



Italian National Agency for New Technologies,  
Energy and Sustainable Economic Development

EXPERT PANEL FOR POLLUTING  
EMISSIONS REDUCTION - EXPAPER

# Studi di impatto sulla salute delle emissioni da trasporto

*CNR Istituto Motori Napoli, 22 Maggio 2018*

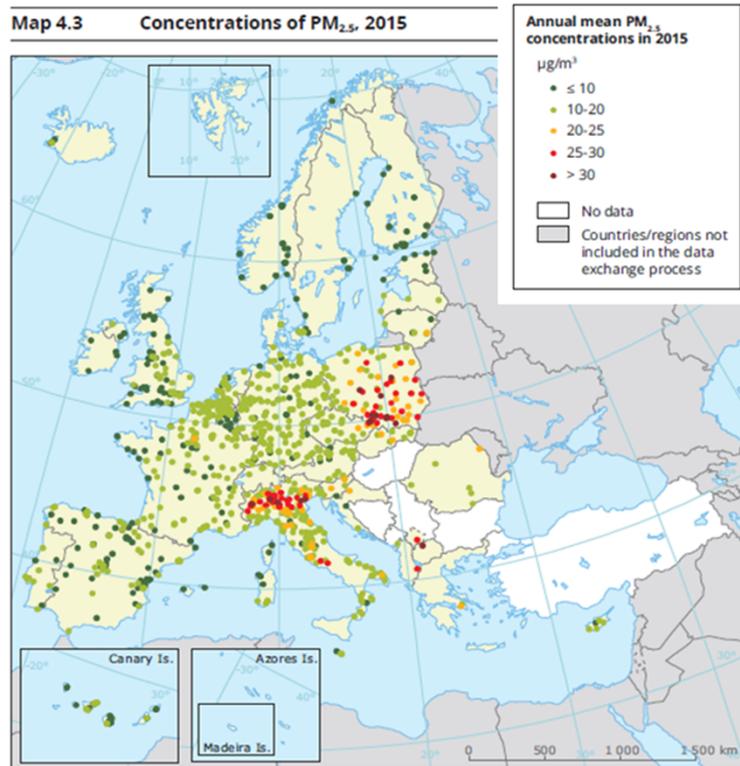


*Maurizio Gualtieri – ENEA SSPT-MET-INAT*

# Outline

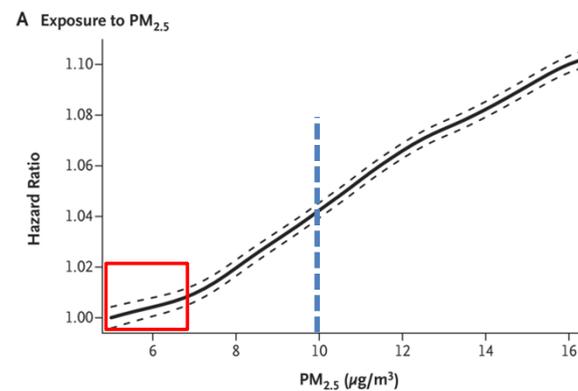
- Introduzione
- Le evidenze epidemiologiche e tossicologiche
- La sorgente traffico: modalità di identificazione
  - source apportionment sperimentale
  - source apportionment modellistico
- Nuove applicazioni per lo studio degli effetti attesi/evitabili

# Introduzione – Qualità dell'aria in EU



**Table ES.1** Percentage of the urban population in the EU-28 exposed to air pollutant concentrations above certain EU and WHO reference concentrations (minimum and maximum observed between 2013 and 2015)

Pollutant	EU reference value (*)	Exposure estimate (%)	WHO AQG (*)	Exposure estimate (%)
PM <sub>2.5</sub>	Year (25)	7-8	Year (10)	82-85
PM <sub>10</sub>	Day (50)	16-20	Year (20)	50-62
O <sub>3</sub>	8-hour (120)	7-30	8-hour (100)	95-98
NO <sub>2</sub>	Year (40)	7-9	Year (40)	7-9
BaP	Year (1)	20-25	Year (0.12) RL	85-91
SO <sub>2</sub>	Day (125)	< 1	Day (20)	20-38



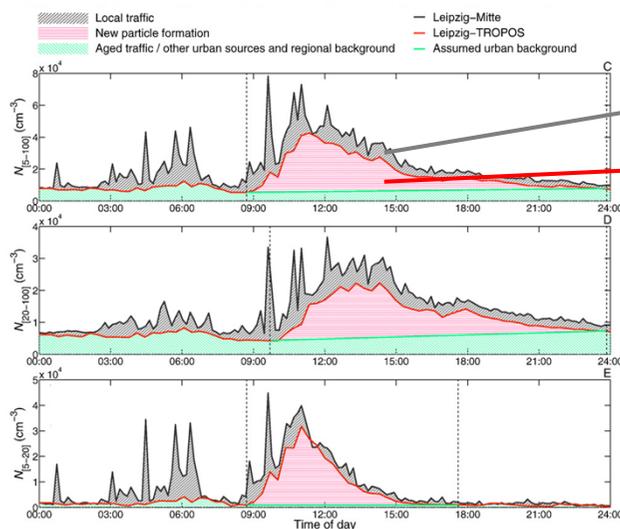
Air quality in Europe — EEA 2017 report 13/2017

Di et al, N Engl J Med 2017;376:2513-22.

# Introduzione: la qualità dell'aria in ambiente urbano

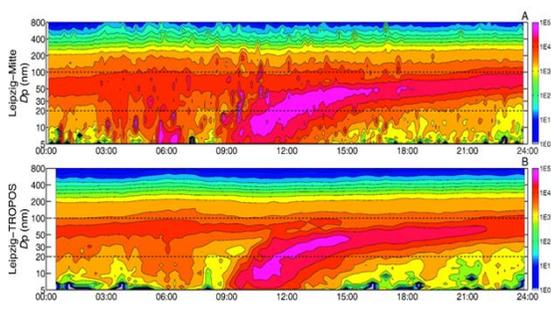
Il contributo delle particelle ultrafini alla qualità dell'aria

Viviamo in ambienti in cui la concentrazione in numero di UFP è elevata



Lato strada - primario

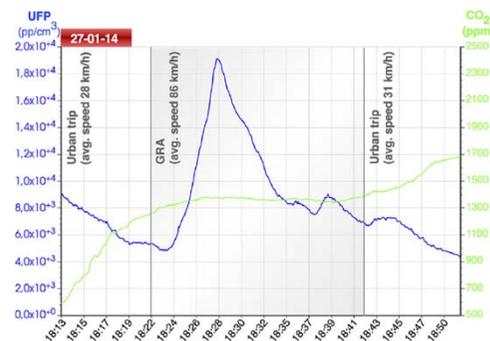
Fondo urbano - secondario



Strada

Fondo urbano

Esposizione durante mobilità in macchina



M. Grana et al. Environmental Pollution 228 (2017) 201–210

N. Ma, W. Birmili / Science of the Total Environment 512–513 (2015) 154–166



# Introduzione: emissioni da processi non da combustione

Oltre alle particelle di origine carboniosa è importante considerare anche emissioni di particelle metalliche/inorganiche.

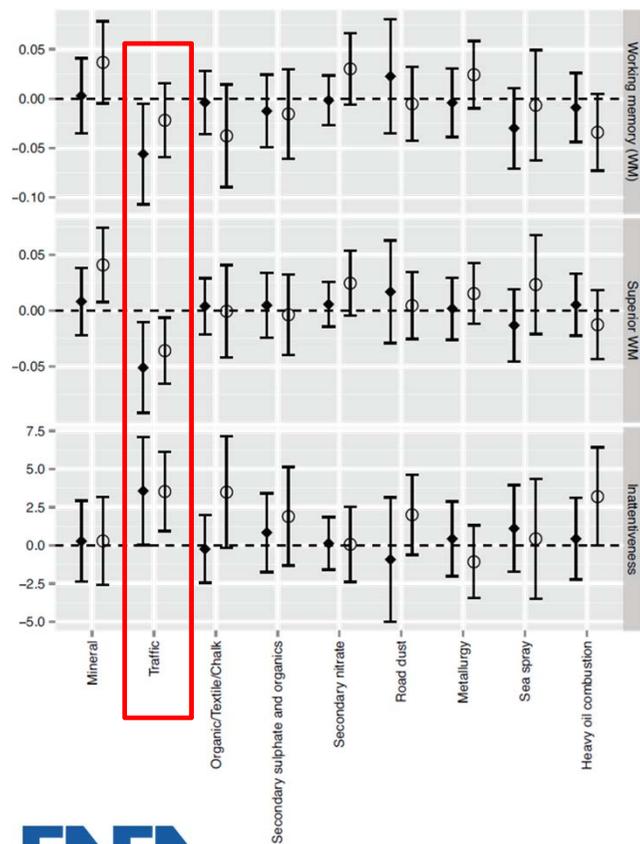
**Table 1**

PM<sub>10</sub> and PM<sub>0.1</sub> airborne concentrations of metals (ng/m<sup>3</sup>) that are known to be used (as nanomaterials) in automotive parts, engine oils and fuels, including the mass percentage (%m/m) in the size fraction smaller than 100 nm.

	Maastunnel Rotterdam			Bentinckplein Rotterdam			Cabauw		
	PM <sub>10</sub> ng/m <sup>3</sup> n = 2	PM <sub>0.1</sub> ng/m <sup>3</sup> n = 1	<100 nm %(m/m)	PM <sub>10</sub> ng/m <sup>3</sup> n = 4	PM <sub>0.1</sub> ng/m <sup>3</sup> n = 3	<100 nm %(m/m)	PM <sub>10</sub> ng/m <sup>3</sup> n = 2	PM <sub>0.1</sub> ng/m <sup>3</sup> n = 2	<100 nm %(m/m)
Mo	4.6 (0.6)	0.039	0.8%	1.7 (0.4)	0.096 (0.043)	5.6%	1.7 (0.6)	0.1 (0.1)	4.9%
Ti	19.1 (7.6)	0.200	1.0%	4.7 (1.7)	0.020 (0.031)	0.4%	1.3 (0.9)	<0.001	<0.2%
Fe	7300 (1700)	7.5	0.1%	520 (120)	3.6 (2.4)	0.7%	190 (95)	0.2 (0.3)	0.1%
Cu	230 (33)	0.27	0.1%	24.2 (5.2)	0.10 (0.05)	0.4%	4.2 (2.8)	<0.001	<0.05%
Ag	0.27 (0.06)	0.003	1.1%	0.14 (0.09)	0.012 (0.008)	8.6%	0.044	<0.001	<2%
Ce	0.92 (0.32)	0.059	6.4%	0.27 (0.07)	0.003 (0.003)	1.1%	0.042 (0.003)	0.0001 (0.0001)	0.2%
W	6.5 (3.7)	1.2	18%	1.0	0.23	23%	0.18	<0.001	<0.6%
Pd	0.10 (0.02)	0.009	9.0%	0.025 (0.013)	0.002 (0.001)	8.0%	0.001 (0.001)	0.0001 (0.0001)	7.0%
Pt	0.015 (0.002)	0.002	13%	0.004 (0.002)	0.0001 (0.0001)	2.5%	0.0004 (0.0004)	<0.0001	3.7%
Rh	0.009 (0.004)	0.0002	2.2%	0.004	<0.0001	<2.3%	0.0002 (0.0002)	<0.0001	<6%
Zn	105 (31)	0.94	0.9%	21.6 (3.0)	0.087 (0.064)	0.4%	11.1 (8.1)	<0.001	<0.01%
Si	560 (220)	5.80	1.0%	810 (190)	<0.001	<0.01%	72	<0.001	<0.01%
B	2.8 (0.3)	0.20	7.0%	1.6 (0.3)	0.3 (0.10)	18%	1.4 (0.7)	0.012 (0.012)	1.2%
Sum	8250	16.0	4.7%	1380	4.5	5.6%	280	0.3	1.5%

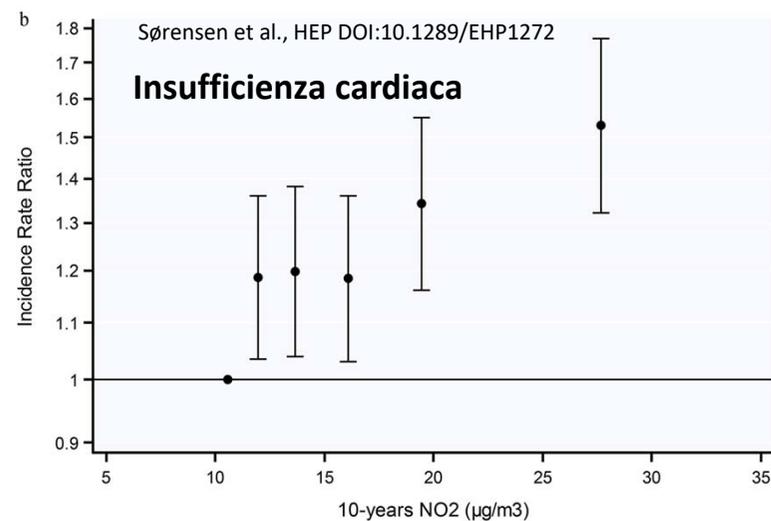
P.S. Bäuerlein et al. Science of the Total Environment 576 (2017) 273–283

# Evidenze epidemiologiche: impatto delle emissioni veicolari



Il particolato da traffico è associato a significative riduzioni di **crescita cognitiva** in bambini delle scuole primarie seguiti per un anno.

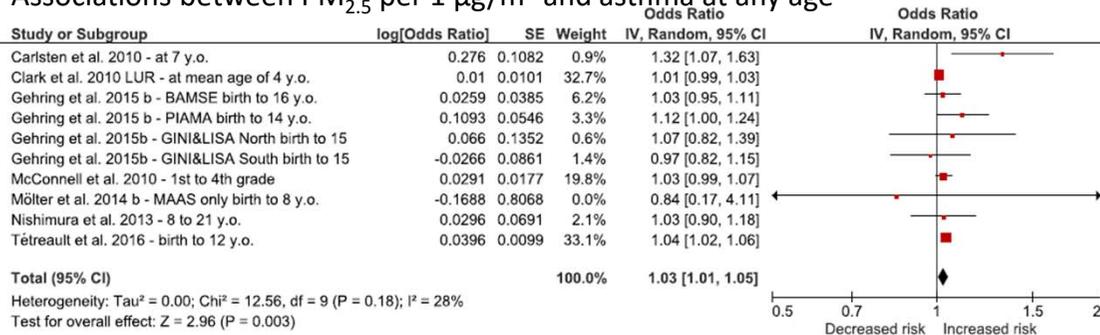
Basagaña et al. 2016. Environ Health Perspect 124:1630–1636



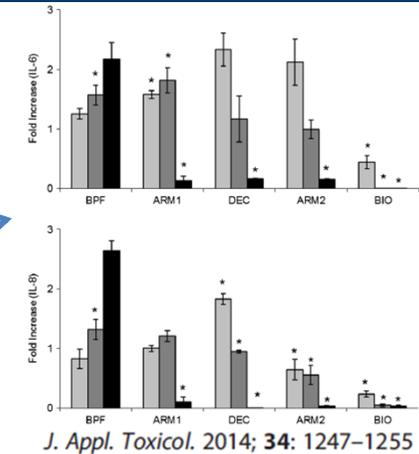
In conclusion, we found an association between air pollution and road traffic noise and risk of incident heart failure, which seemed strongest among persons with a vascular system that was already impaired by other conditions. Furthermore, there were indications of combined effects of noise and air pollution.

# Evidenze epidemiologiche: impatto delle emissioni veicolari

Associations between PM<sub>2.5</sub> per 1 µg/m<sup>3</sup> and asthma at any age

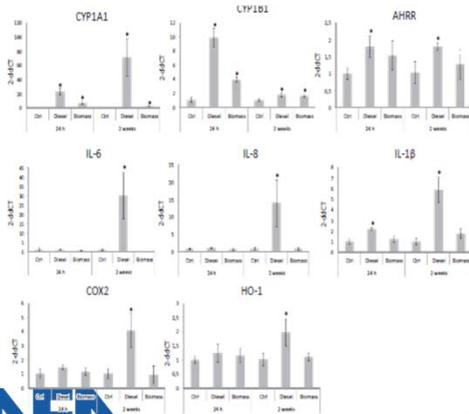


Valutazione degli effetti di emissioni da diversi combustibili: possibilità di confronto degli effetti delle emissioni

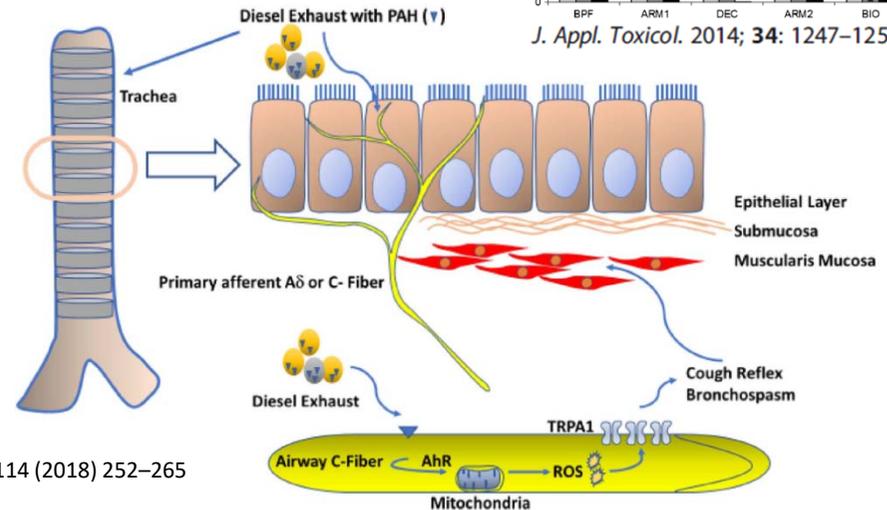


H. Khreis et al. / *Environment International* 100 (2017) 1-31

Longhin et al. *Environmental Pollution* 215 (2016) 366-375

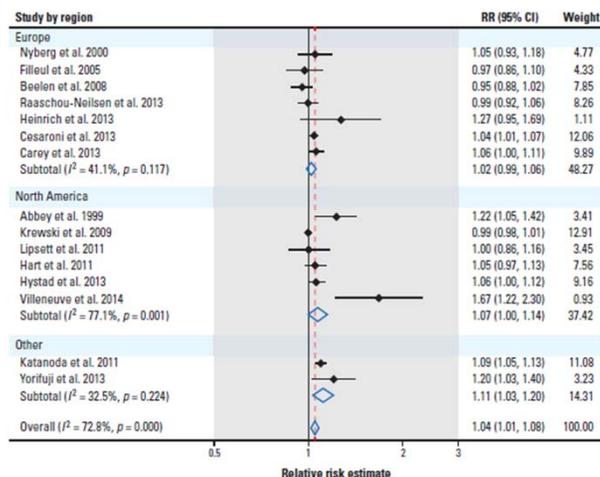


Studi tossicologici in vitro permettono di identificare gli effetti a livello delle cellule di interesse (effetti infiammatori, ossidativi e/o genotossici)



Reis et al. *Environment International* 114 (2018) 252-265

# Evidenze epidemiologiche: impatto delle emissioni veicolari



Hamra et al 2015 Health Perspect 123:1107–1112

Le emissioni da traffico (NO<sub>2</sub>) sono associate a un incremento significativo dell'incidenza di tumore al polmone

International Agency for Research on Cancer



PRESS RELEASE  
N° 213

12 June 2012

**Figure 1.** Forest plot of study-specific estimates of relative risk (RR) of lung cancer associated with a 10-µg/m<sup>3</sup> increase in exposure to NO<sub>2</sub>. The meta-estimate and weights in the forest plot are estimated from random effects meta-analyses.

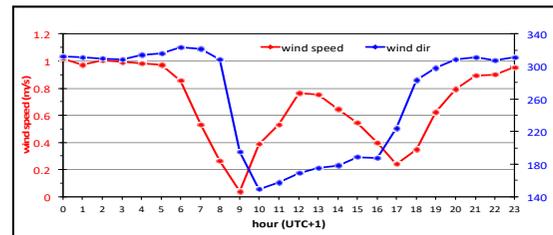
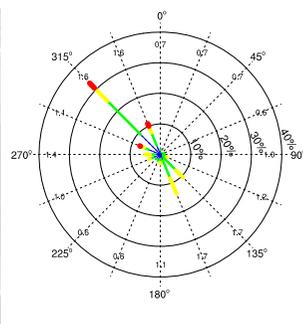
Never-smoker or quit smoking ≥ 10 years			
Distance to A1 (m)			
≥ 200	587	1.00 (Referent)	1.00 (Referent)
50–199	13	0.86 (0.49, 1.49)	0.90 (0.52, 1.57)
0–49	4	3.15 (1.16, 8.50)	3.26 (1.17, 9.11)
Continuous (per 100 m)	604	0.98 (0.88, 1.09)	0.98 (0.88, 1.09)
Distance to A1–A2 (m)			
≥ 200	557	1.00 (Referent)	1.00 (Referent)
50–199	36	0.99 (0.71, 1.39)	1.03 (0.73, 1.45)
0–49	11	1.05 (0.58, 1.91)	1.07 (0.59, 1.96)
Continuous (per 100 m)	604	0.98 (0.91, 1.04)	0.97 (0.90, 1.03)
Distance to A1–A3 (m)			
≥ 200	324	1.00 (Referent)	1.00 (Referent)
50–199	188	1.10 (0.91, 1.31)	1.09 (0.91, 1.31)
0–49	92	1.00 (0.79, 1.26)	1.03 (0.81, 1.30)
Continuous (per 100 m)	604	1.00 (0.95, 1.04)	0.99 (0.95, 1.04)

## IARC: DIESEL ENGINE EXHAUST CARCINOGENIC

Lyon, France, June 12, 2012 -- After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), today classified diesel engine exhaust as **carcinogenic to humans (Group 1)**, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Puett et al., 2014. Environ Health Perspect 122:926–932

# Il contributo delle emissioni da traffico: SA sperimentale



AMS: Caratteristiche	PM 50% cutoff ( $\mu\text{m}$ )	Flusso (lpm)	Tempo campionamento (min)	Supporto campionamento
URG900D AIM	2.5	3	55	no
SUNSET Semi-continuos EC/OC analyzer	2.5/1	8	90 (30)	quarzo

Uso di metodi di campionamento e analisi automatici:

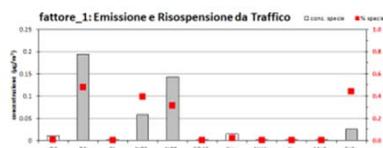
Riduzione o assenza di artefatti nel campione

- assenza di manipolazione del campione
- minor intervallo di campionamento
- assenza di filtro di campionamento

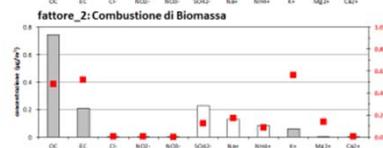
**Specie campionate (frazione PM2.5):**

(OC, EC,  $\text{Cl}^-$ ,  $\text{NO}_2^-$ ,  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Na}^+$ ,  $\text{NH}_4^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$ )

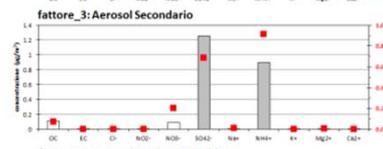
# Il contributo delle emissioni da traffico: PMF



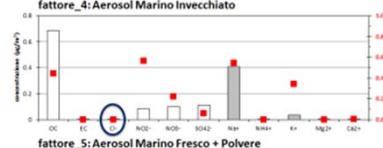
**Traffico (emissione e risospensione)**  
 EC = 48%,  $\text{NO}_2^-$  = 39%,  $\text{NO}_3^-$  = 31%,  $\text{Ca}^{2+}$  = 44%



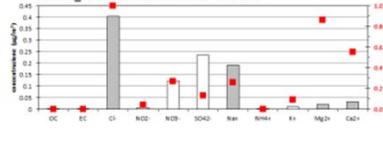
**Combustione di Biomassa**  
 OC = 48%, EC = 52%,  $\text{K}^+$  = 56%, ( $\text{SO}_4^{2-}$  = 12%)



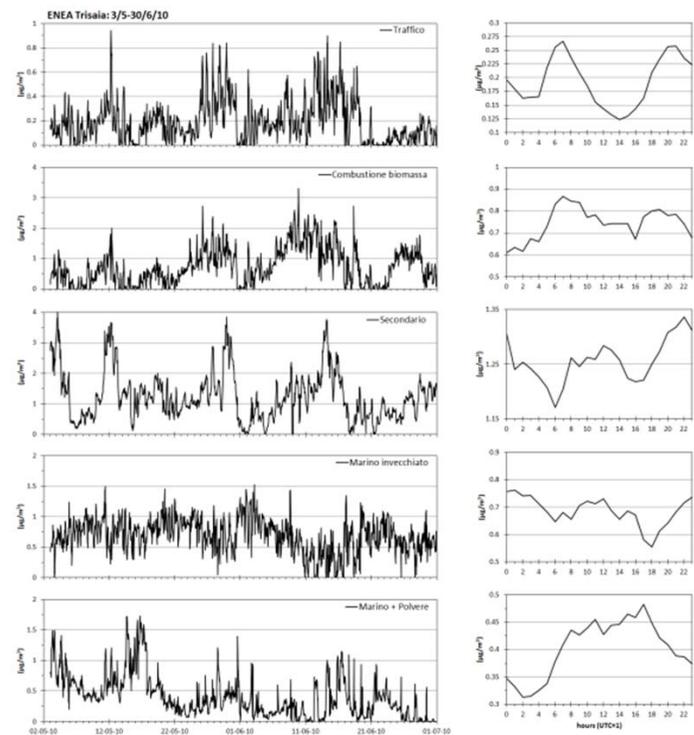
**Aerosol Secondario (solfati)**  
 $\text{SO}_4^{2-}$  = 69%,  $\text{NH}_4^+$  = 91%



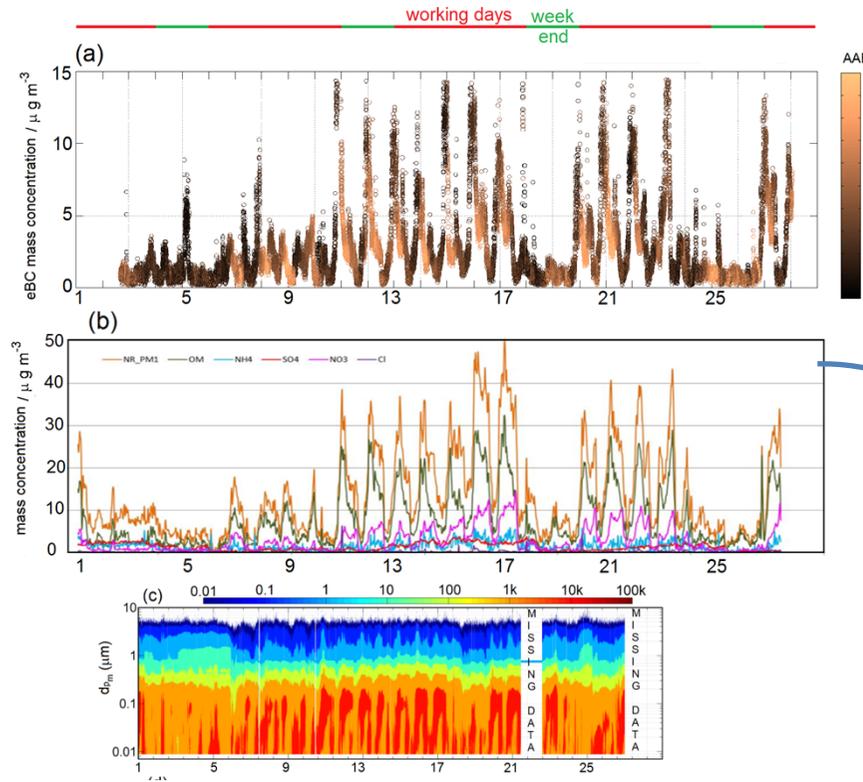
**Aerosol Marino Invecchiato**  
 $\text{Na}^+$  = 54%,  $\text{K}^+$  = 34%, (OC = 44%,  $\text{NO}_2^-$  = 57%)



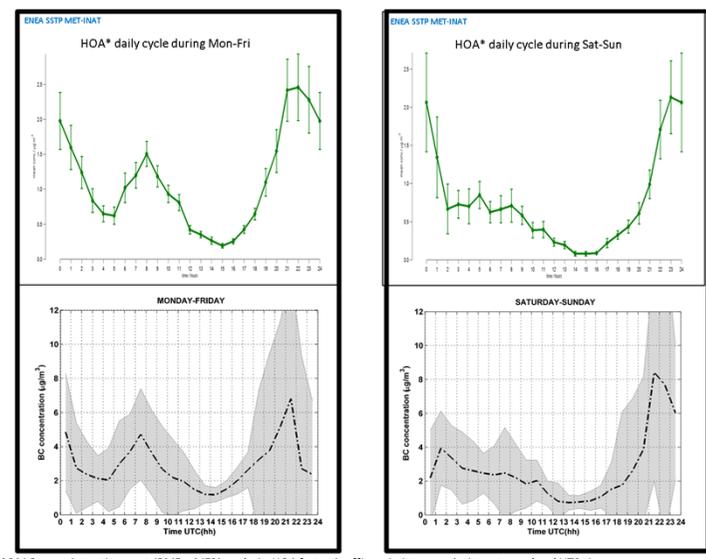
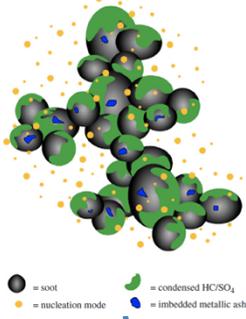
**Aerosol Marino Fresco + Polvere**  
 $\text{Cl}^-$  = 100%,  $\text{Na}^+$  = 26%,  $\text{Mg}^{2+}$  = 86%,  
 $\text{Ca}^{2+}$  = 55%, ( $\text{SO}_4^{2-}$  = 13%)



# Identificare il contributo delle emissioni da traffico: SA e PMF



Aerosol  
Chemical  
Speciation  
Monitor



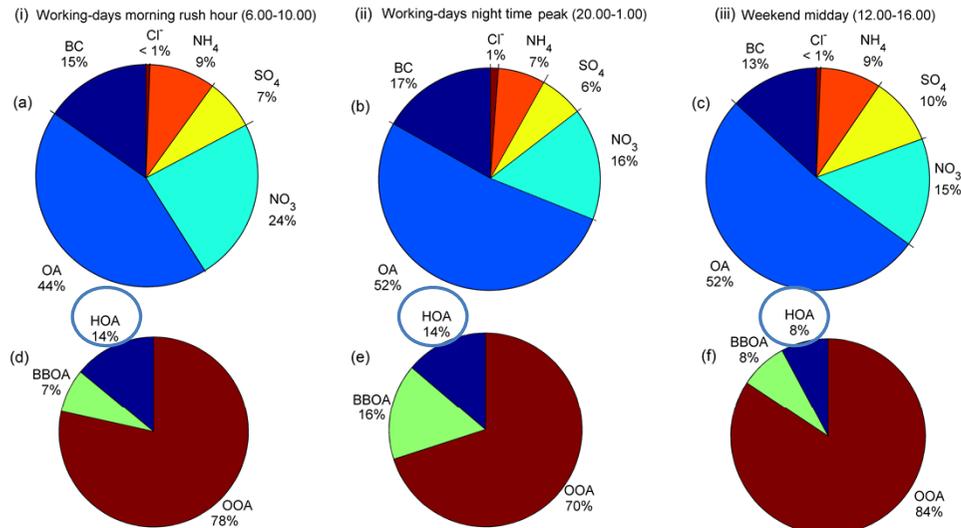
\*OM Source Apportionment (PMF – ME2) analysis; HOA factor (traffic emission assoc.); time-stamp: local UTC+1

Identificazione sorgenti  
Mediante analisi PMF

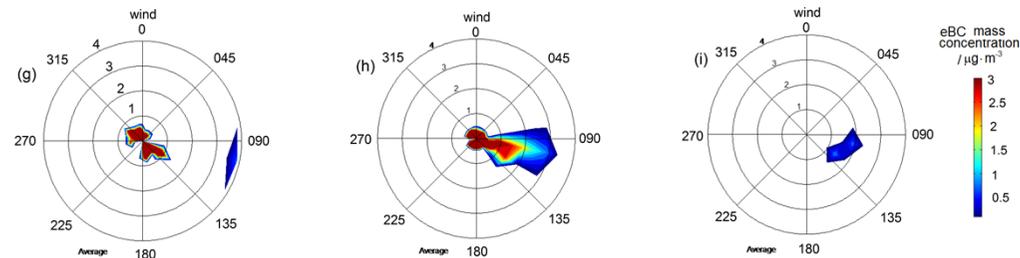


# Identificare il contributo delle emissioni da traffico: PMF e SA

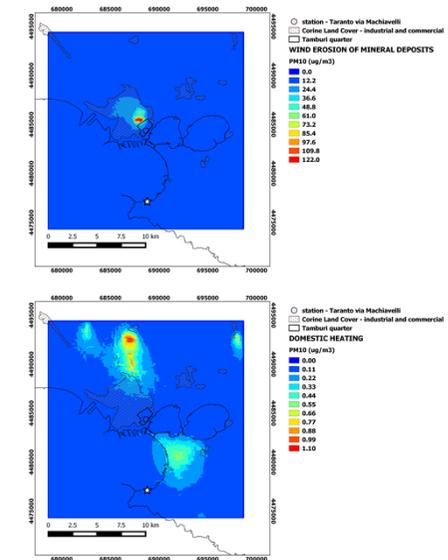
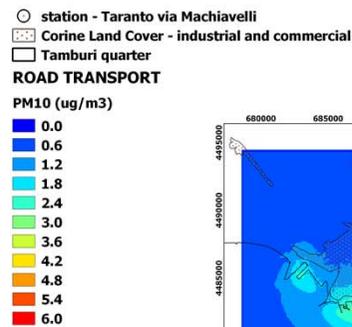
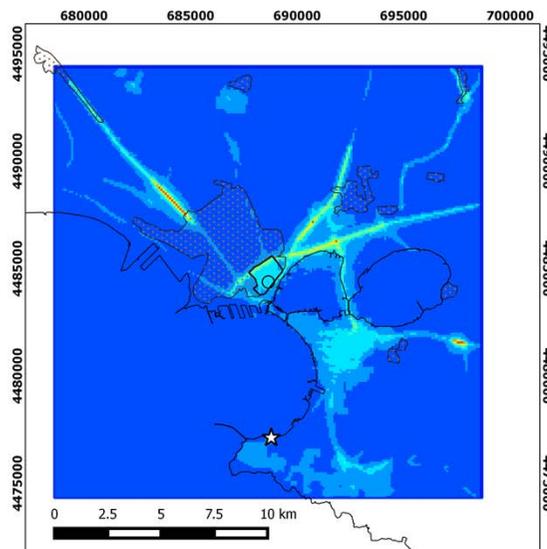
ACSM + BC



BC e direzione vento



# Il contributo delle emissioni da traffico: SA modellistico



Simulazione di dispersione in atmosfera di sostanze caratteristiche di diverse sorgenti e ricostruzione di tipologia e apporti quantitativi delle sorgenti a scala locale (fino a 20 km x 20 km, dettaglio fino a 100 m):

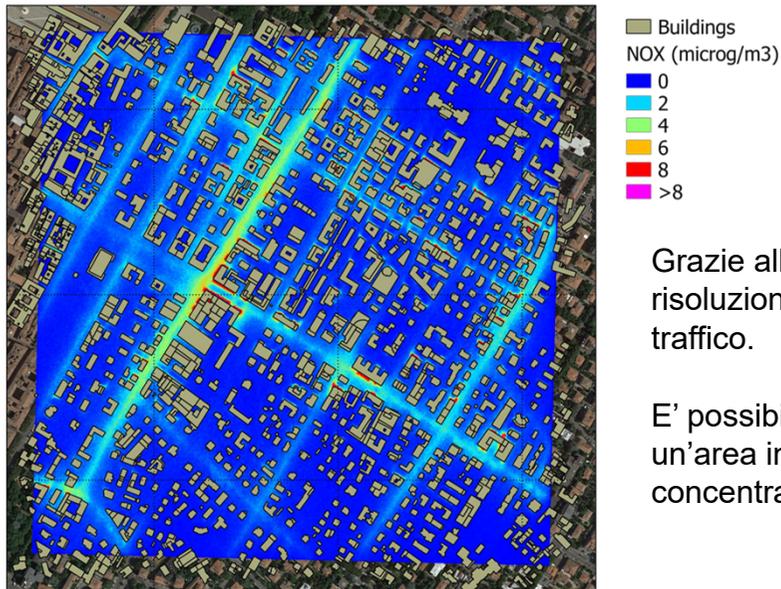
Grande dettaglio delle sorgenti

Possibilità di trattare condizioni di vento debole, particolarmente critiche per la dispersione

No interazione chimica con atmosfera pulita e con altre emissioni = solo contributi primari

# Il contributo delle emissioni da traffico: SA modellistico

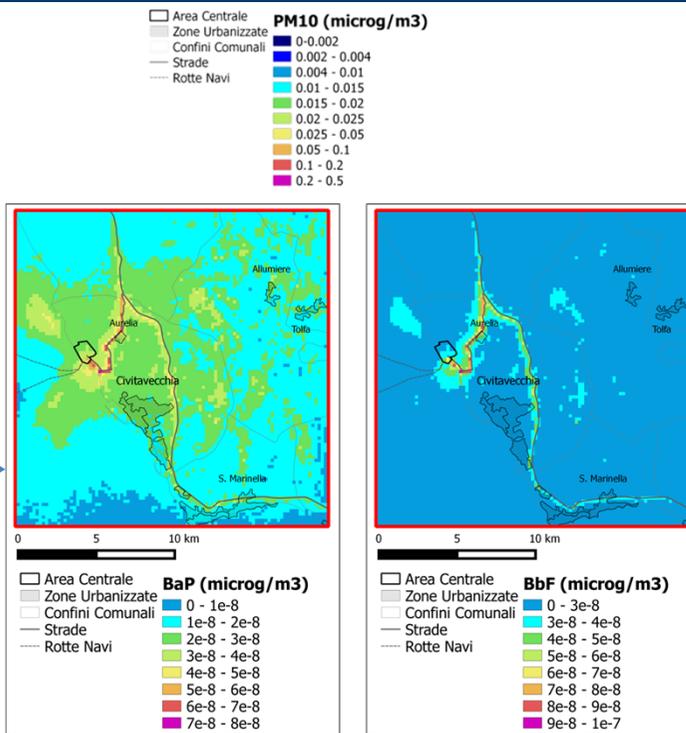
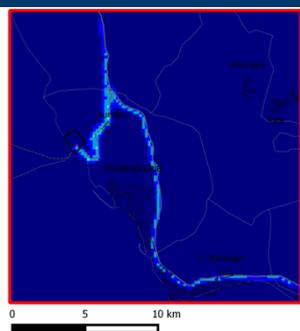
Daily average NOx concentration 12-05-2017



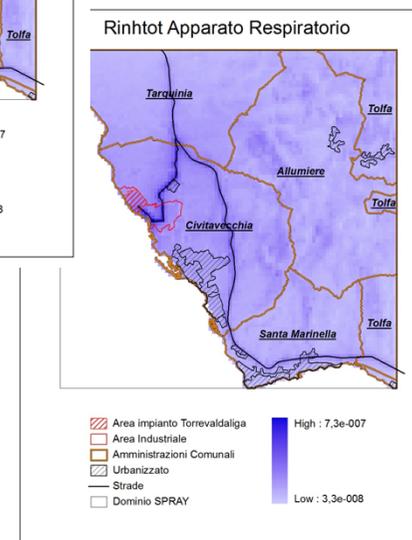
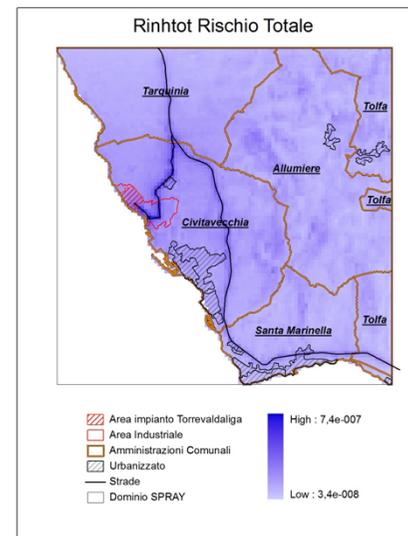
Grazie alla simulazione a microscala è possibile definire con maggiore risoluzione (pochi metri) le zone maggiormente influenzate dalla sorgente traffico.

E' possibile quindi identificare in base alle caratteristiche topografiche di un'area in esame se sono presenti aree particolarmente soggette ad elevate concentrazioni di inquinanti aerodispersi associati alla sorgente di interesse.

# Il contributo delle emissioni da traffico: SA e impatti



Identificazione di specifiche specie chimiche



Stima del rischio da esposizione

# Nuove applicazioni per lo studio degli effetti attesi/evitabili

I modelli *In vitro* possono essere usati in sostituzione dei modelli *in vivo* e permettono di indagare gli effetti di particelle e/o gas a livello di tessuti bersaglio

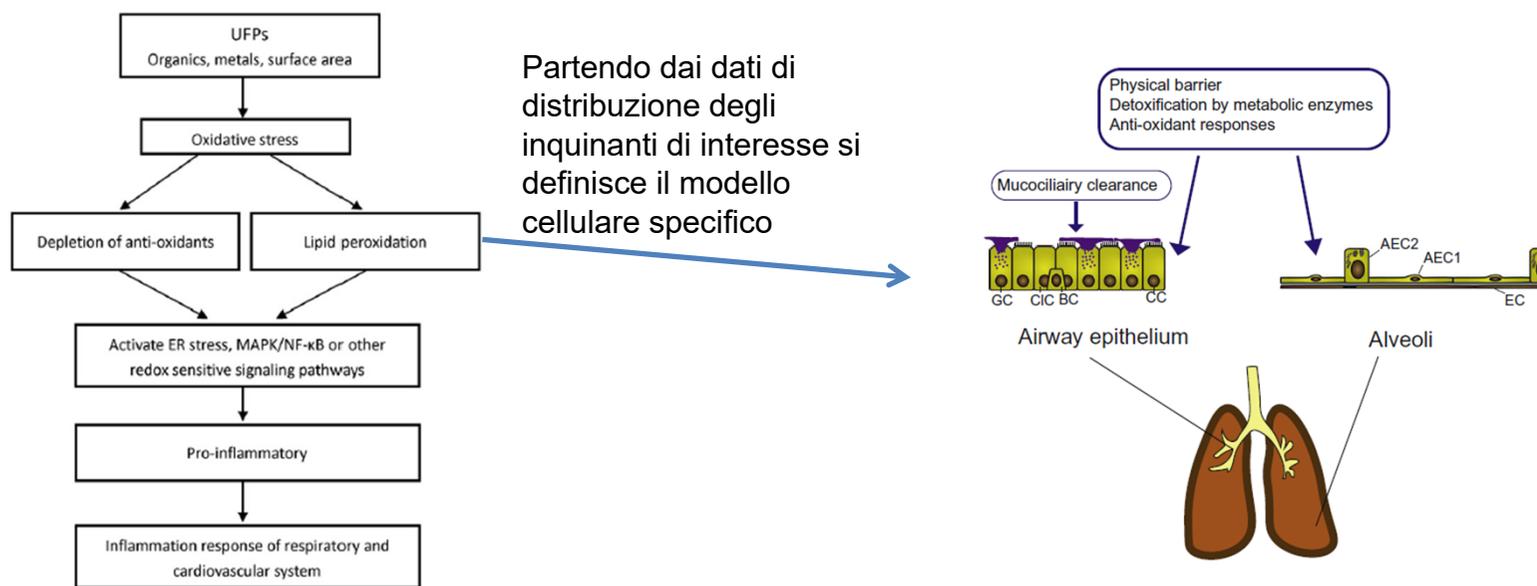


Fig. 5. The molecular mechanism of inflammation aroused from UFPs.

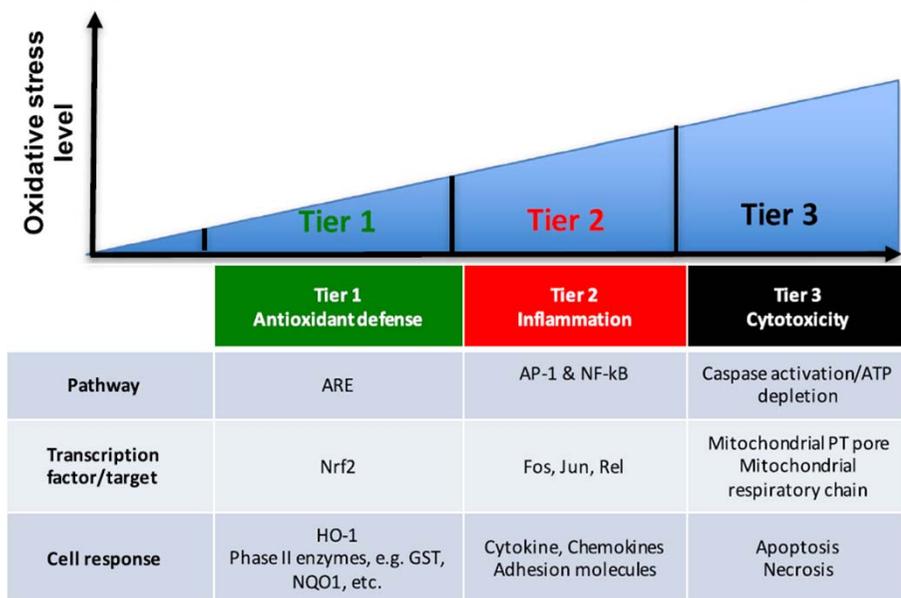
P.S. Hiemstra et al. *Toxicology in Vitro* 47 (2018) 137–146

R. Chen et al. / *Biochimica et Biophysica Acta* 1860 (2016) 2844–2855



# Nuove applicazioni per lo studio degli effetti attesi/evitabili

## Il problema della rilevanza per l'esposizione umana



Klein et al. Particle and Fibre Toxicology (2017) 14:7

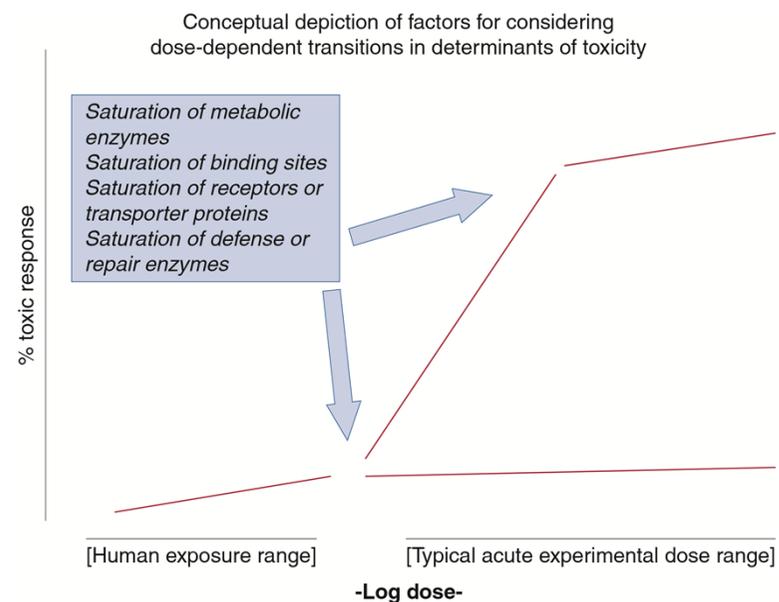
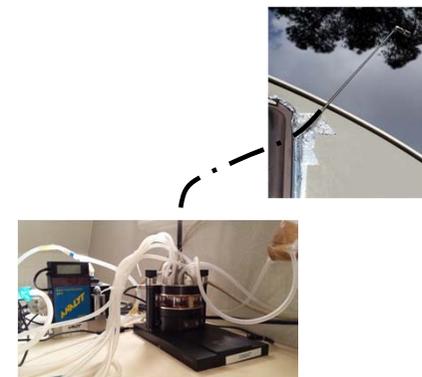


Figure 28-3. Conceptual depiction of factors for considering dose-dependent transitions in determinants of toxicity. (From: Sikker Jr., et al., 2004.)

# Nuove applicazioni per lo studio degli effetti attesi/evitabili

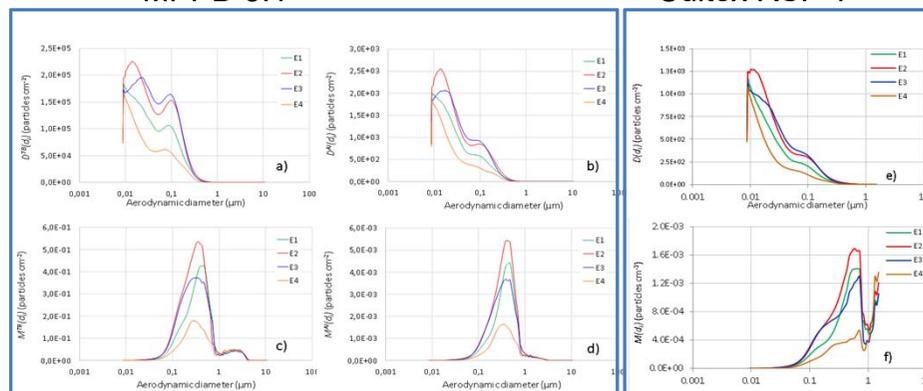


Sistemi di esposizione innovativi permettono di testare senza generare artefatti particelle aerodisperse sia in condizioni ambientali sia in laboratorio

Questi sistemi permettono di mimare la deposizione attesa a livello polmonare nell'uomo

MPPD 3.1

Cultex RSF-1

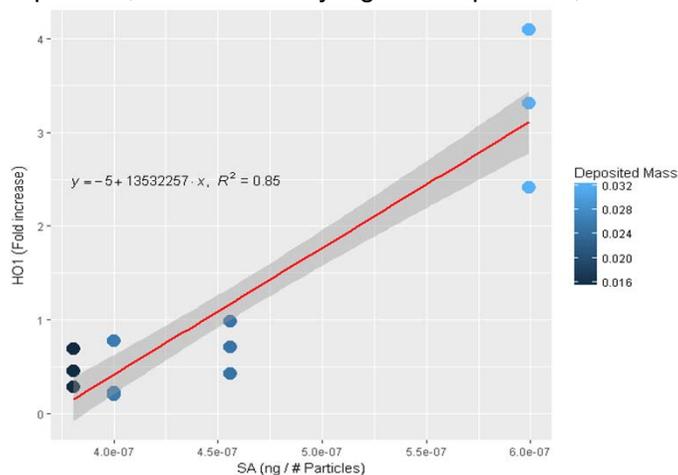


# Nuove applicazioni per lo studio degli effetti attesi/evitabili

PM Parameter	NR PM1 (µg/m³)	fNR PM1	Mass (µg/cm²)	Number (#/cm²)	Ntot (#/m³)	Dmed (nm)	BC (µg/m³)	fBC	PAHs (ng/m³)	fPAHs	OM (µg/m³)	fOM	NH <sub>4</sub> <sup>+</sup> (µg/m³)	fNH <sub>4</sub> <sup>+</sup>	NO <sub>3</sub> (µg/m³)	fNO <sub>3</sub>	Cl <sup>-</sup> (µg/m³)	fCl <sup>-</sup>
Biological response																		
IL-6 (FI)	-0.69*			-0.74**	-0.80**				-0.77**		-0.77*			0.89*		-0.69*		0.97**
NQO1 (FI)	0.79**		0.80**	0.63**	0.45**	0.94 <sup>^</sup>	0.46*	-0.62**		-0.72**	0.66*		0.98**		0.77*	0.65*	0.87**	
HO1 (FI)	0.78**		0.77**	0.64**	0.47**	0.87 <sup>^</sup>	0.48*				0.66*		0.93**		0.78*	0.68*	0.86*	
CYP1B1 (FI)		-0.96*			0.41*	-0.74 <sup>^</sup>		0.96 <sup>^</sup>	0.63**	0.88 <sup>^</sup>		0.71 <sup>^</sup>	-0.64*	-0.68*			-0.93 <sup>^</sup>	-0.56**
AhR (FI)										-0.40*								

\* = statistically significant p < 0.05, \*\* = statistically significant p < 0.01, ^ statistically significant p < 0.001

$$SA = \frac{(NO_3 + NH_4)}{N_{tot}} * 10^{-6}$$



E' possibile quindi individuare le correlazione tra risposte biologiche e parametri chimico-fisici delle particelle di interesse, individuando descrittori compositi composizione-effetto

## Conclusioni

There is a need for **better linking epidemiological, toxicological and modeling studies** to improve the tools available for risk assessment of various aerosol exposures.

Darquenne et al. Journal of Aerosol Science 99 (2016) 1–5

Too little is known about how **different components** contribute to the overall **toxicity of particulate matter**. Such information could inform policy strategies to reduce deaths [..]. Techniques for detecting highly reactive and short-lived hazardous compounds [..] could be combined with **toxicological experiments**. These might include **exposing cell cultures to ambient air..**

Lelieveld and Pöschl Nature 551 (2017) , 291-293

# Conclusioni

ENEA mediante strumenti modellistici e sperimentali è in grado di studiare a diverse scale (regionale e locale) e a diversa risoluzione temporale (orario/giornaliero...) il contributo delle diverse sorgenti che determinano una alterazione della qualità dell'aria, tra cui le emissioni derivanti dalla mobilità su strada

I modelli possono fornire indicazioni sugli effetti sulla salute attesi

Grazie a strumenti di indagine innovativi è possibile studiare gli effetti potenziali attesi da specifiche sorgenti emissive o la riduzione degli effetti a seguito dell'introduzione di nuove tecnologie. Questi sistemi sperimentali possono essere applicati a ricerche in campo e/o in laboratorio permettendo una maggiore versatilità rispetto ai "classici" sistemi cellulari.

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Italian National Agency for New Technologies,  
Energy and Sustainable Economic Development

EXPERT PANEL FOR POLLUTING  
EMISSIONS REDUCTION - EXPAPER

# Studi di impatto sulla salute delle emissioni da trasporto

*CNR Istituto Motori Napoli, 22 Maggio 2018*



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