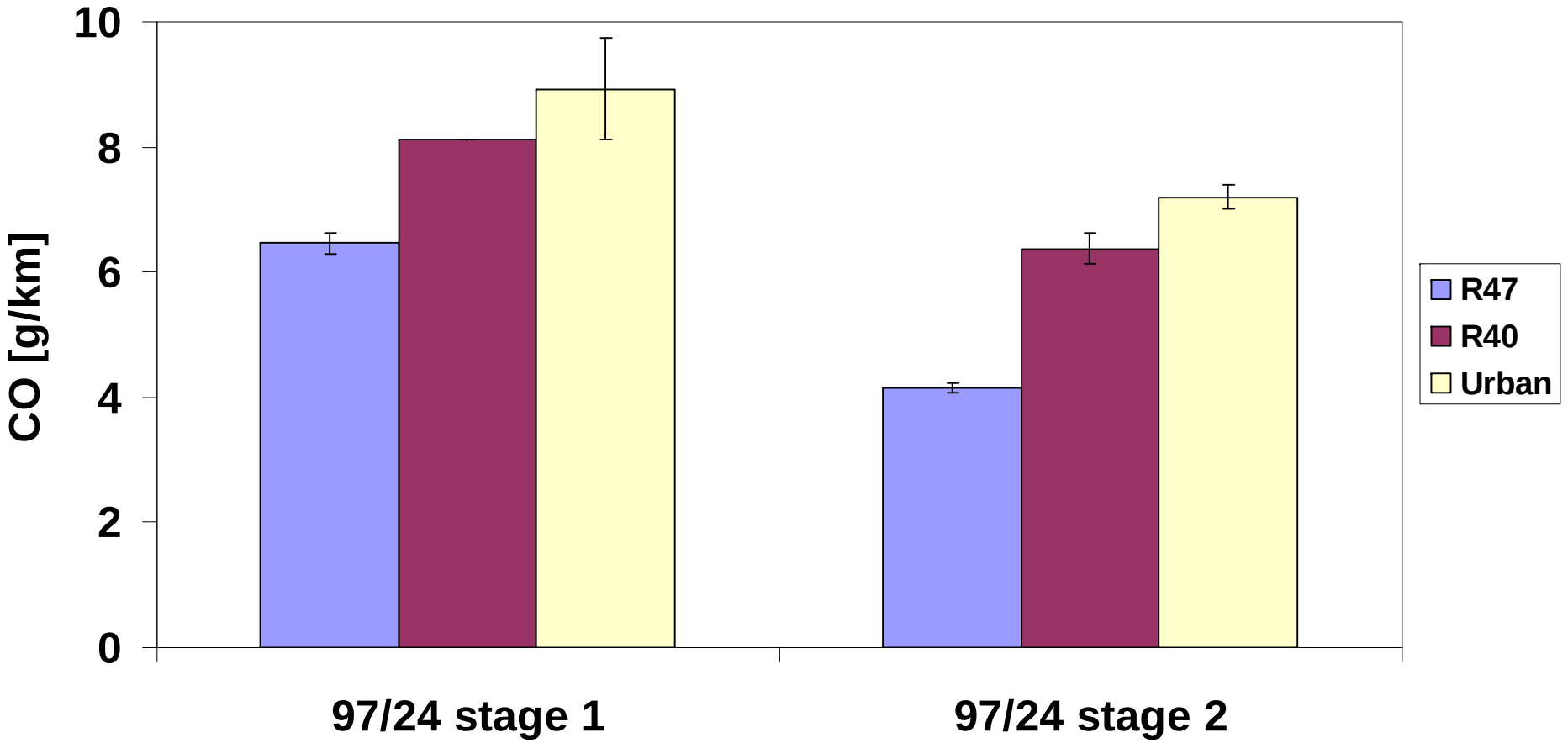
	2-S 97/24 Stage 1		2-S 97/24 Stage 2		4-S 97/24 Stage 1		4-S 97/24 Stage 2	
	CO [g/km]	HC+NOx [g/km]	CO [g/km]	HC+NOx [g/km]	CO [g/km]	HC+NOx [g/km]	CO [g/km]	HC+NOx [g/km]
TEST	6,46	2,66	4,15	4,31	7,83	1,11	3,38	0,51
STANDARD LIMITS	97/24 Stage 1		97/24 Stage 2		97/24 Stage 1		97/24 Stage 2	
	6	3	1	1,2	6	3	1	1,2

CO hot 2S vs. emission standard

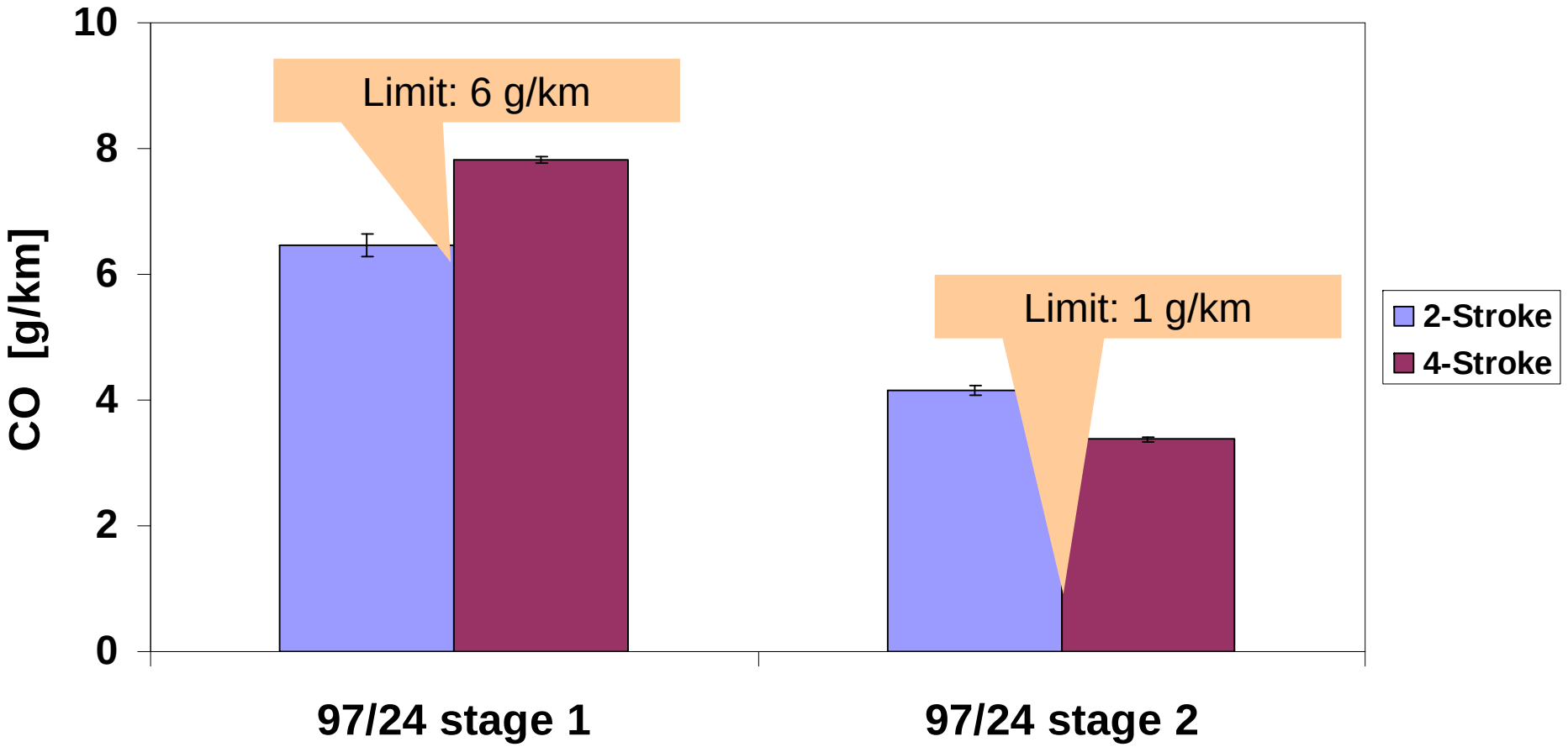


** Copert 4 provides an hot CO emission factor not dependent by speed*

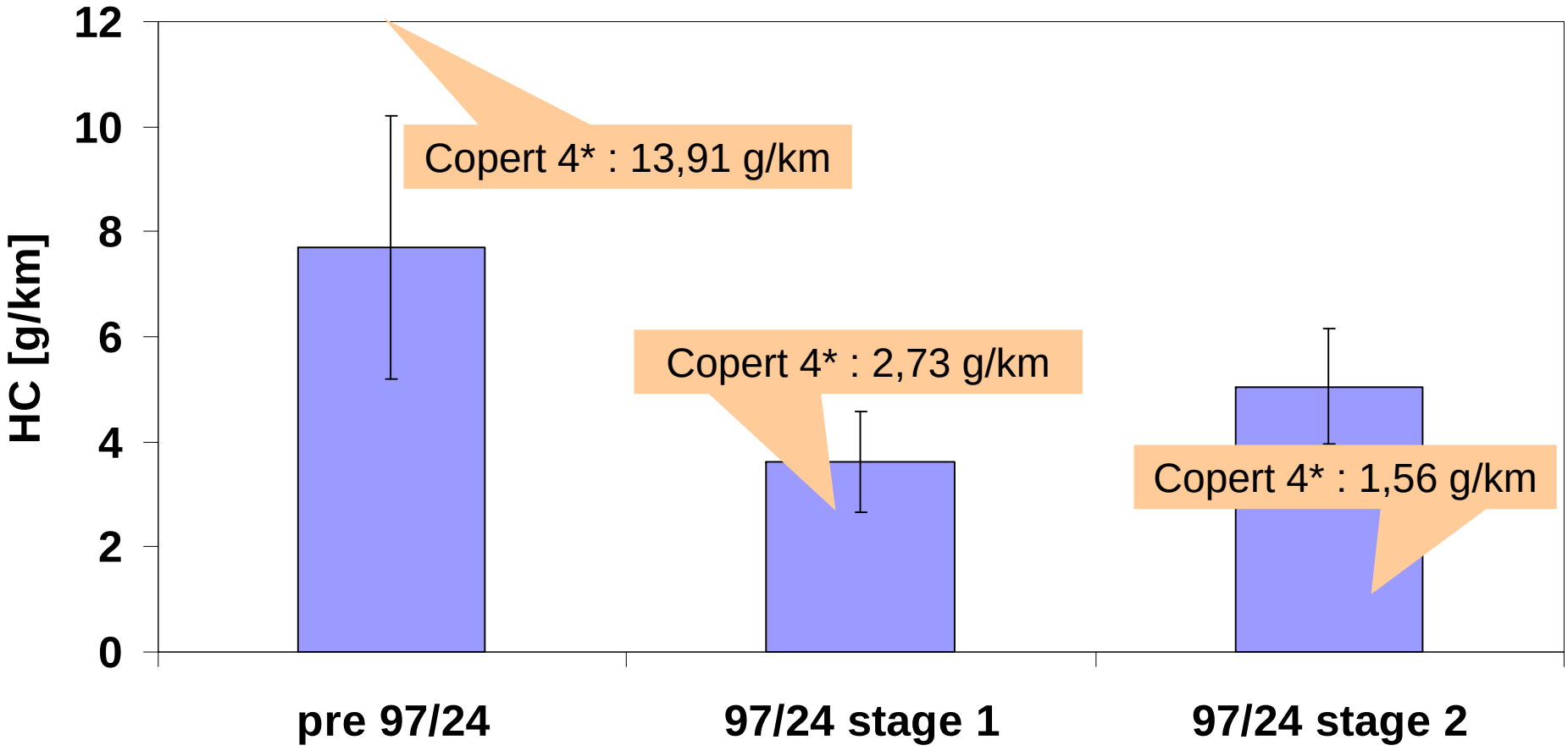
CO hot 2S vs. driving cycle



CO hot 2S - 4S (R47 cycle)

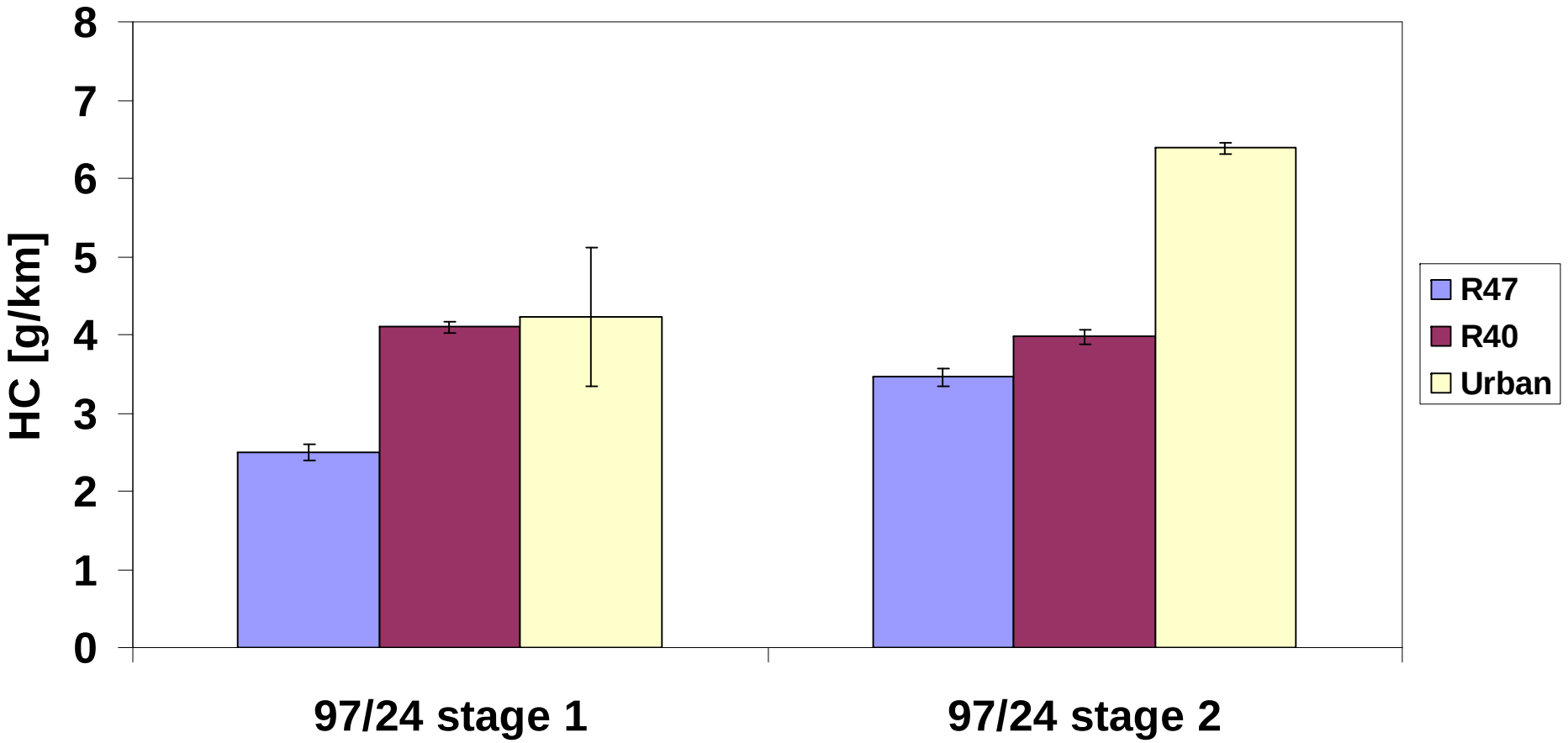


HC hot 2S vs. emission standard

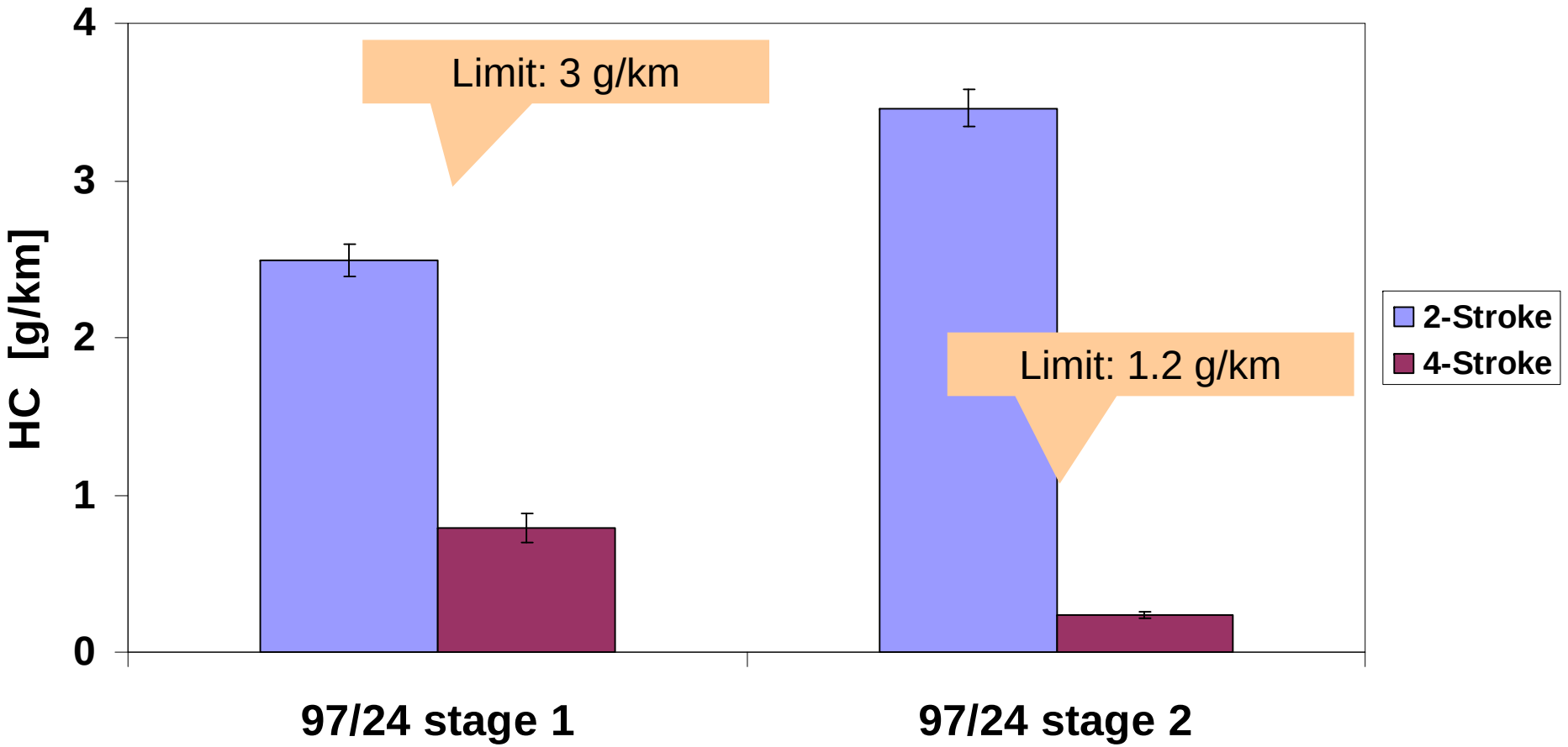


** Copert 4 provides an hot HC emission factor not dependent by speed*

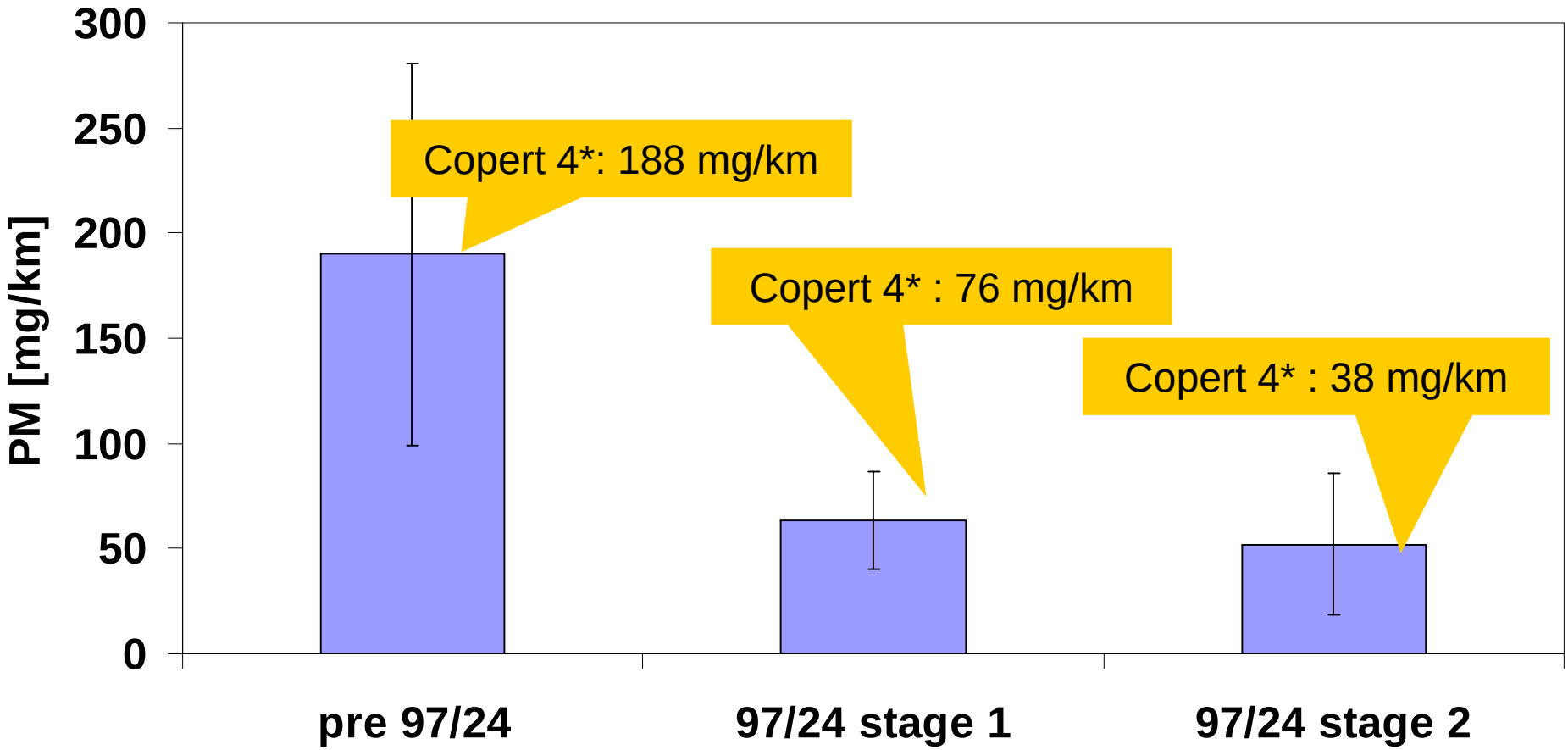
HC hot 2S vs. driving cycle



HC hot 2S – 4S (R47 cycle)

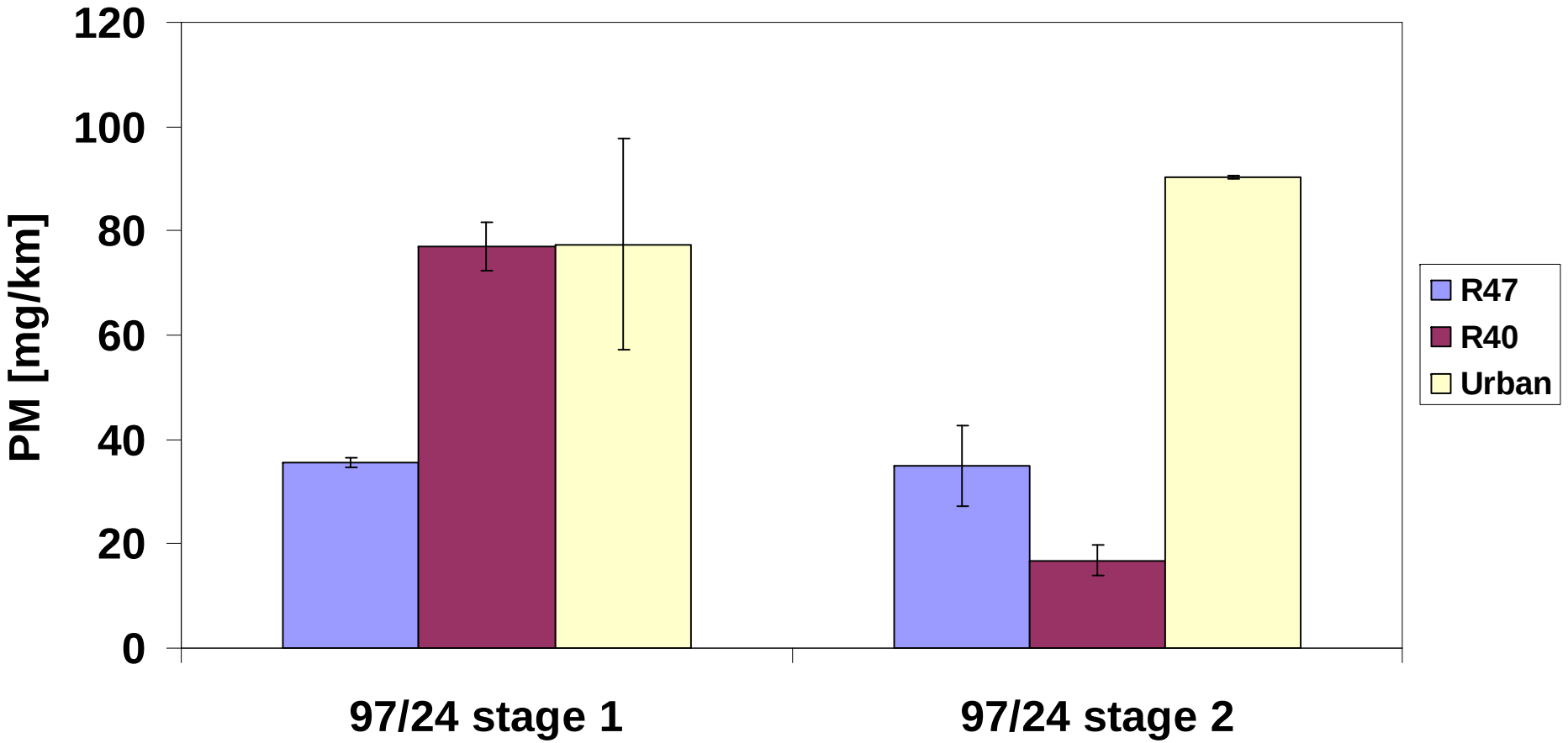


PM 2S vs. emission standard

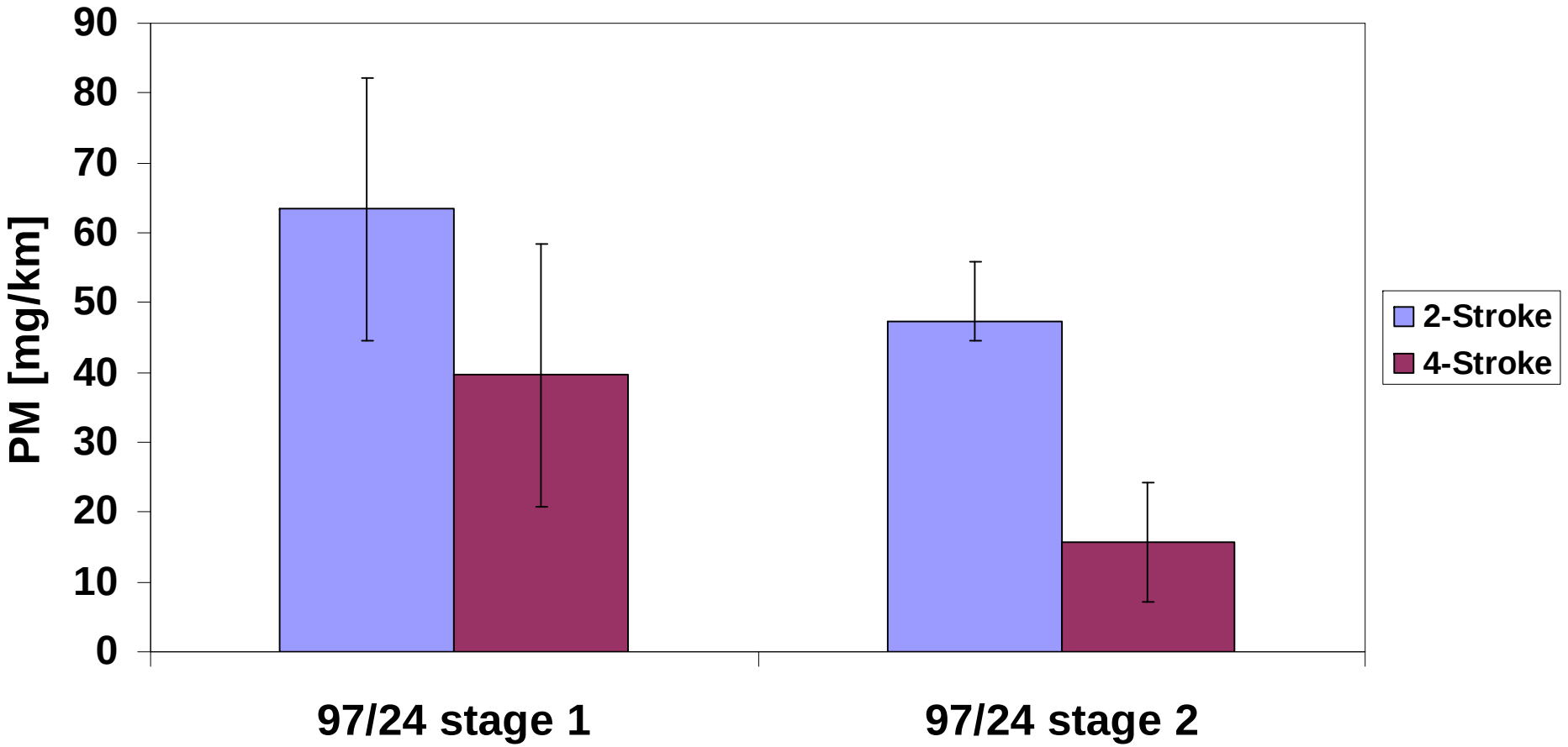


** Copert 4 provides an hot PM emission factor not dependent by speed*

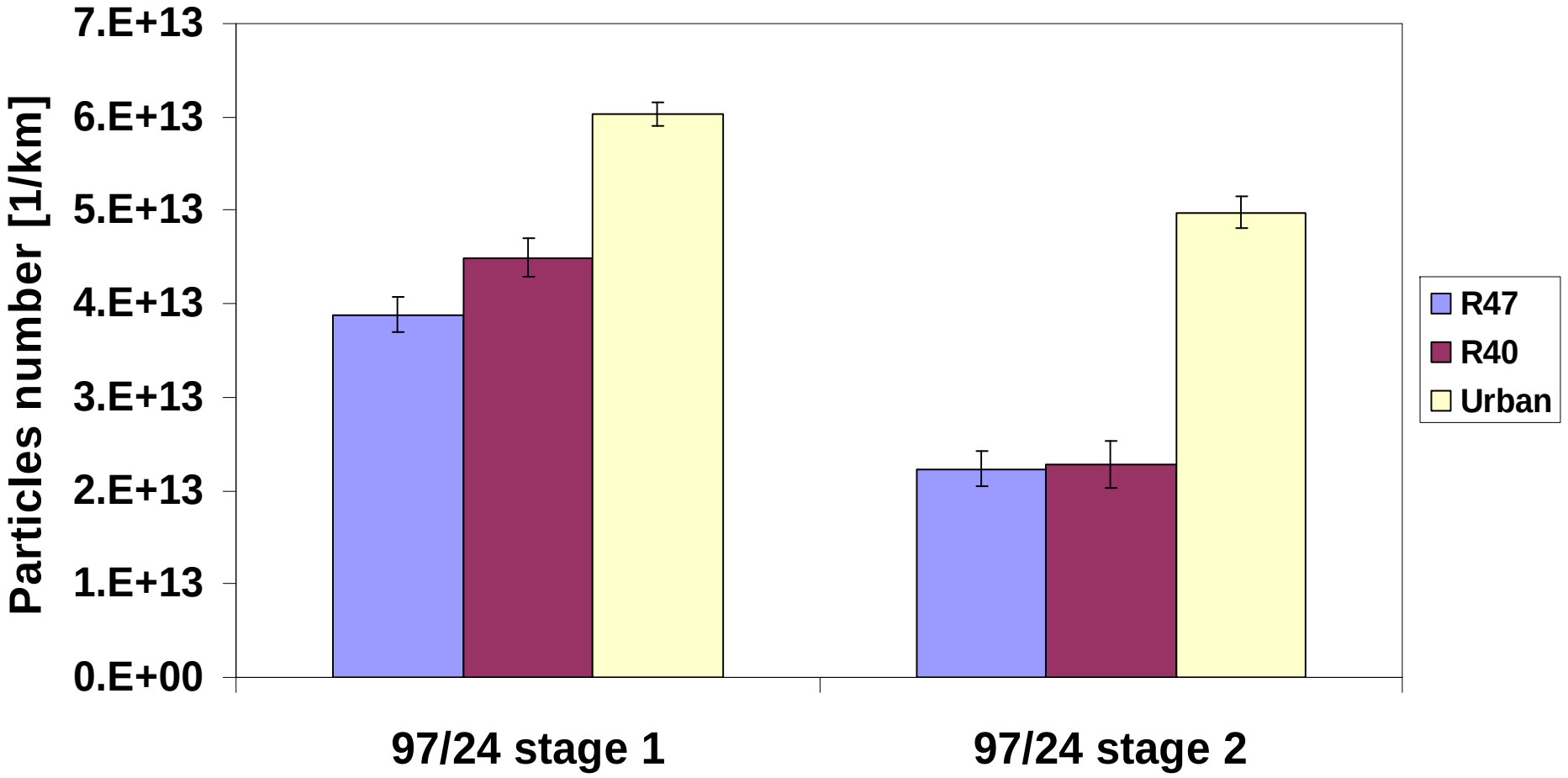
PM 2S vs. driving cycle



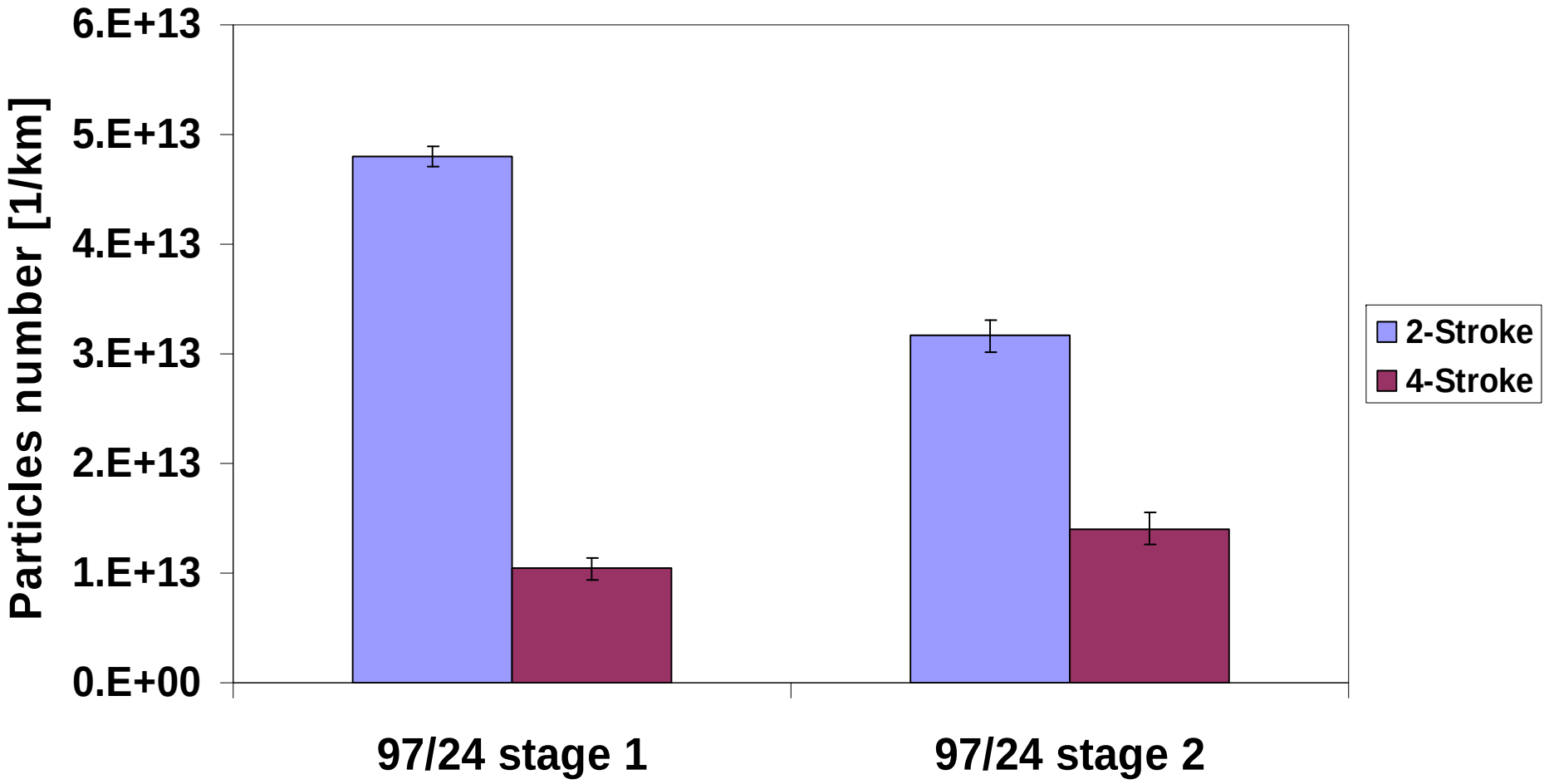
PM 2S – 4S


PM [mg/km]
90
80
70
60
50
40
30
20
10
0
97/24 stage 1
97/24 stage 2
2-Stroke
4-Stroke

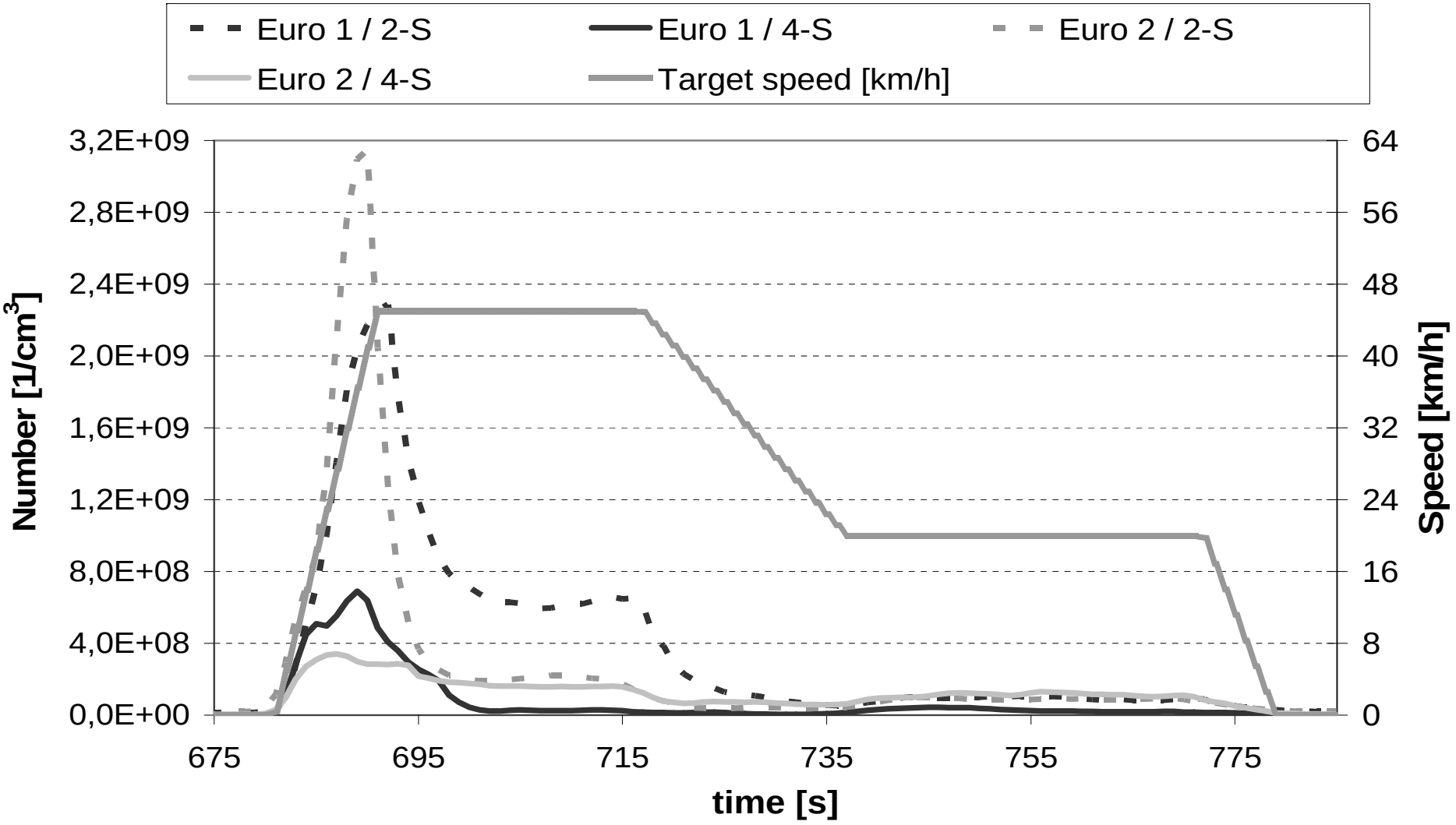
Particles number 2S vs. driving cycle



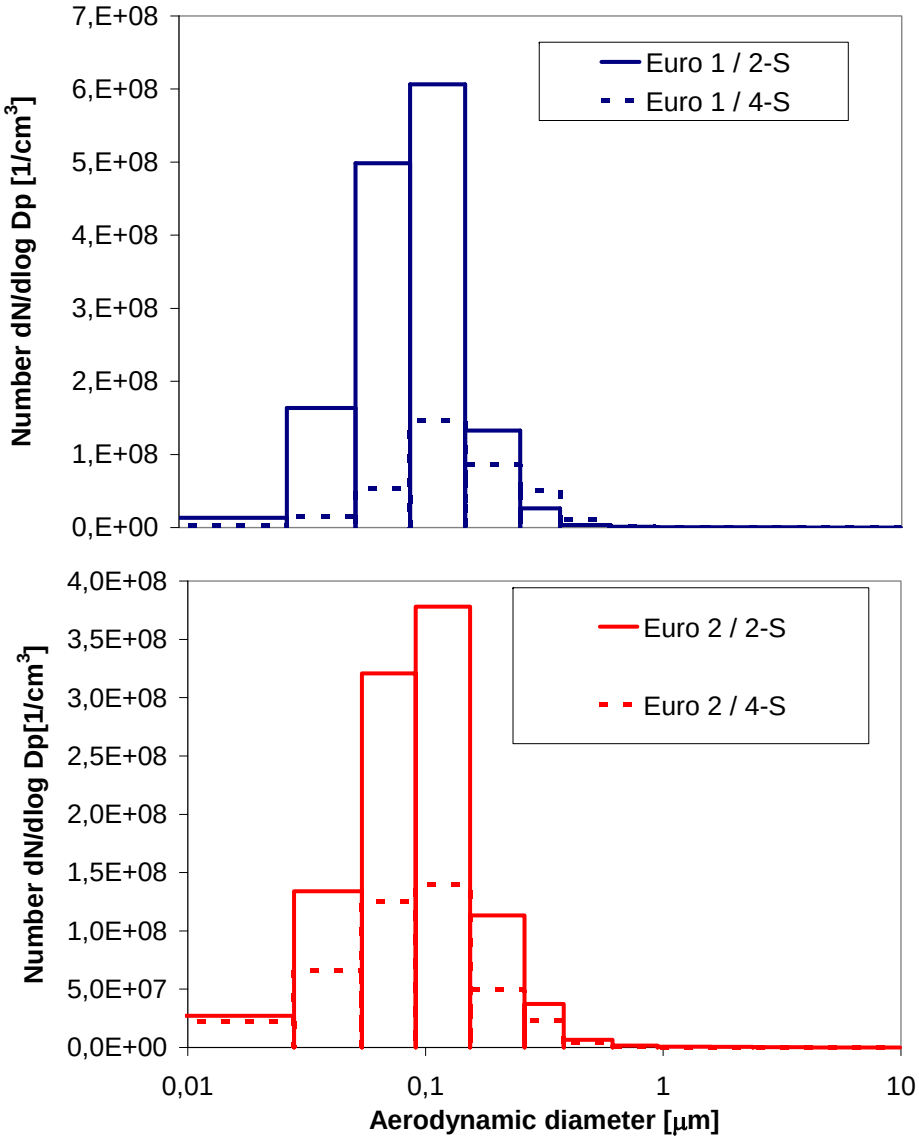
Particles number 2S – 4S



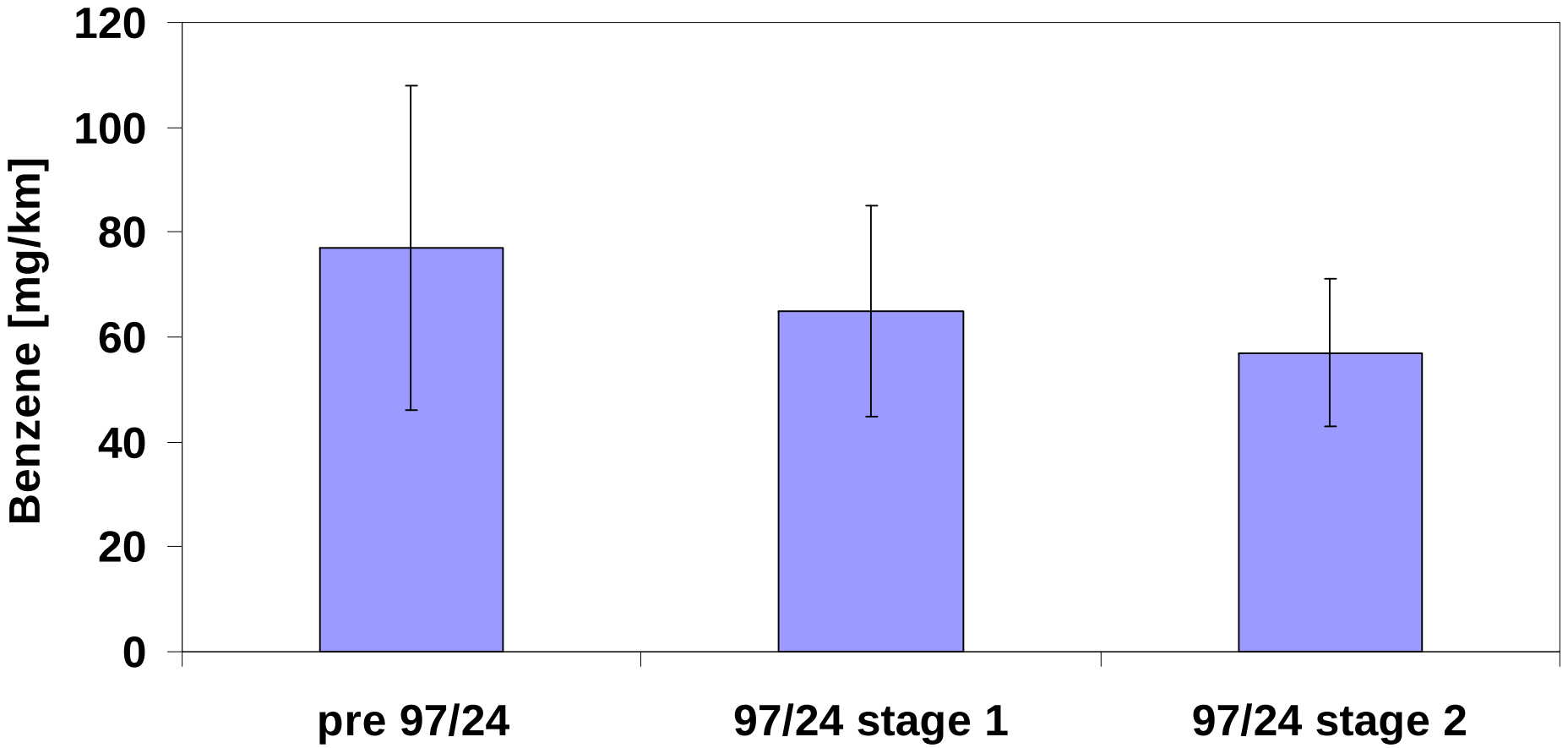
Instantaneous Particles number 2S – 4S



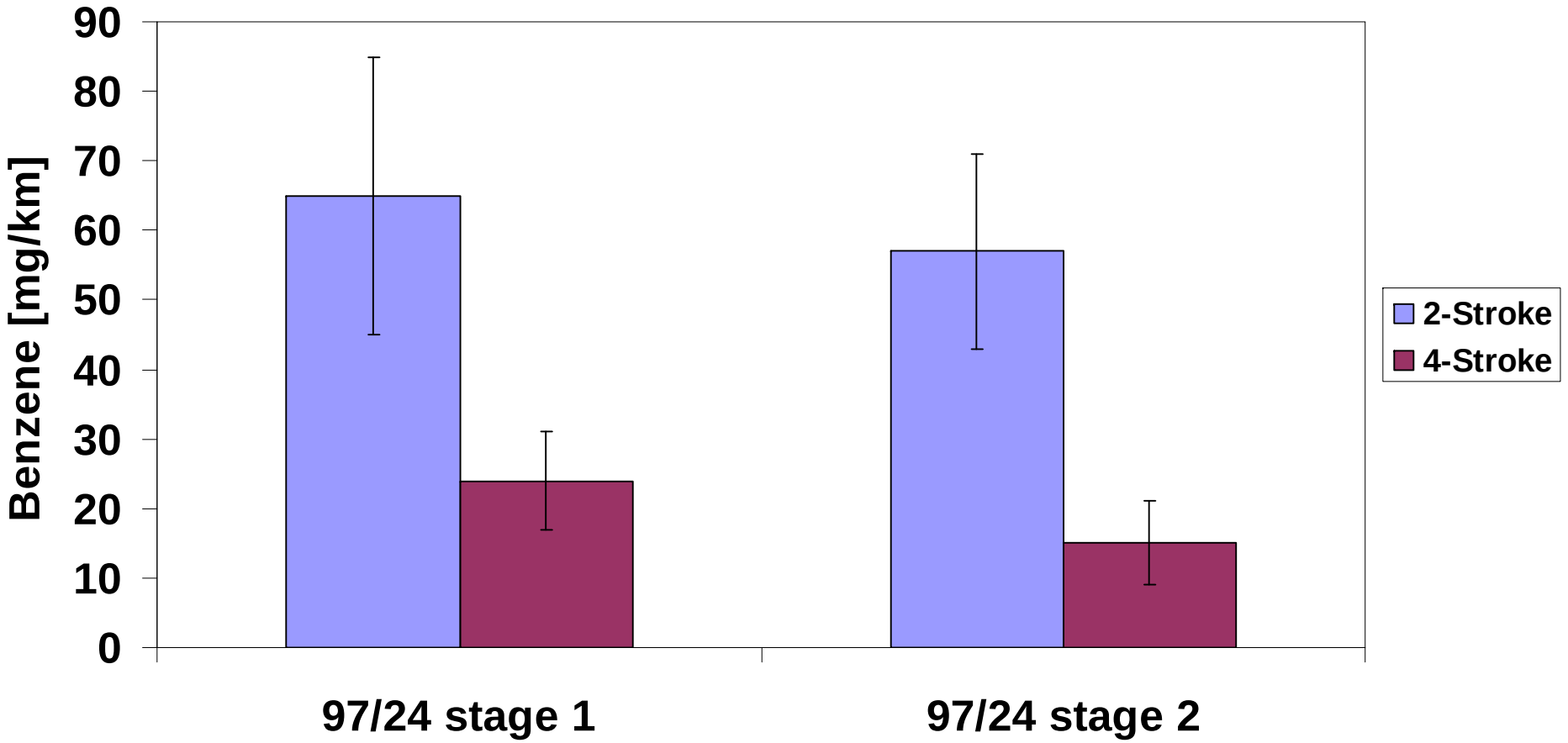
Particles size distribution



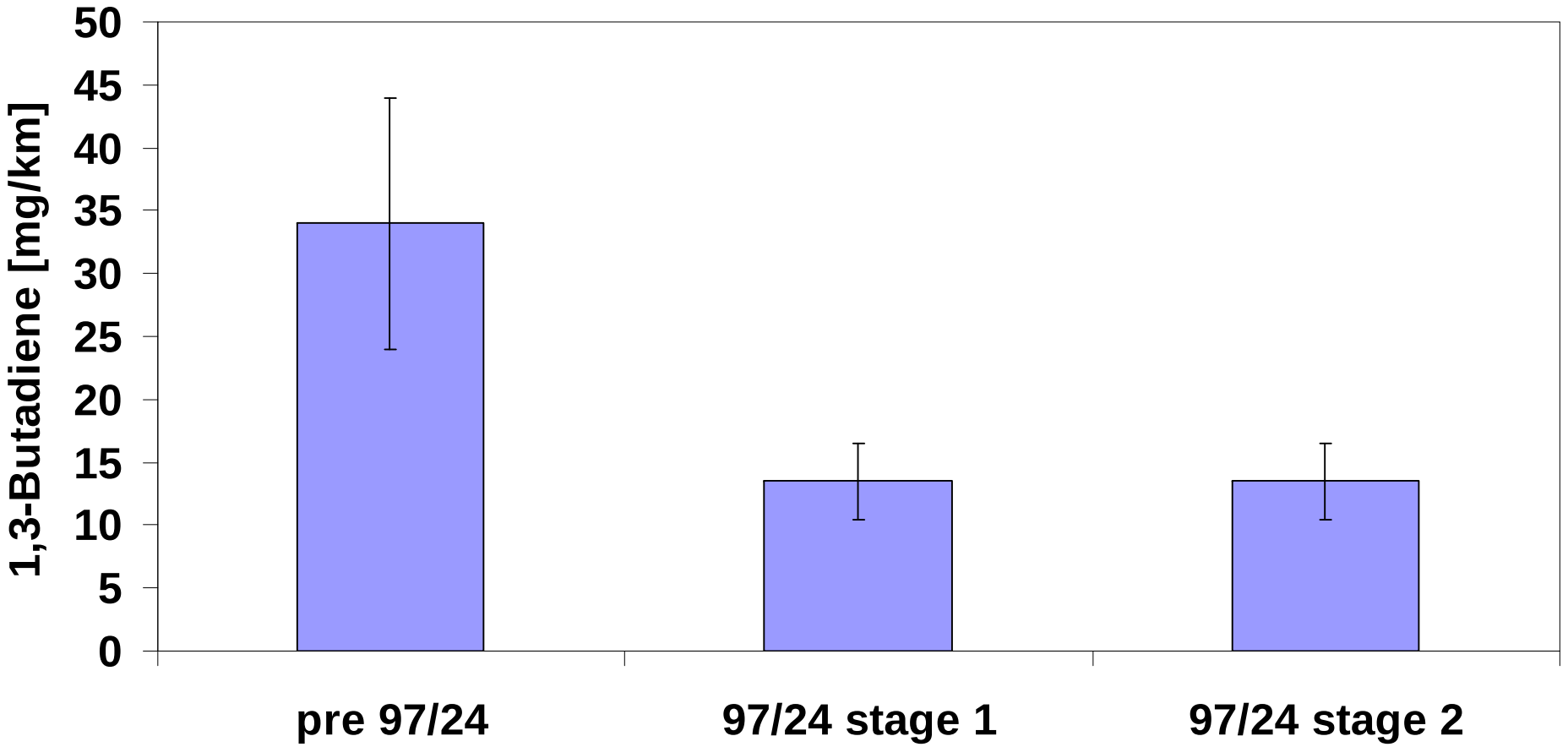
Benzene 2S vs. emission standard



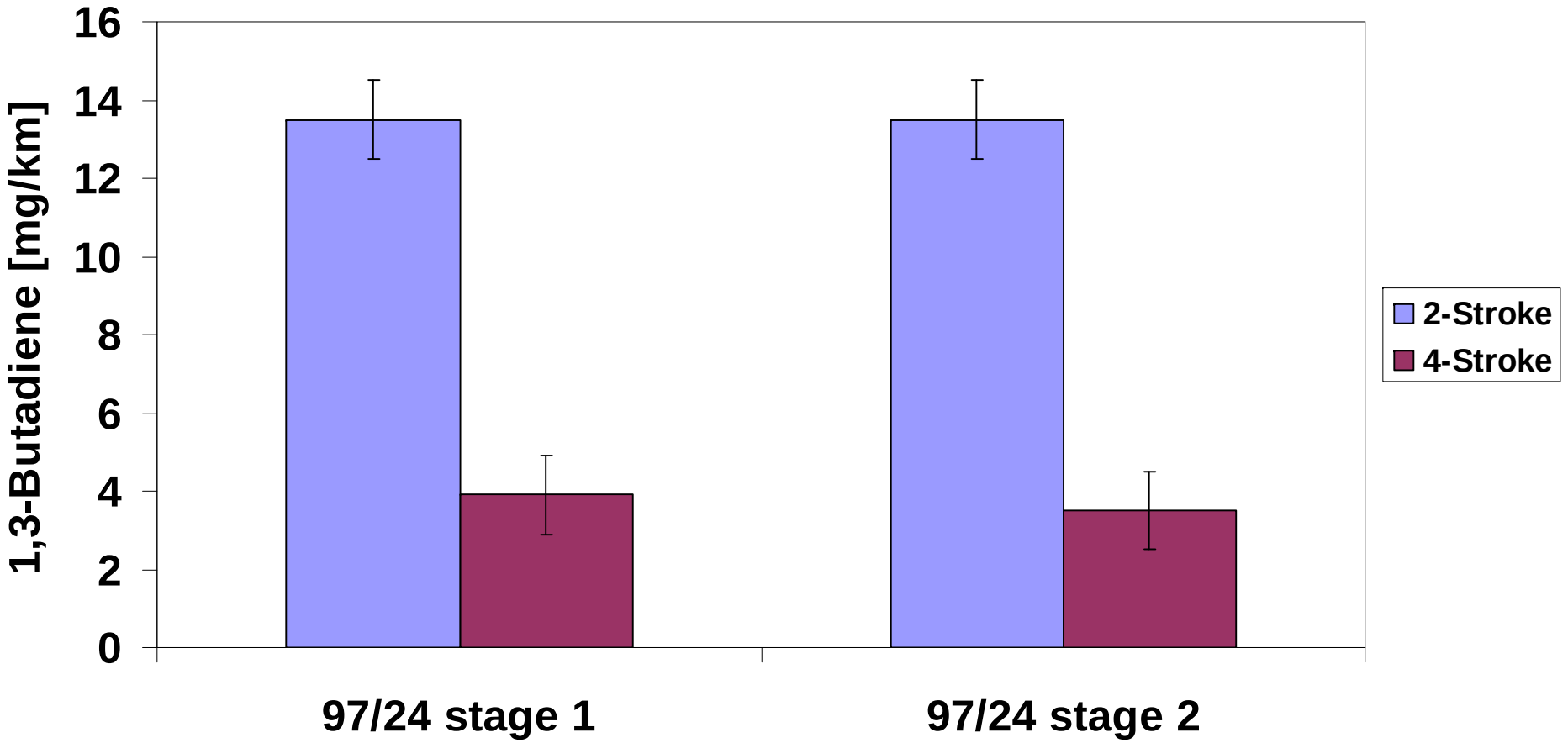
Benzene 2S – 4S



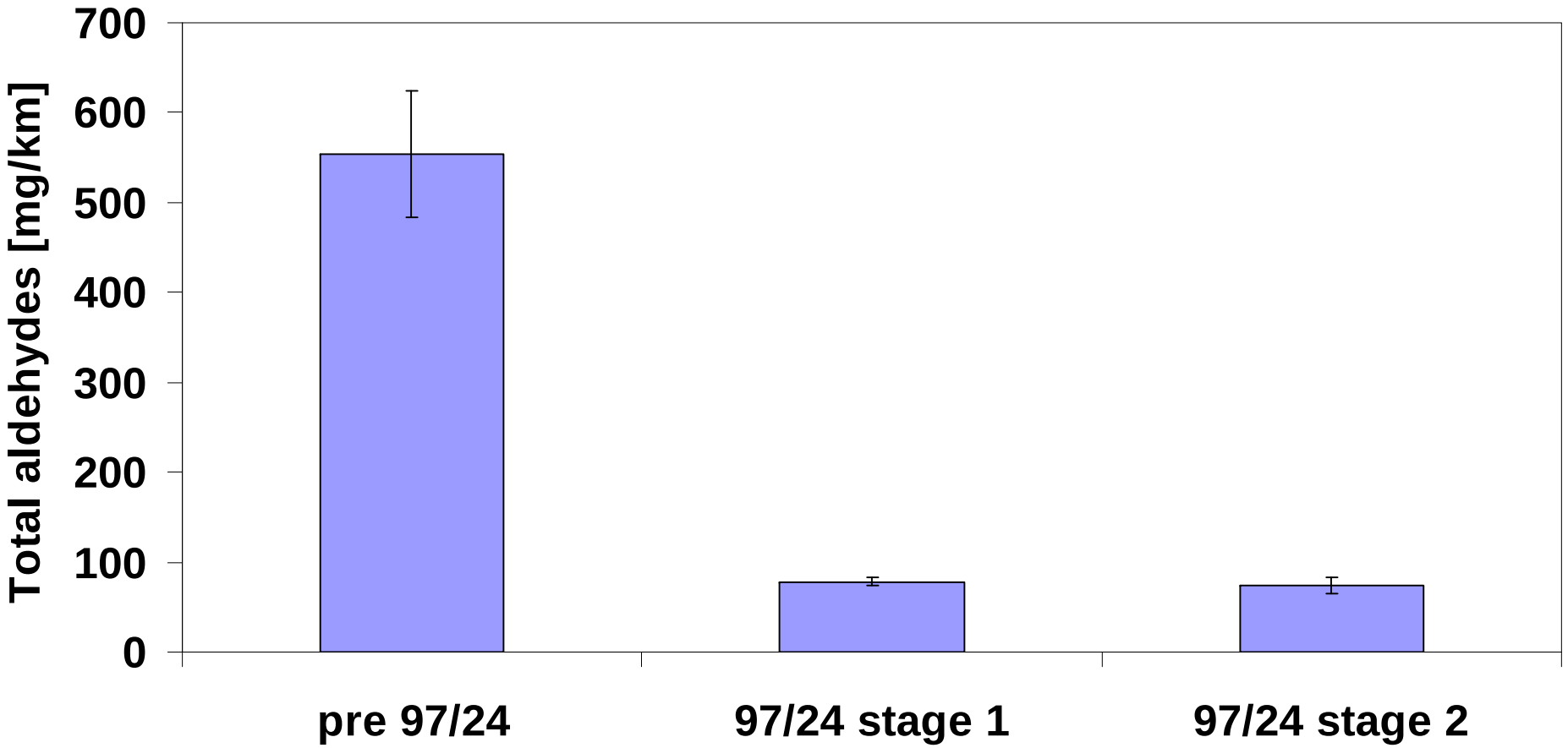
1,3-Butadiene 2S vs. emission standard



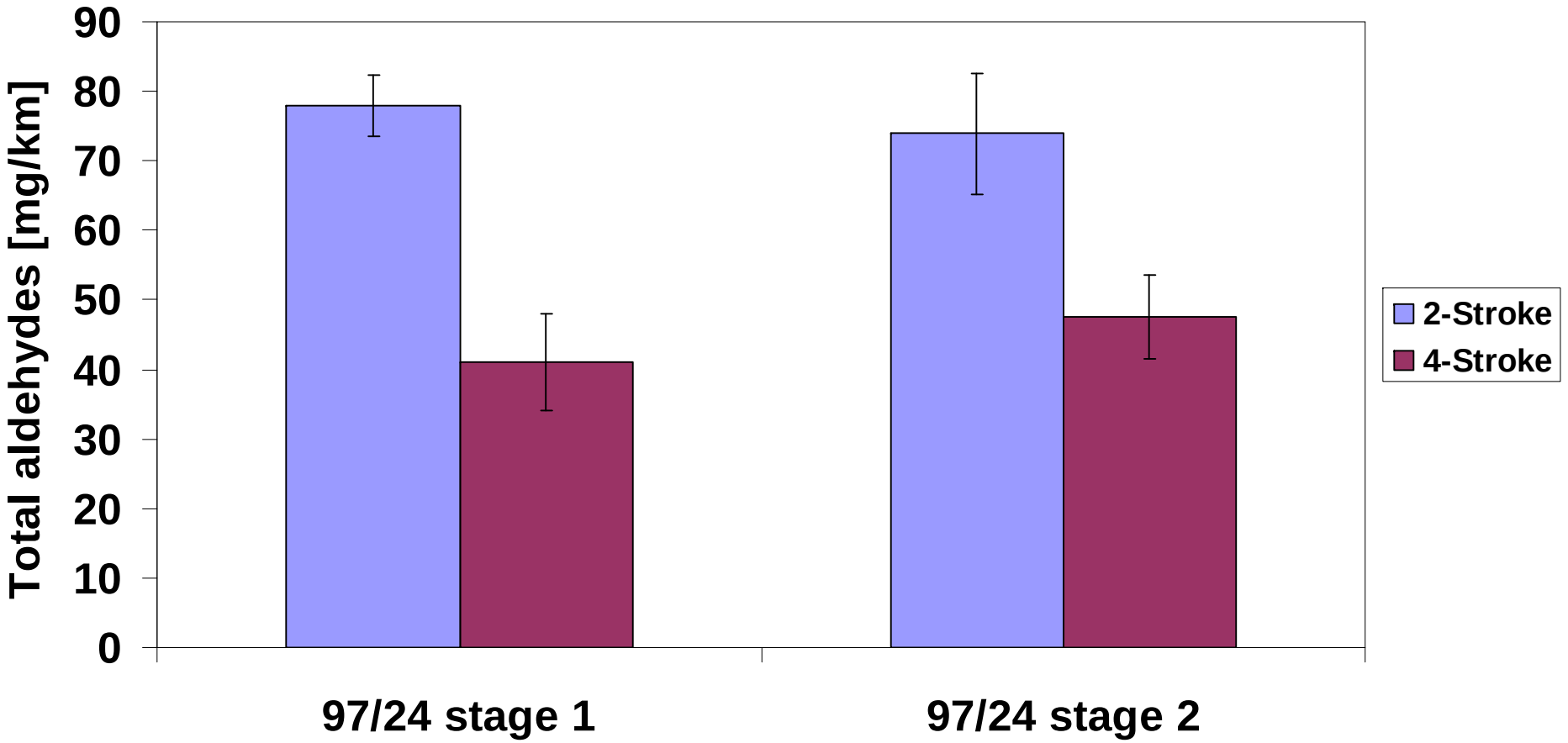
1,3-Butadiene 2S – 4S



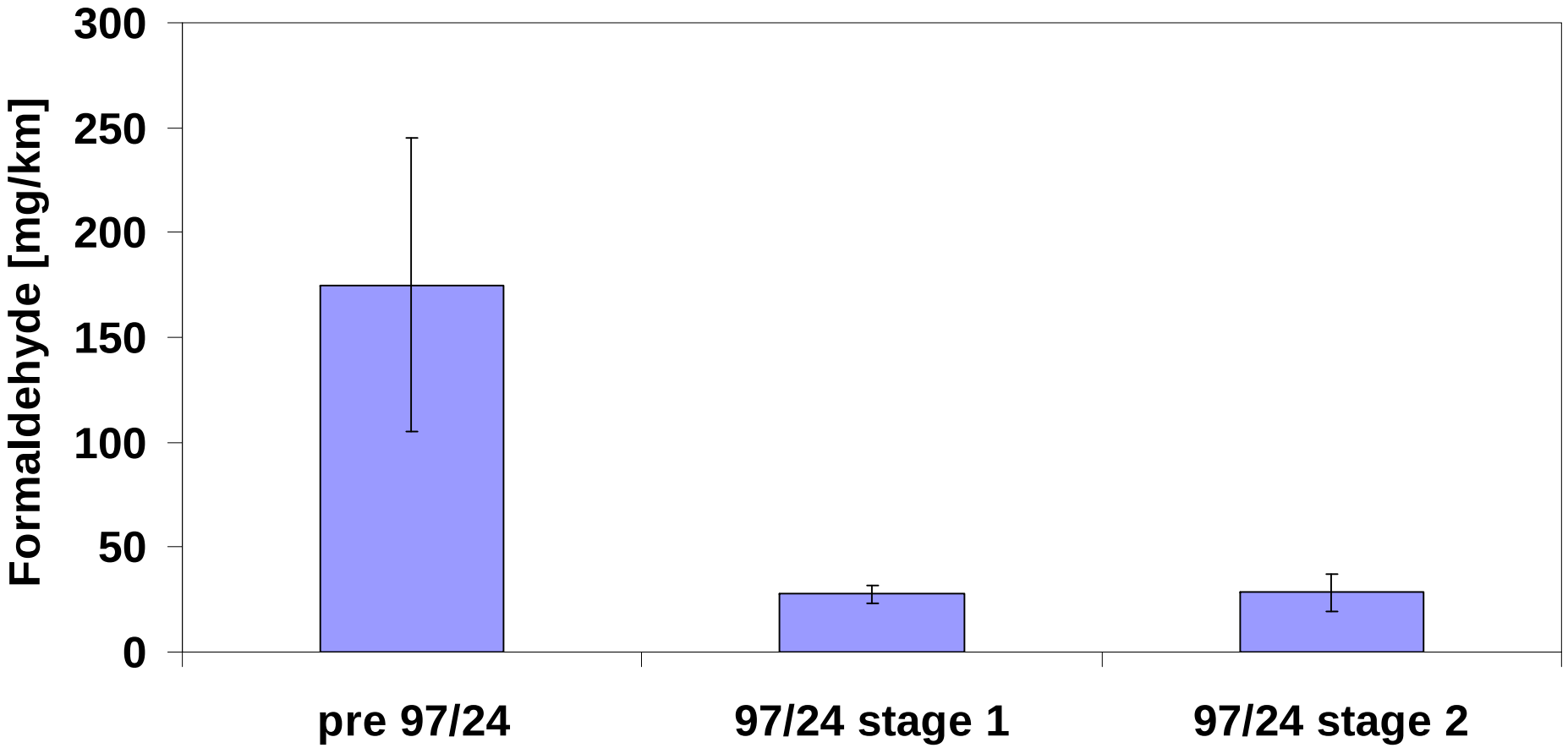
Total aldehydes 2S vs. emission standard



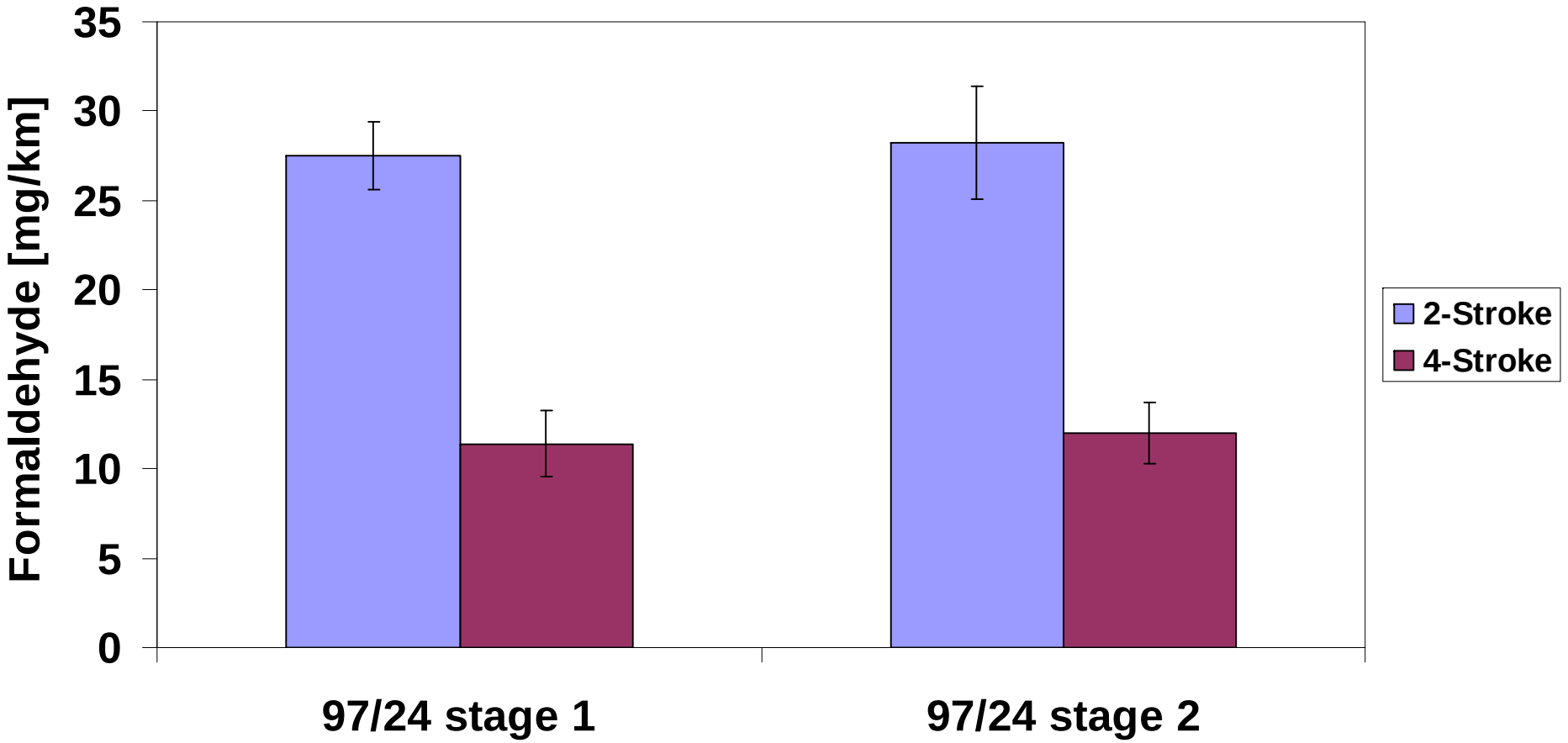
Total aldehydes 2S – 4S



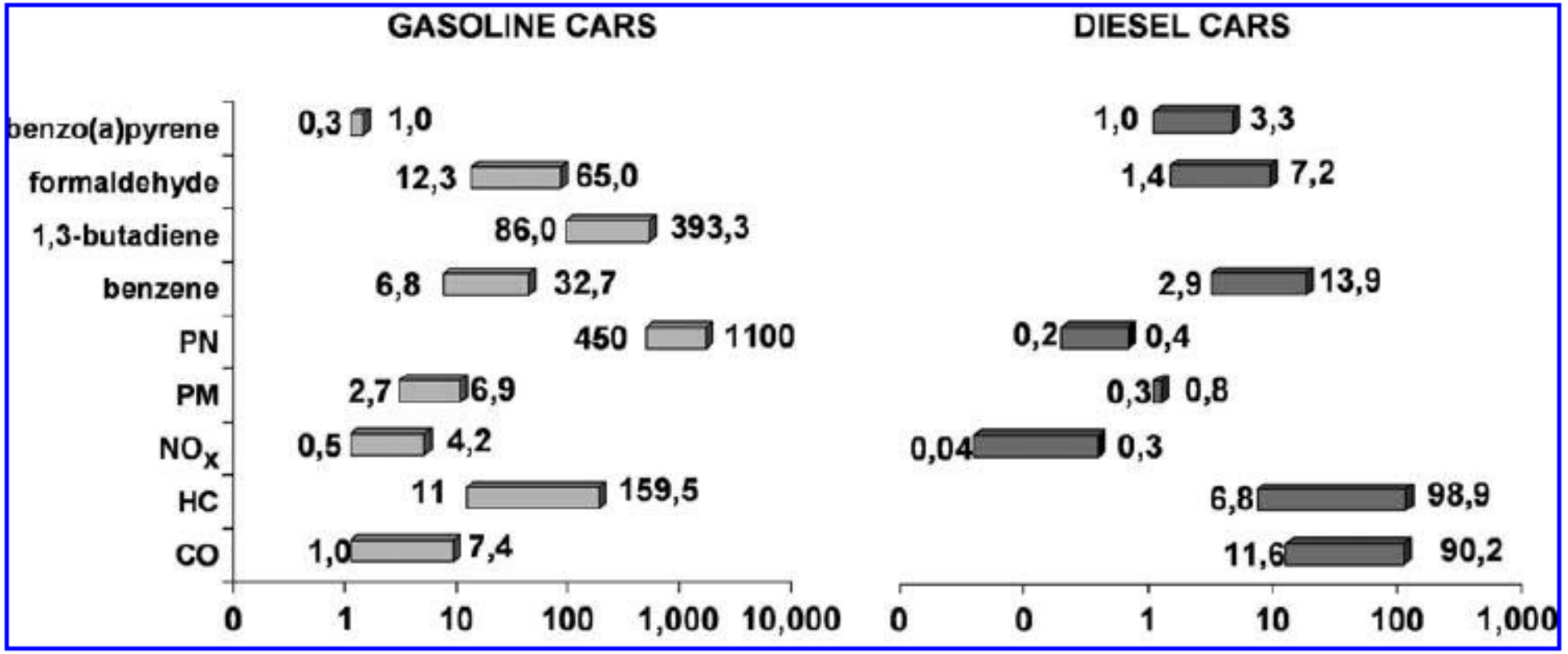
Formaldehyde 2S vs. emission standard



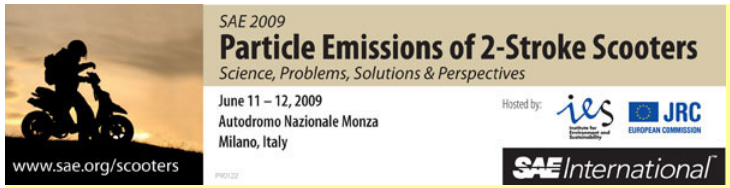
Formaldehyde 2S – 4S



Euro 2 mopeds / Euro 3 cars emission ratio



M.V. Prati, M.A. Costagliola “Emissions of Fine Particles and Organic Compounds from Mopeds”. ENVIRONMENTAL ENGINEERING SCIENCE, Vol. 26, Number 1, 2009



Conclusions

- **Regulated emissions from in use mopeds often exceeded the relative emission standards, in particular for 97/24 stage 2.**

- **Although exhaust after-treatment systems and engine development reduced regulated emissions from 2S mopeds, some pollutants are still remarkably higher than those emitted by 4S mopeds.**

- **Similar trends have been observed for unregulated emissions.**

- **Driving cycle has a considerable effect on regulated and unregulated emissions.**

- **The sample size is at the moment small, but the present results can provide a picture of moped emission levels.**