Health effects of airborne particles

Ioar Rivas

RI-URBANS (101036245)
1st Science Meeting, 19th October 2022

Donora 1948 & London 1952

Donora (USA), 27th – 31st October 1948

14,000 inhabitants:

20 deaths + 6,000 with respiratory problems

Steel industry

→ First federal clean air laws in the 1950s and 1960s

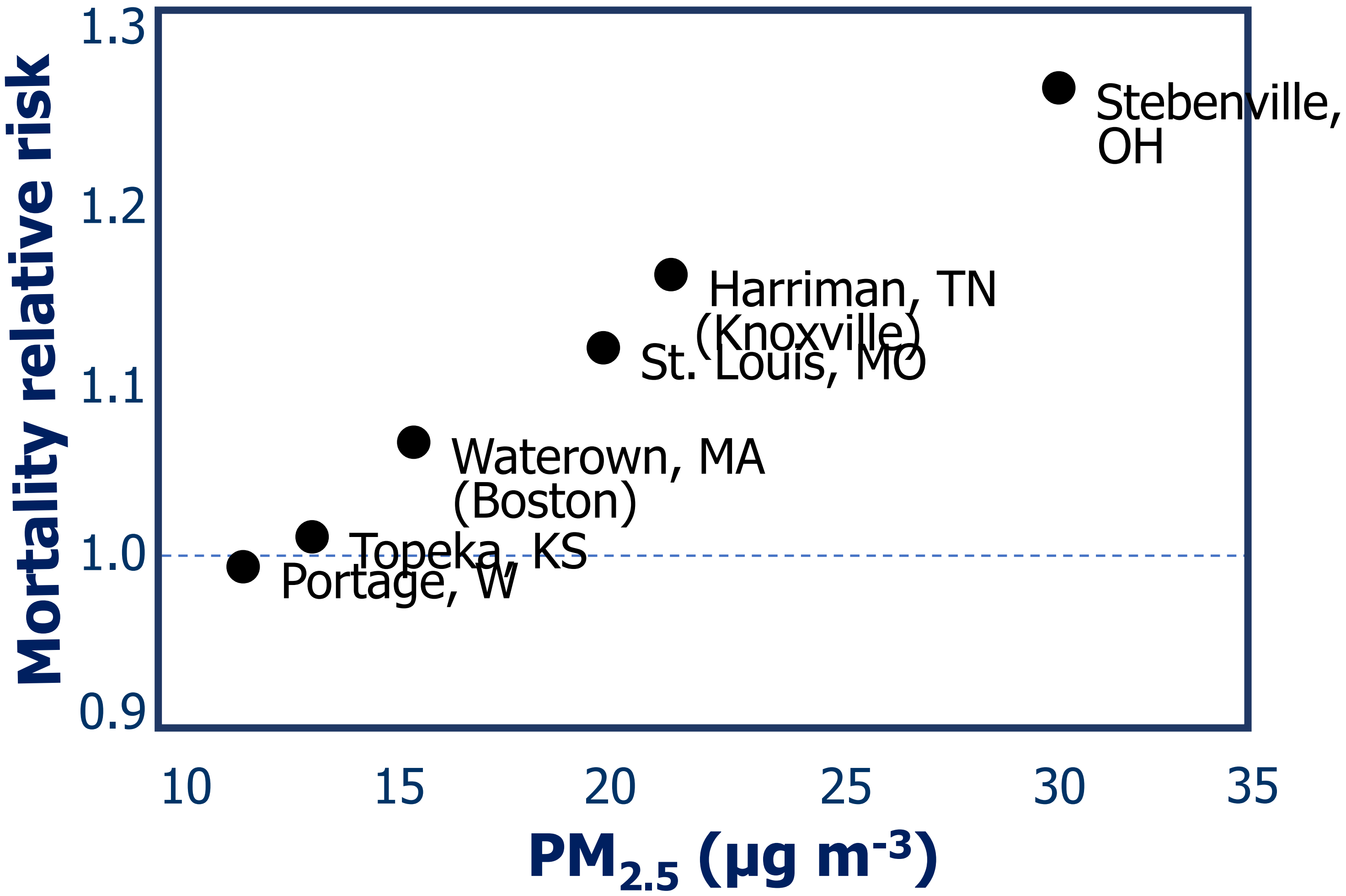
London (UK), 5th – 9th December 1952

Greater London: about 8 millions inhabitants
4,000 died [probably 10 to 12,000 deaths]
100,000 with respiratory problems

Very cold days, intensive use of coal for heating

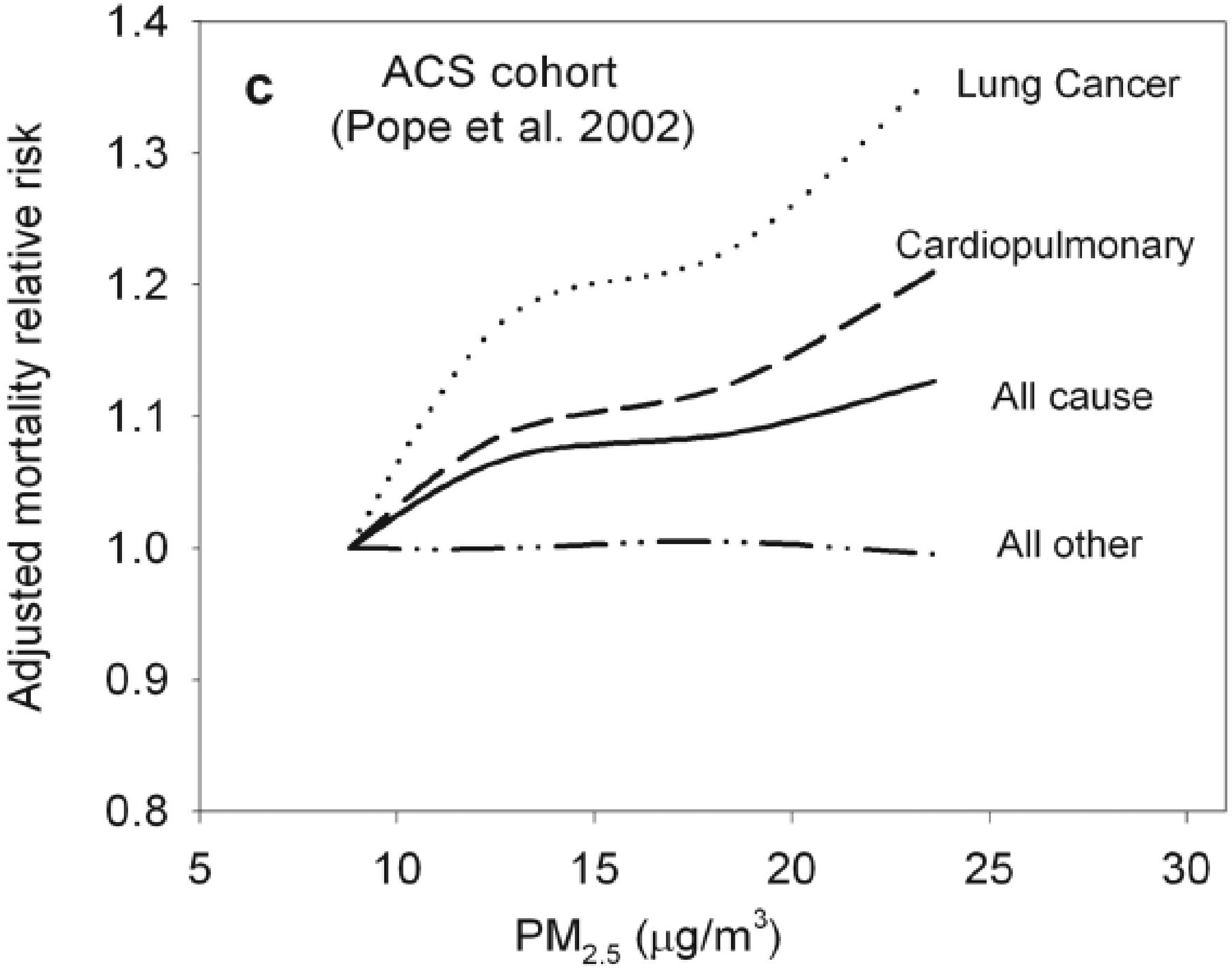
→ Clean air act 1956

The Hardvard six cities study: $PM_{2.5}$ and mortality



Dockery et al.(1993). An association between air pollution and mortality in six U.S. cities. N. Engl. J. Med. 329, 1753 – 1759.

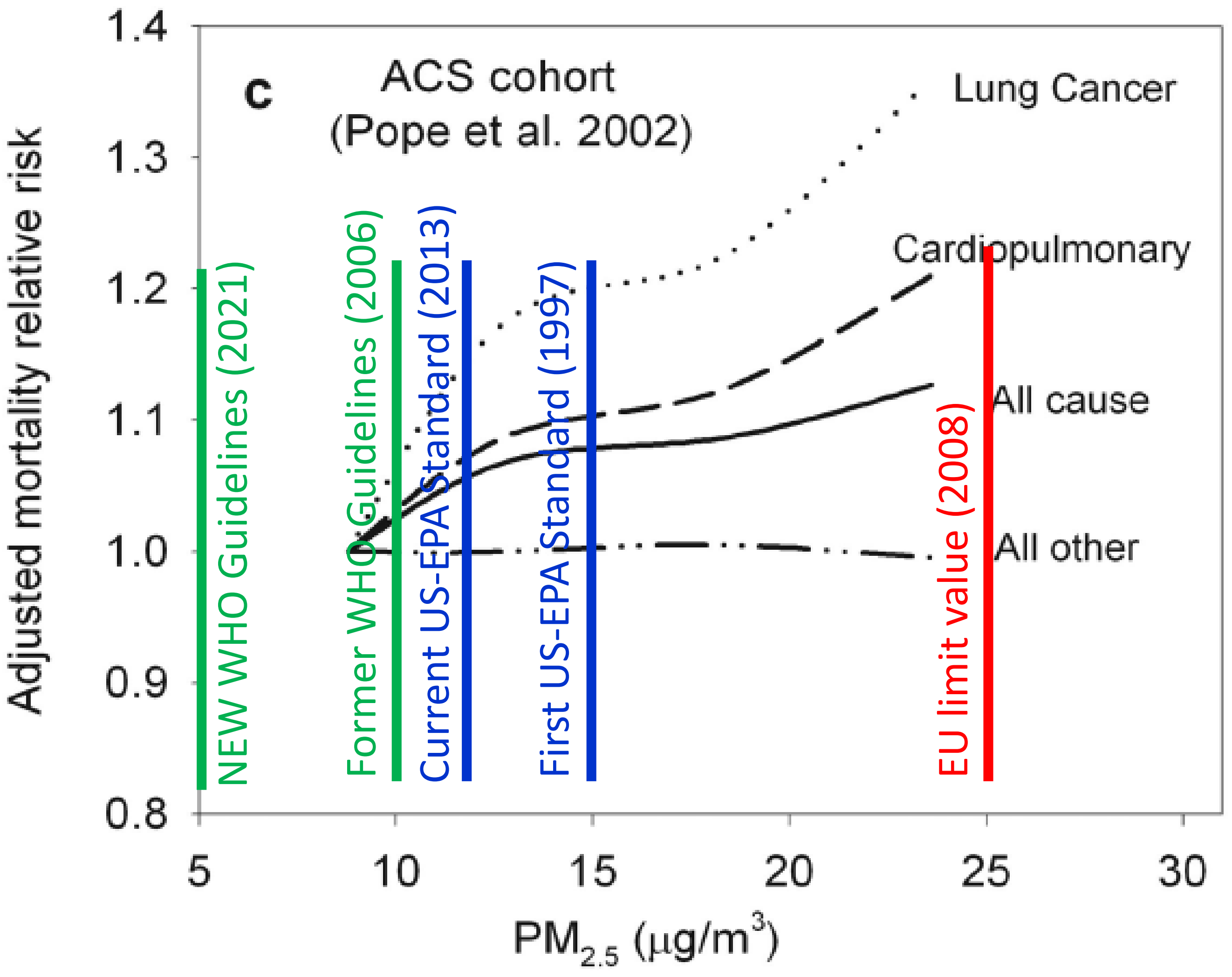
ACS study: Confirmation of previous findings



Pope et al. (2002). Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. J.Am.Med.Assoc. 287, 1132-1141.

ACS study: Confirmation of previous findings

Standards and guidelines refer to annual averages



European Commission
HORIZON 2020
RI-URBANS

Pope et al. (2002). Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. J.Am.Med.Assoc. 287, 1132-1141.

Global Burden of Disease

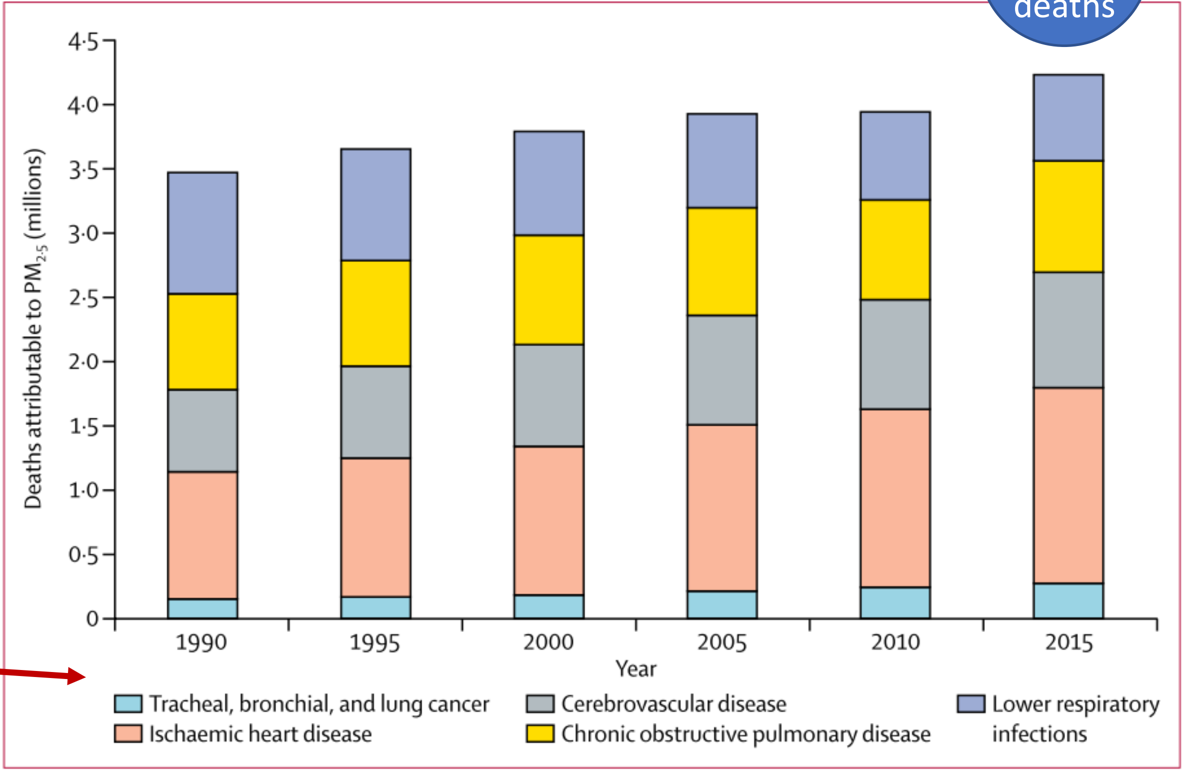
Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015

Aaron J Cohen*, Michael Brauer*, Richard Burnett, H Ross Anderson, Joseph Frostad, Kara Estep, Kalpana Balakrishnan, Bert Brunekreef, Lalit Dandona, Rakhi Dandona, Valery Feigin, Greg Freedman, Bryan Hubbell, Amelia Jobling, Haidong Kan, Luke Knibbs, Yang Liu, Randall Martin, Lidia Morawska, C Arden Pope III, Hwashin Shin, Kurt Straif, Gavin Shaddick, Matthew Thomas, Rita van Dingenen, Aaron van Donkelaar, Theo Vos, Christopher J L Murray, Mohammad H Forouzanfar†

The Lancet (2017)

$PM_{2.5}$

4.2 millions deaths



Only accounting for those diseases for which the evidence is very well established

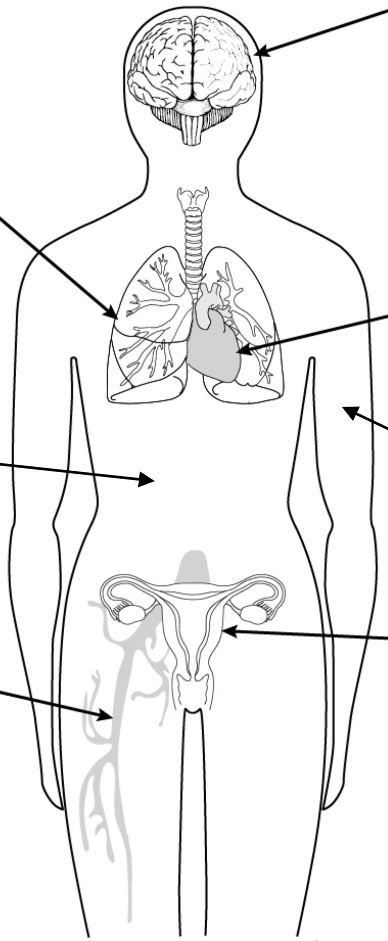
Figure 4: **Deaths attributable to ambient particulate matter pollution by year and cause**
$PM_{2.5}$=particle mass with aerodynamic diameter less than 2·5 μm.

Long list of health effects of air pollution

- **Respiratory Disease Mortality**
- **Respiratory Disease Morbidity**
- **Lung Cancer**
- **Pneumonia**
- Upper and lower respiratory symptoms
- Airway inflammation
- Decreased lung function
- Decreased lung growth

- Insulin Resistance
- **Type 2 diabetes**
- **Type 1 diabetes**
- Bone metabolism
- Obesity

- **High blood pressure**
- Endothelial dysfunction
- Increased blood coagulation
- Systemic inflammation
- **Deep Venous Thrombosis**



- **Stroke**
- Neurological development
- Mental Health
- **Neurodegenerative diseases**

- **Cardiovascular Disease Mortality**
- **Cardiovascular Disease Morbidity**
- **Myocardial Infarction**
- **Arrhythmia**
- **Congestive Heart Failure**
- Changes in Heart Rate Variability
- ST-Segment Depression

- Skin Aging

- **Premature Birth**
- **Decreased Birth Weight**
- Decreased foetal growth
- In uterine growth retardation
- Decreased sperm quality
- Pre-eclampsia
- Epigenetic changes

Bold type indicates conditions currently included in the Global Burden of Disease categories

Adapted from Thurston et al. (2017). A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. Eur Respir J. 49, 1600419.

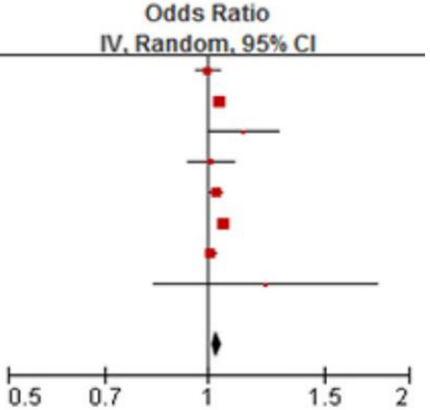
PM2.5 & birth outcomes

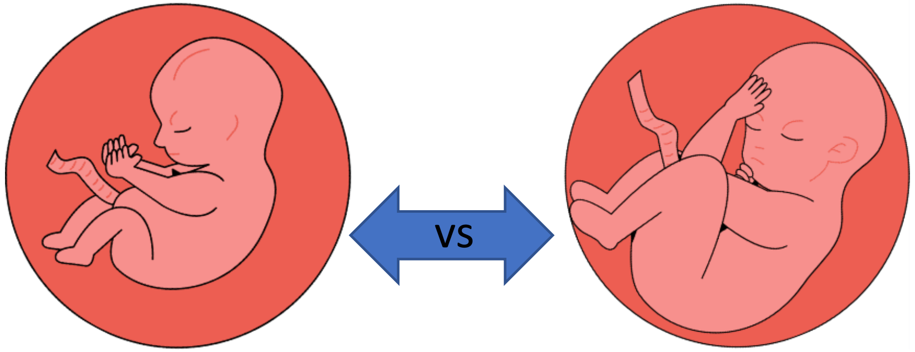
$PM_{2.5}$ (IQR increase) and preterm birth

C

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Random, 95% CI
Ayaz Hyder S2 2014	0	0.0208	10.2%	1.00 [0.96, 1.04]
Eric Lavigne 2016	0.0392	0.0079	21.9%	1.04 [1.02, 1.06]
Gavin Pereira 2013	0.1222	0.0624	1.7%	1.13 [1.00, 1.28]
Gavin Pereira 2014	0.01	0.0421	3.5%	1.01 [0.93, 1.10]
Jun Wu 2009	0.0296	0.01	19.6%	1.03 [1.01, 1.05]
Sandie Ha 2014	0.0516	0.0063	23.6%	1.05 [1.04, 1.07]
Simone C Gray 2014	0.01	0.0102	19.4%	1.01 [0.99, 1.03]
Ulrike Gehring 2011	0.1989	0.1965	0.2%	1.22 [0.83, 1.79]
Total (95% CI)			**100.0%**	**1.03 [1.01, 1.05]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 19.12$, df = 7 (P = 0.008); $I^2 = 63\%$
Test for overall effect: Z = 3.73 (P = 0.0002)





< 37 weeks of gestation

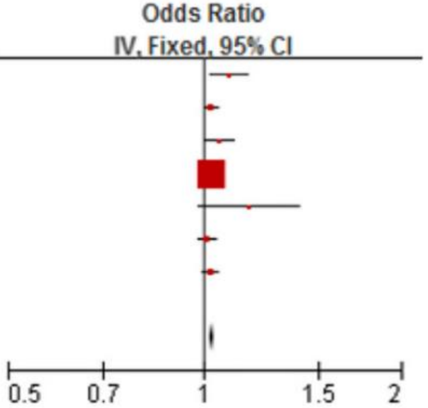
≥ 37 weeks of gestation

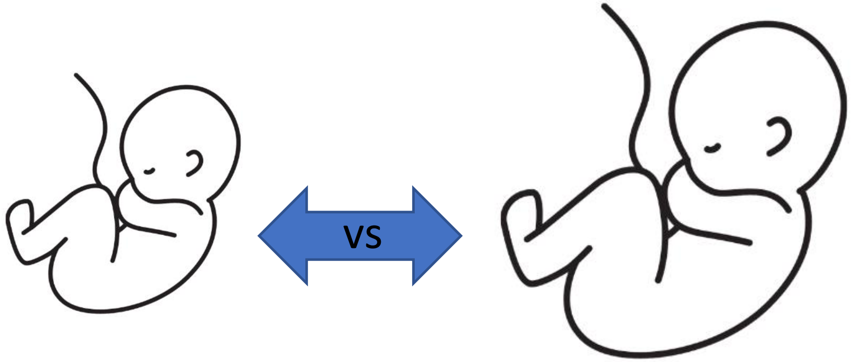
$PM_{2.5}$ (IQR increase) and term low birth weight

A

Study or Subgroup	log[Odds Ratio]	SE	Weight	Odds Ratio IV, Fixed, 95% CI
Ayaz Hyder S2 2014	0.0862	0.0339	1.1%	1.09 [1.02, 1.16]
Keita Ebisu 2012	0.0218	0.0121	8.5%	1.02 [1.00, 1.05]
Michelle L. Bell 2007	0.0526	0.0258	1.9%	1.05 [1.00, 1.11]
Olivier Laurent UCD 2014	0.0247	0.004	77.8%	1.03 [1.02, 1.03]
Payam Dadvand 2014	0.157	0.0904	0.2%	1.17 [0.98, 1.40]
Rupa Basu 2014	0.01	0.0154	5.2%	1.01 [0.98, 1.04]
Simone C Gray 2014	0.0198	0.0152	5.4%	1.02 [0.99, 1.05]
Total (95% CI)			**100.0%**	**1.03 [1.02, 1.03]**

Heterogeneity: $Chi^2 = 7.67$, df = 6 (P = 0.26); $I^2 = 22\%$
Test for overall effect: Z = 7.03 (P < 0.00001)





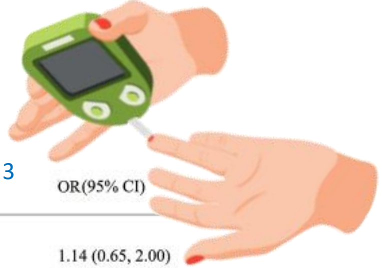
< 2.5 kg

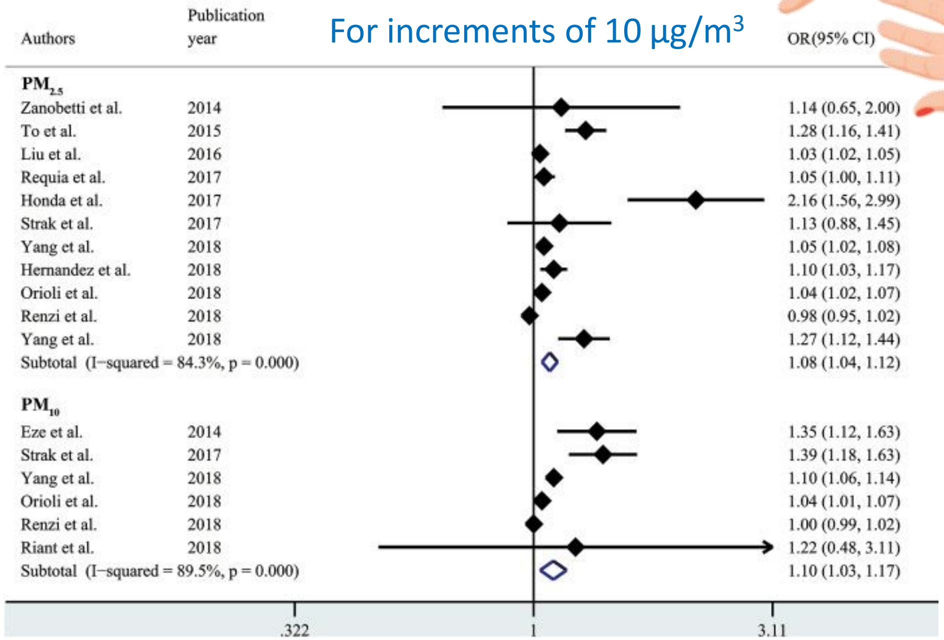
≥ 2.5 kg

Li et al. (2017). Association between ambient fine particulate matter and preterm birth or term low birth weight: An updated systematic review and meta-analysis. Environ. Pollut. 227, 596–605.

PM2.5 & diabetes and obesity

Type 2 Diabetes Prevalence

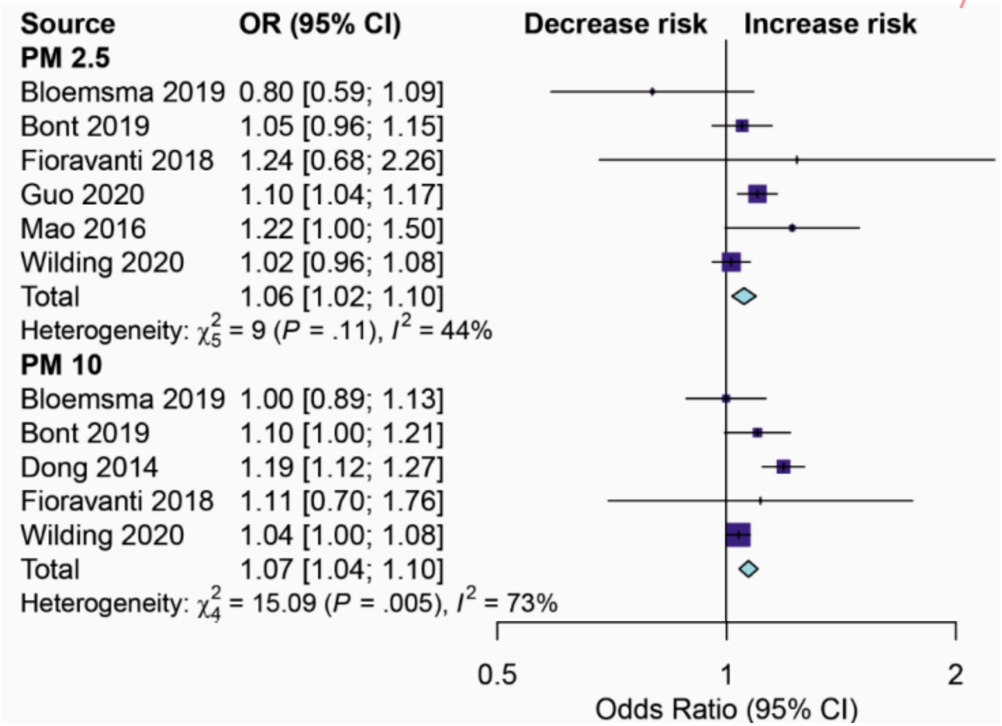




Yang et al. (2020). Ambient air pollution and diabetes: A systematic review and meta-analysis. Environmental Research, 180(June 2019), 108817.

Obesity

In children



Parasin, N., Amnuaylojaroen, T., & Saokaew, S. (2021). Effect of air pollution on obesity in children: A systematic review and meta-analysis. Children, 8(5), 1–16.

Pope et al. (2002). Lung cancer, cardiopulmonary mortality and long-term exposure to fine particulate air pollution. J.Am.Med.Assoc. 287, 1132-1141.

Air pollution & brain development and diseases

Alzheimer

Environment International
Volume 157, December 2021, 106864

Associations between air pollution and biomarkers of Alzheimer's disease in cognitively unimpaired individuals

Silvia Alemany[a, b, c, 1], Marta Crous-Bou[d, e, f, 1], Natalia Vilor-Tejedor[b, d, g, h], Marta Milà-Alomà[b, d, i, j], Marc Suárez-Calvet[d, i, j, k], Gemma Salvadó[d, i], Marta Cirach[a, b, c], Eider M. Arenaza-Urquijo[d, i, j], Gonzalo Sanchez-Benavides[d, i, j], Oriol Grau-Rivera[d, i, j, k], Carolina Minguillon[d, i, j], Karine Fauria[d, i, j], Gwendlyn Kollmorgen[l], Juan Domingo Gispert[b, d, i, m], Mireia Gascón[a, b, c], Mark Nieuwenhuijsen[a, b, c], Henrik Zetterberg[n, o, p, q], Kaj Blennow[n, o] ... José Luis Molinuevo[d]

Parkinson

International Journal of Hygiene and Environmental Health
Volume 222, Issue 3, April 2019, Pages 402-409

Air pollution and Parkinson's disease: A systematic review and meta-analysis up to 2018

Maria-Iosifina Kasdagli[a], Klea Katsouyanni[a, b], Konstantina Dimakopoulou[a], Evangelia Samoli[a]

Mental health

(depression, anxiety, suicide)

Behavioural problems

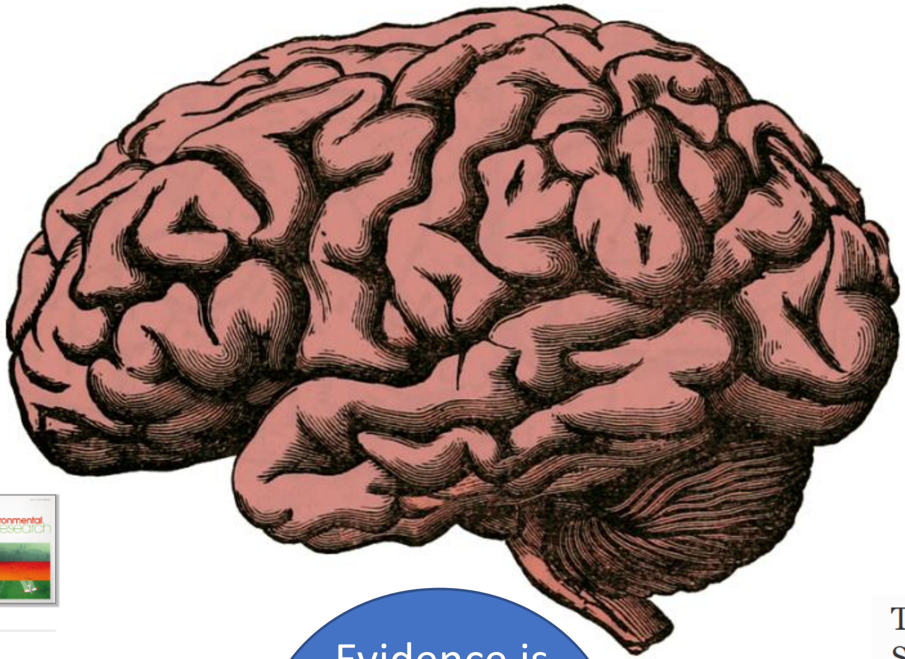
(emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems, and prosocial behavior)

Environment International
Volume 118, September 2018, Pages 154-168

Review article

Is there a link between air pollution and mental disorders?

Massimiliano Buoli[a], Silvia Grassi[a], Alice Caldiroli[a], Greta Silvia Carnevali[a], Francesco Mucci[a], Simona Iodice[b], Laura Cantone[b], Laura Pergoli[b], Valentina Bollati[b]



Cognition

BREATHE Brain Air School investigation

Barcelona Life Study Cohort BiSC

Environmental Research
Volume 147, May 2016, Pages 383-398

Review article

Exposure to air pollution and cognitive functioning across the life course – A systematic literature review

Angela Clifford[a], Linda Lang[a, b], Ruoling Chen[a, b], Kaarin J. Anstey[c], Anthony Seaton[d]

Evidence is still **weak** for many outcomes

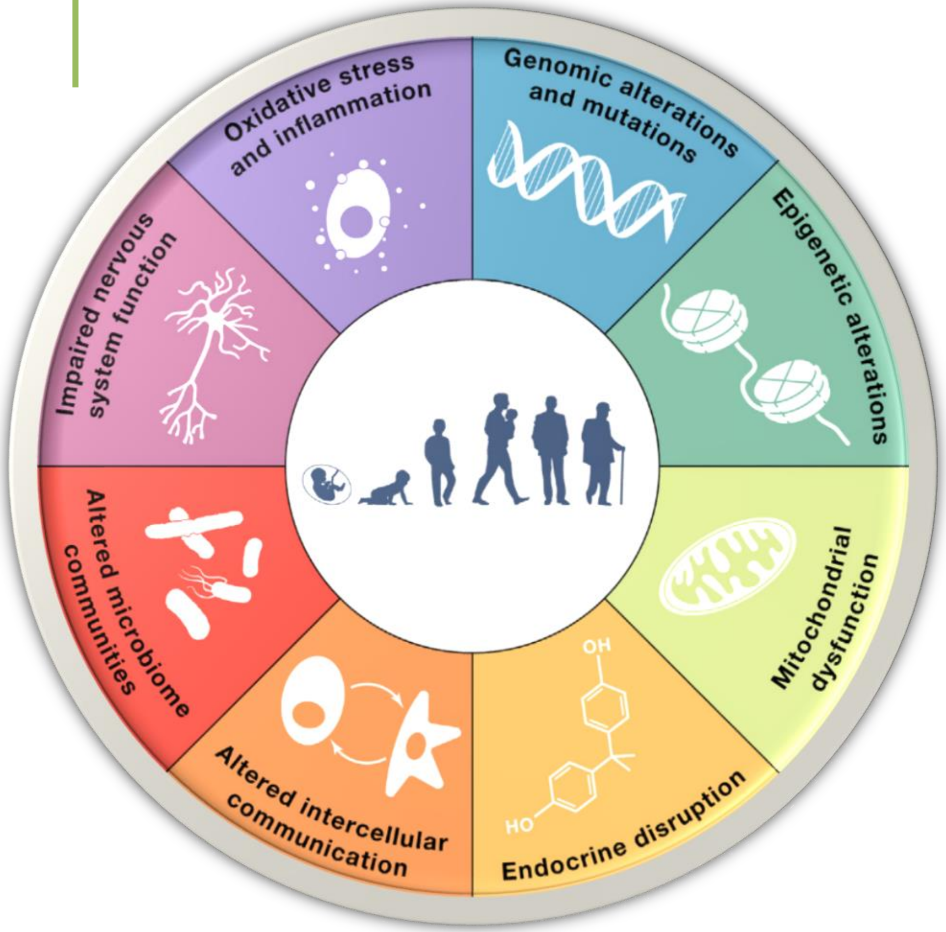
Changes in brain structures/function

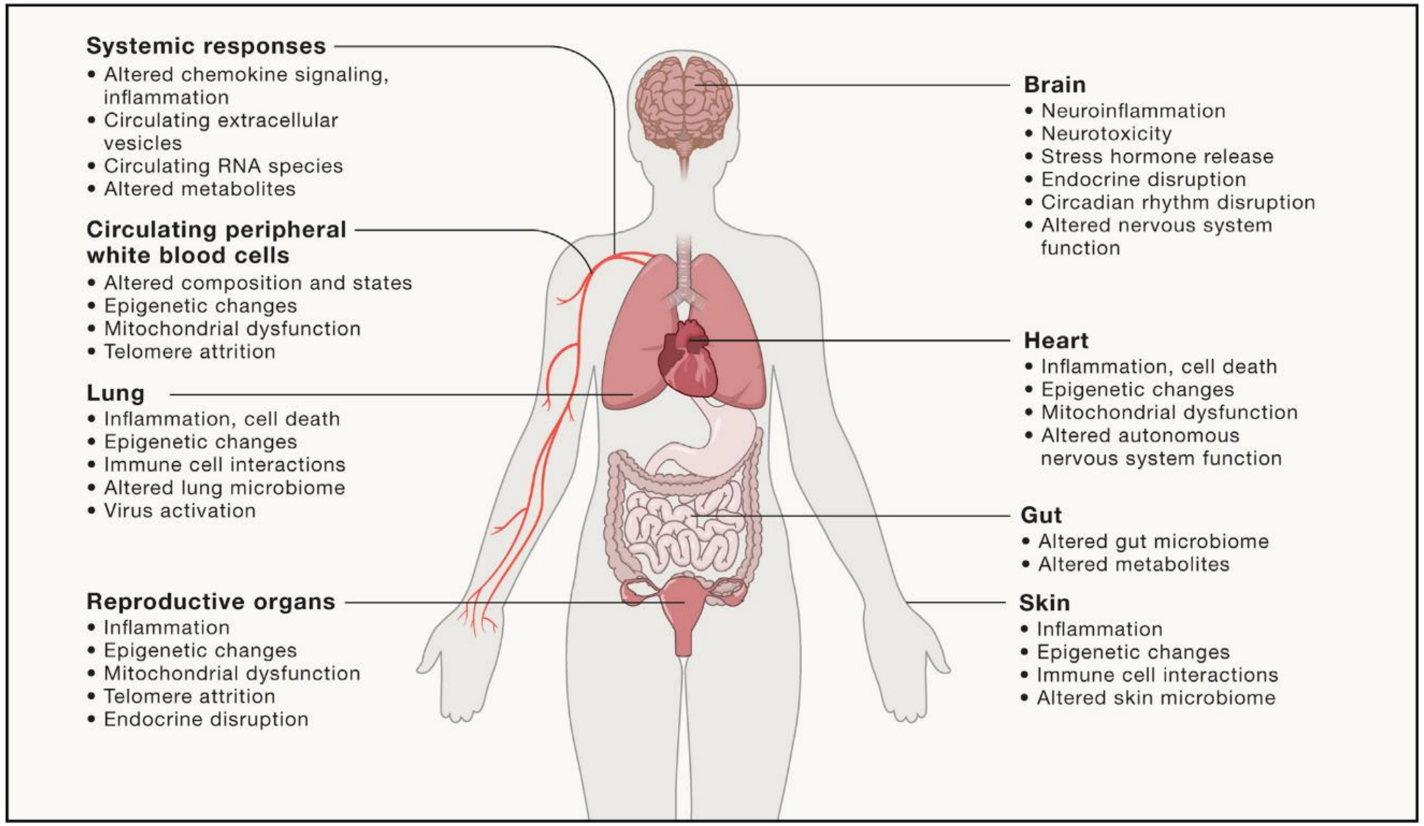
The Effects of Air Pollution on the Brain: a Review of Studies Interfacing Environmental Epidemiology and Neuroimaging

Paula de Prado Bert, Elisabet Mae Henderson Mercader, Jesus Pujol, Jordi Sunyer & Marion Mortamais

Current Environmental Health Reports 5, 351–364 (2018) | Cite this article

What are the mechanisms





Peters and Nawrot.(2021). Hallmarks of environmental insults. Cell, 184, 1455-1468.

Health effects of UFP

- Inconsistent or insufficient evidence for a causal association between UFP and all-cause, cardiovascular and respiratory mortality for both short-term effects (acute exposure) and long-term effects (chronic exposure).

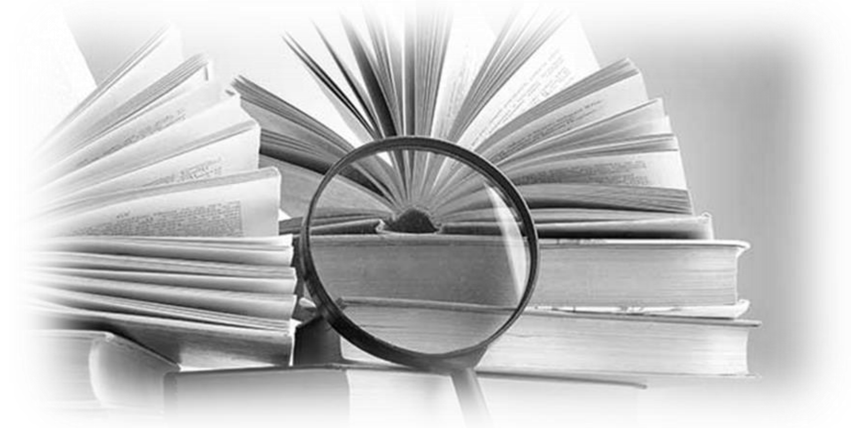
2021

UFP: no guidelines for UPF, but good practice statements based on current evidence

Health effects of UFP

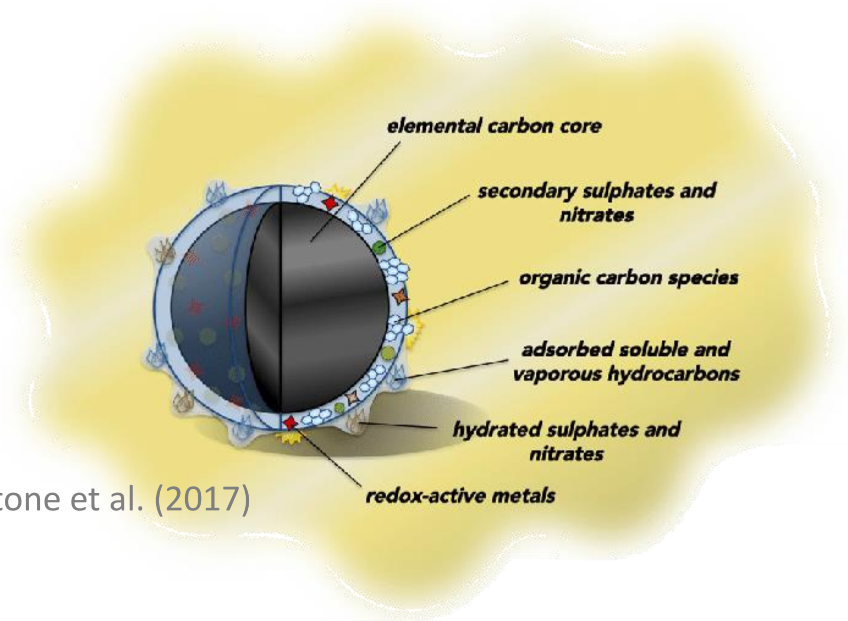
- **Limited and inconsistent evidence** of associations between UFP and mortality:
  - Few studies reported null or not significant results except for specific lags and/or causes.
    - Lag0, 1 or 01 in Rome (Forastiere et al., 2005), Helsinki (Kettunen et al., 2007), London (Atkinson et al., 2010)
  - Weak and inconsistent results for **multicity studies** (Lanzinger et al., 2016; Stafoggia et al., 2017)
  - Adverse health effects may increase with **decreasing particle size** (Meng et al., 2013)
- Health effects of **specific UFP sources** have not been explored.
  - Primary UFP associated with mortality in Barcelona while associateions were observed for secondary UFP in the industrial city of Huelva (Tobías et al., 2018).

The **evidence is still inadequate**, given the lack of long time series of UFP Number Concentrations (PNC) and Particle Number Size Distributions (PNSD).



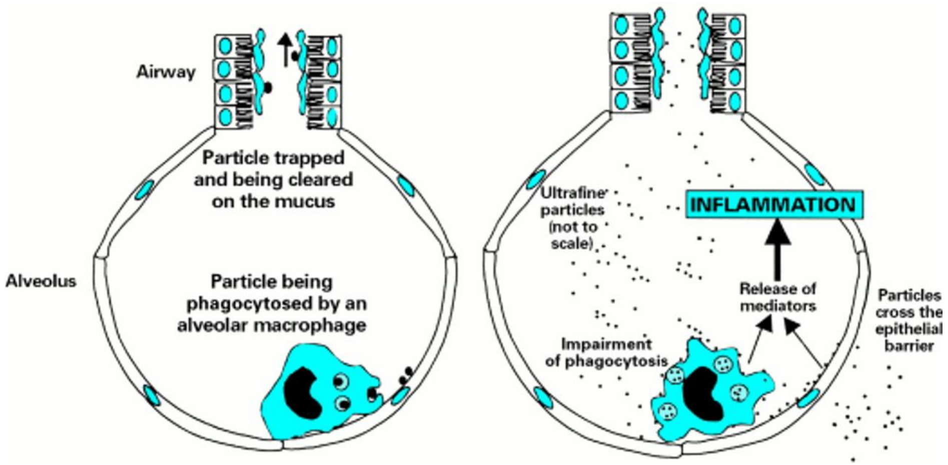
UFP show higher toxicity than other PM fractions

- **Large Surface-area/mass →** UFP carry large amounts of adsobed material per unit mass



Stone et al. (2017)

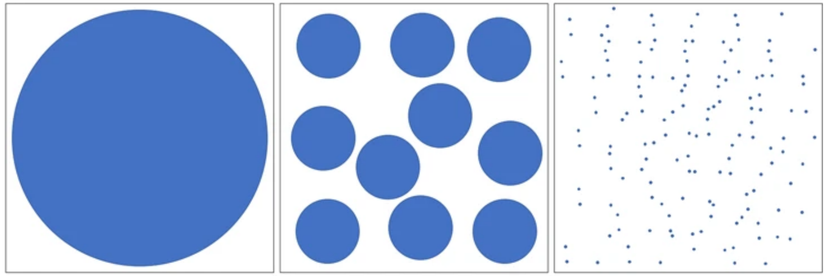
- **Small size →**
  - Lower particle clearance than PM by mucus and macrophages phagocytosis → oxidative stress & inflammation
  - reaches circulatory system and organs



Donaldson et al. (2001)

Peculiarities of UFP

- Number vs mass
- Particle dynamics
- Spatial distribution
- Sources

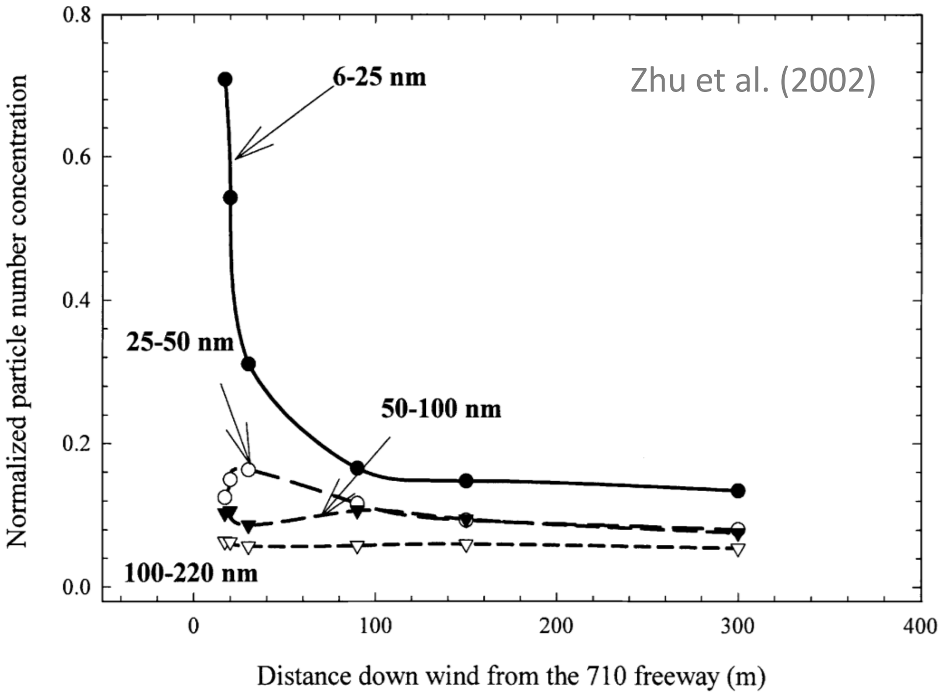


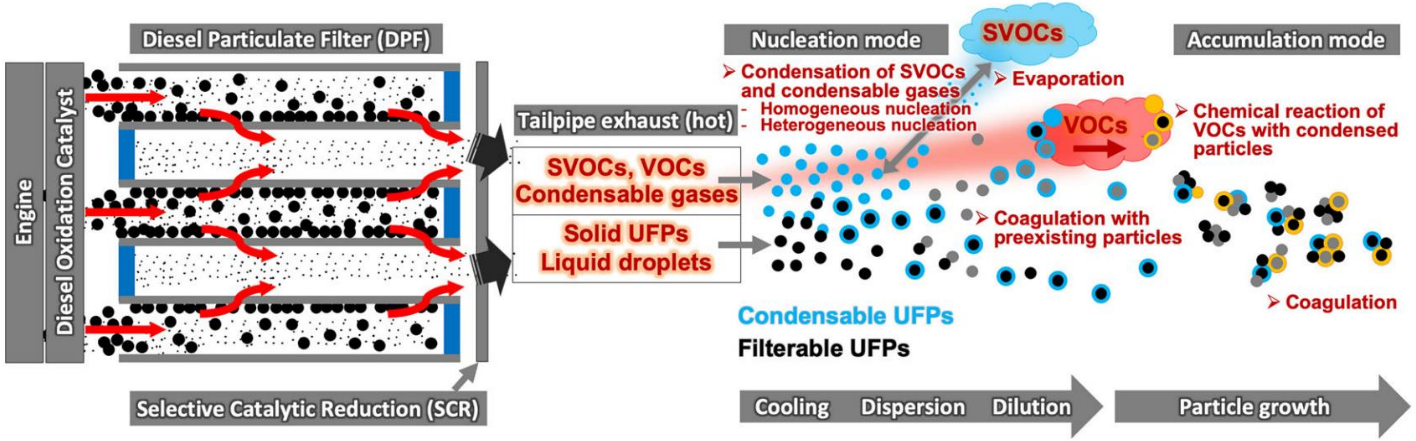
	10 μm (Coarse)	2.5 μm (Fine)	0.1 μm (Ultrafine)
Total mass	1	1	1
Particle number	1	64	1,000,000
Surface area per particle	1	0.0625	0.0001
Total surface area per mass	1	4	100
	• Filtered in proximal airway • May irritate skin, mucosa	• Reaches peripheral airway • Cannot enter systemic circulation	• Higher adsorbed toxic material on surface • May enter systemic circulation

Kwon et al. (2020)

Peculiarities of UFP

- Number vs mass
- Particle dynamics
- Spatial distribution
- Sources





Kwon et al. (2020)

Exposure missclassification

- Traditional methods of air pollution exposure assessment for UFP are not optimal for UFP due to high spatial and temporal variability → **Bias towards the null**

WHO AQG 2021:

Box 4.2. Good practice statement – UFP

The GDG decided to formulate the following four good practice statements on UFP to guide national and regional authorities and research towards measures to reduce ambient ultrafine particle concentrations.

1. Quantify ambient UFP in terms of particle number concentration (PNC) for a size range with a lower limit of ≤ 10 nm and no restriction on the upper limit.
2. Expand the common air quality monitoring strategy by integration of UFP monitoring into existing air quality monitoring. Include size-segregated real-time PNC measurements at selected air monitoring stations in addition to, and simultaneously with, other airborne pollutants and characteristics of PM.
3. Distinguish between low and high PNC to guide decisions on the priorities of UFP source emission control. Low PNC can be considered < 1000 particles/cm3 (24-hour mean). High PNC can be considered > 10 000 particles/cm3 (24-hour mean) or 20 000 particles/cm3 (1-hour).
4. Utilize emerging science and technology to advance approaches to the assessment of exposure to UFP for application in epidemiological studies and UFP management.

Time series analysis in 4 European cities

- Quantification of the **sources contributing to ultrafine particle** number size distributions (PNSD)

- Associations between the exposure to the **different sources of PNSD** and **mortality** and hospital admissions

in:
- London
- Barcelona
- Zurich
- Helsinki

Health[1]UP$_2$: This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 747882

Rivas et al. (2021)

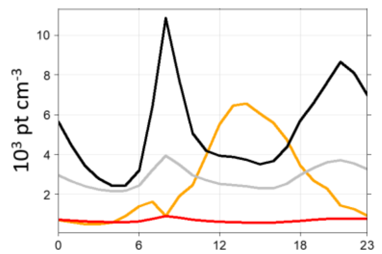
Source contributions

Summary statistics of daily averages of total PNC and the different sources contributing to UFP by city.

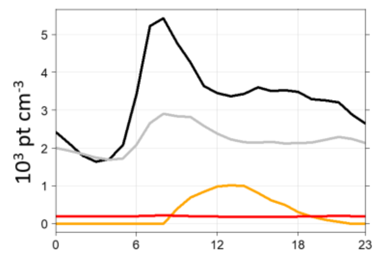
Increasing particle size

UFP source (pt cm^{-3})	BARCELONA (2013-2016)		HELSINKI (2007-2016)		LONDON (2010-2014)		ZURICH (2011-2014)	
	Mean (SD)	IQR	Mean (SD)	IQR	Mean (SD)	IQR	Mean (SD)	IQR
Total PNC	11371 (4049)	5601	7006 (3689)	4012	5562 (2409)	2921	9491 (4054)	4735
Photonucl	2601 (2176)	2875	315 (435)	350	211 (292)	263	283 (306)	321
Fresh traffic	5213 (2938)	3582	3264 (2378)	2742	3465 (1340)	1818	6530 (3054)	3449
Urban	2835 (1414)	1744	2222 (1569)	1706	1719 (1321)	1429	2426 (1376)	1739
Secondary	675 (481)	581	197 (186)	183	166 (174)	170	316 (241)	4735

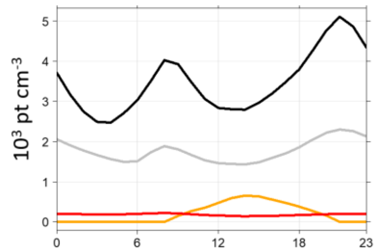
BCN 2013 – 2016 -- 4 sources --



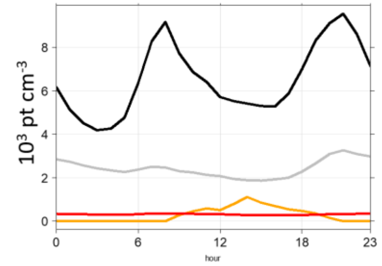
HSK 2007 – 2016 -- 5 sources --



LND 2010 – 2016 -- 4 sources --

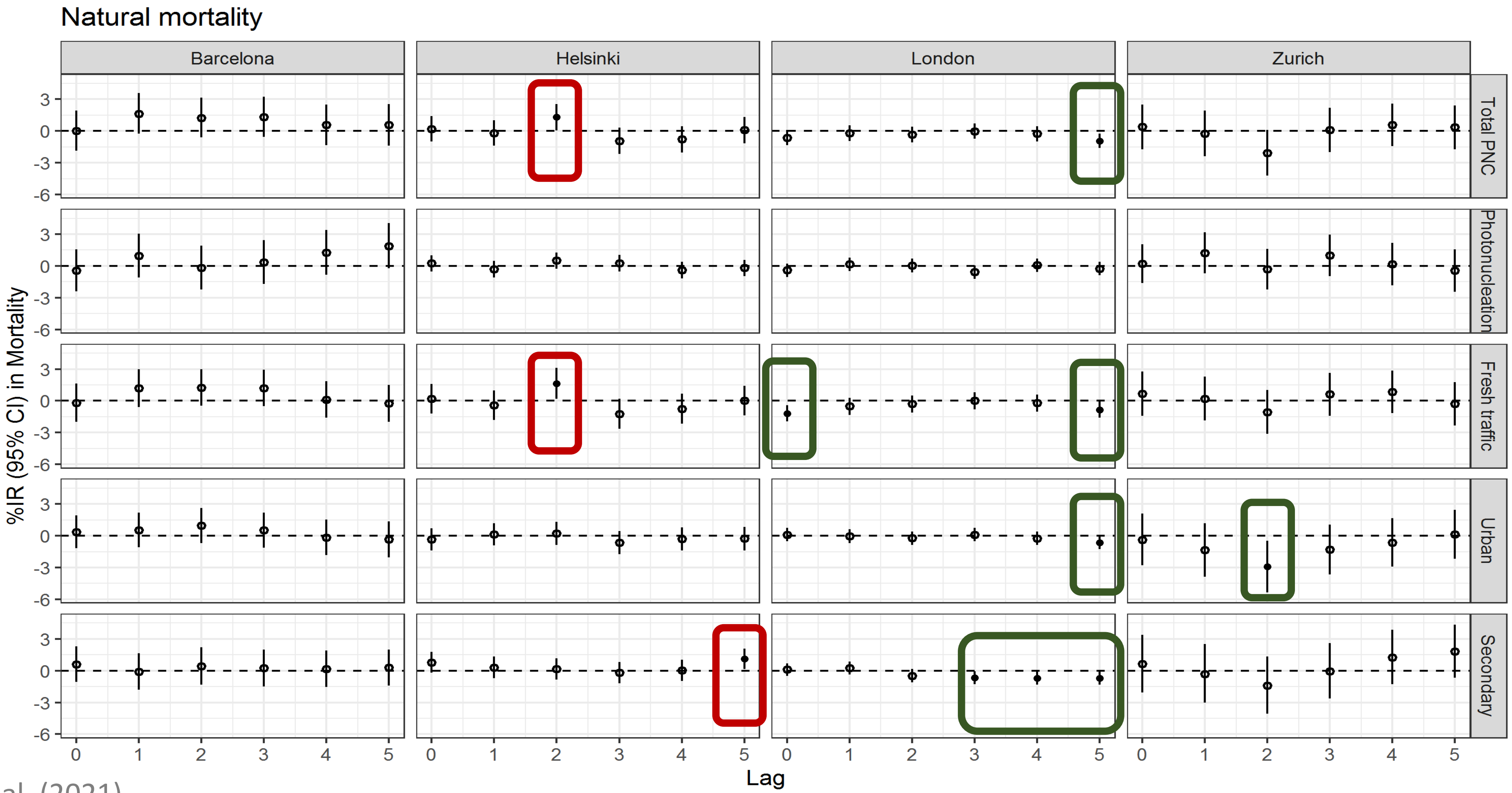


ZRC 2011 – 2014 -- 4 sources --



Rivas et al. (2021)

Associations with natural mortality



GLM with quasi-Poisson regression adjusted for:

- seasonality
- temperature (cold and hot)
- relative humidity,
- bank holiday
- day of the week

Rivas et al. (2021)

Summary table

Increased risk
Reduced risk

Associations between:

	BARCELONA	HELSINKI	LONDON	ZURICH
NATURAL [PNC → ≈1.3% IR mortality per IQR increase]		Total PNC (L2) Fresh Traff (L2) Seconary (L5)	Total PNC (L5) F. Traff (L0, L5) Urban (L5) Secondary (L3-L5)	Urban (L2)
CARDIOVASCULAR [PNC → ≈3.8% IR mortality per IQR incease]	Total PNC (L1)	Photonucl (L1) Secondary (L3)	Total PNC (L3) Fresh Traff (L3) Secondary (L5)	Total PNC (L0) Fresh Traff (L0)
RESPIRATORY [PNC → ≈ 2.4 – 9.4% IR mortality per IQR increase]	Total PNC (L5) Photonucl (L2)	Secondary (L5)	Total PNC (L3) Fresh Traff (L3)	Total PNC (L1) Fresh Traff (L1) Urban (L1, L2)

Inconsistent results across cities, sources and lags for associations.
Total PNC and fresh traffic were the exposures for which we found association more often.
Photonucleation was associated with reduced risk of mortality

Rivas et al. (2021)

Final remarks

- Evidence on the effects of **PM** on the **respiratory and cardiovascular** system is very strong.
- The number of studies exploring **other diseases** (foetal growth, metabolic, brain) are increasing and evidence of association is being built.
- **New air pollution metrics and pollutants** need to be further studied in epidemiological studies as their health effects are yet to be quantified
- **Limited evidence** for associations between **UFP** and all-cause, cardiovascular and respiratory mortality.
- There is a need to **expand PNSD measurements** as part of the routine monitoring stations

Health effects of airborne particles

Ioar Rivas

RI-URBANS (101036245)
1st Science Meeting, 19th October 2022