Understanding the Health Impact of Ambient Ultrafine Particles

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NCAA Fall Membership Meeting
Washington DC
October 21, 2019

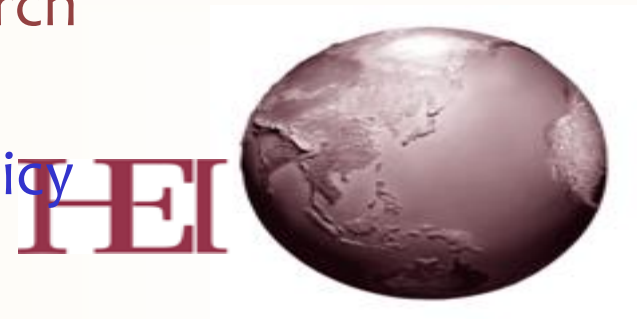
Outline of Presentation

- What is the Health Effects Institute
- Brief introduction to ambient particulate matter
- HEI evaluation of UFP literature (2013)
- German evaluation of UFP literature (2018)
- Where are we now?

- Take Home Message: Scientific knowledge on human health effects from exposure to ambient UFPs is quite uncertain

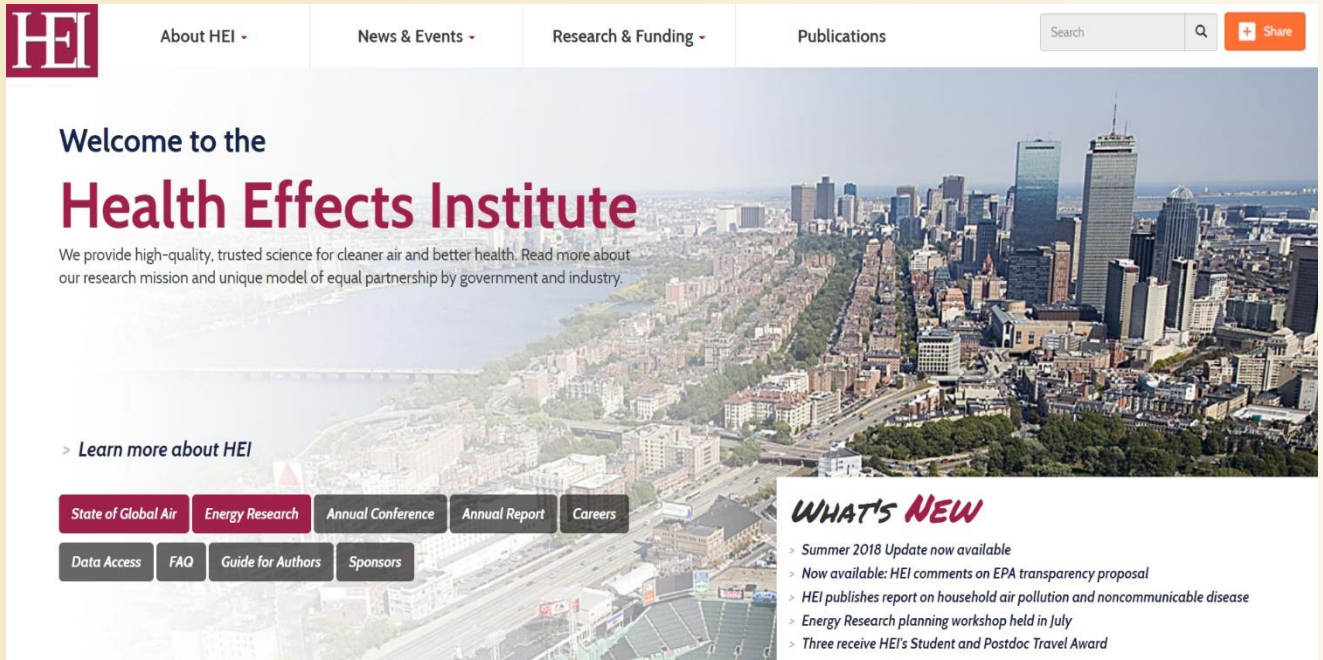
What is the Health Effects Institute

- Independent, non-profit institute, providing high quality, impartial scientific information on the health effects of air pollution, since 1980
- Balanced Core Support:
  - US EPA and Industry (Worldwide Motor Vehicle, incl. heavy-duty manufacturers)
- Additional Partners
  - DOE, CARB, Oil Industry (API, CONCAWE), Foundations
- Governance
  - Independent Board of Directors
  - Expert Scientific Committees – Develop, oversee and intensively peer review all research
- Hundreds of scientific reviews, reanalysis, and original research conducted aound the world
- Scientific Research Organization: HEI does not advocate policy
- www.healtheffects.org



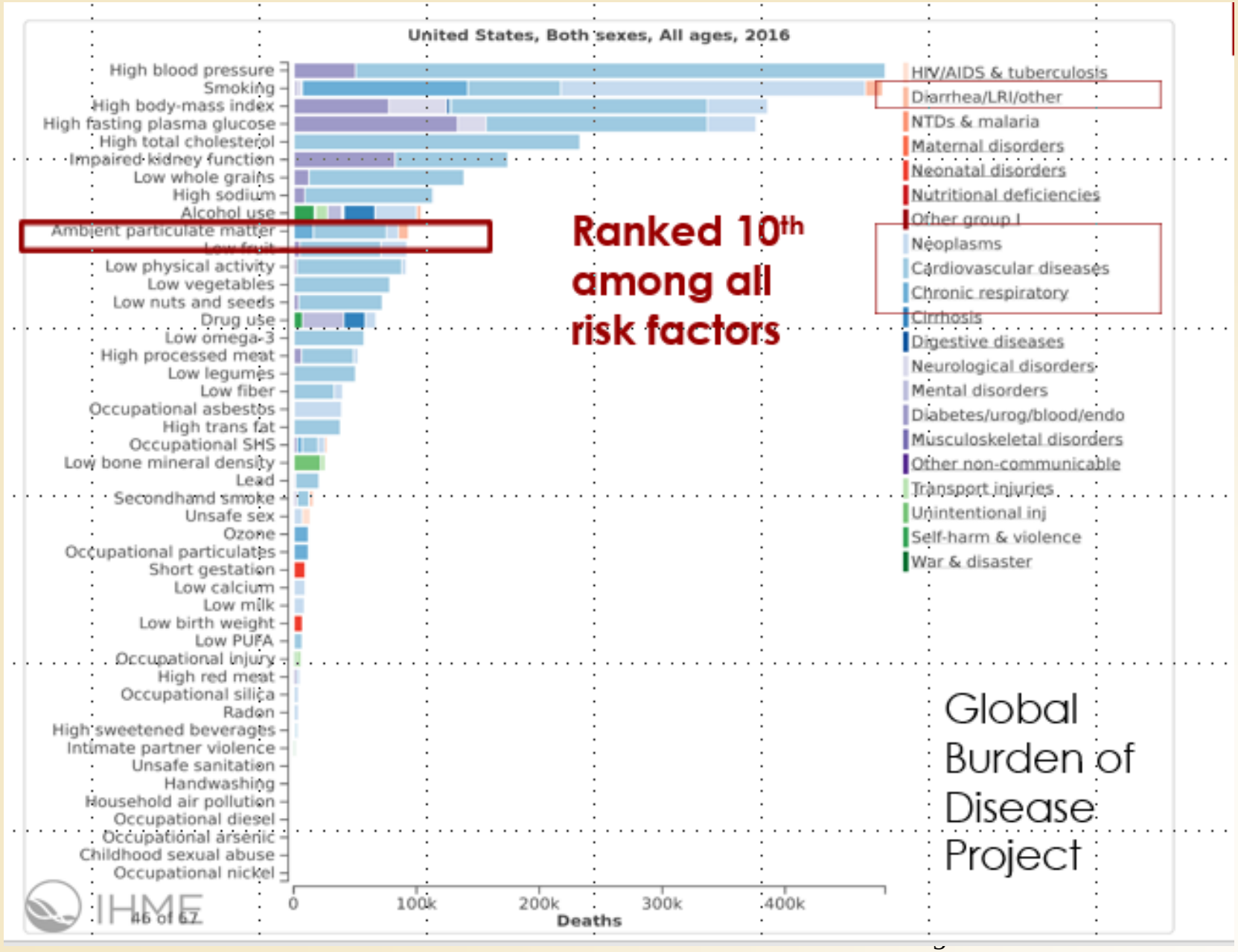
HEI's Activities

- ***Targeted Research and Reanalysis***
  - Over 350 Studies on a wide variety of air pollutants: PM, ozone, diesel, air toxics, Exposure, Epidemiology Accountability
  - Reanalysis of critical studies
- ***Authoritative Literature Reviews***
- ***Global Health***
  - Middle and Low Income Countries
- ***NEW Energy Research Program***
  - Potential Exposures and from unconventional oil and gas development



All Publications available for free at www.HealthEffects.org

HEI

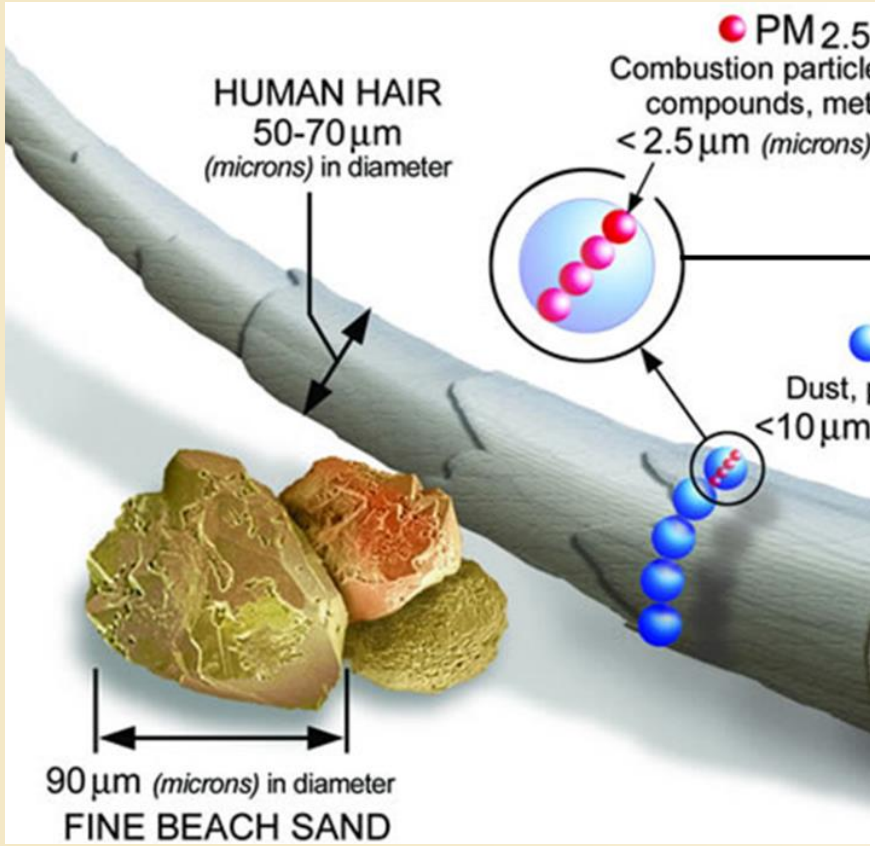


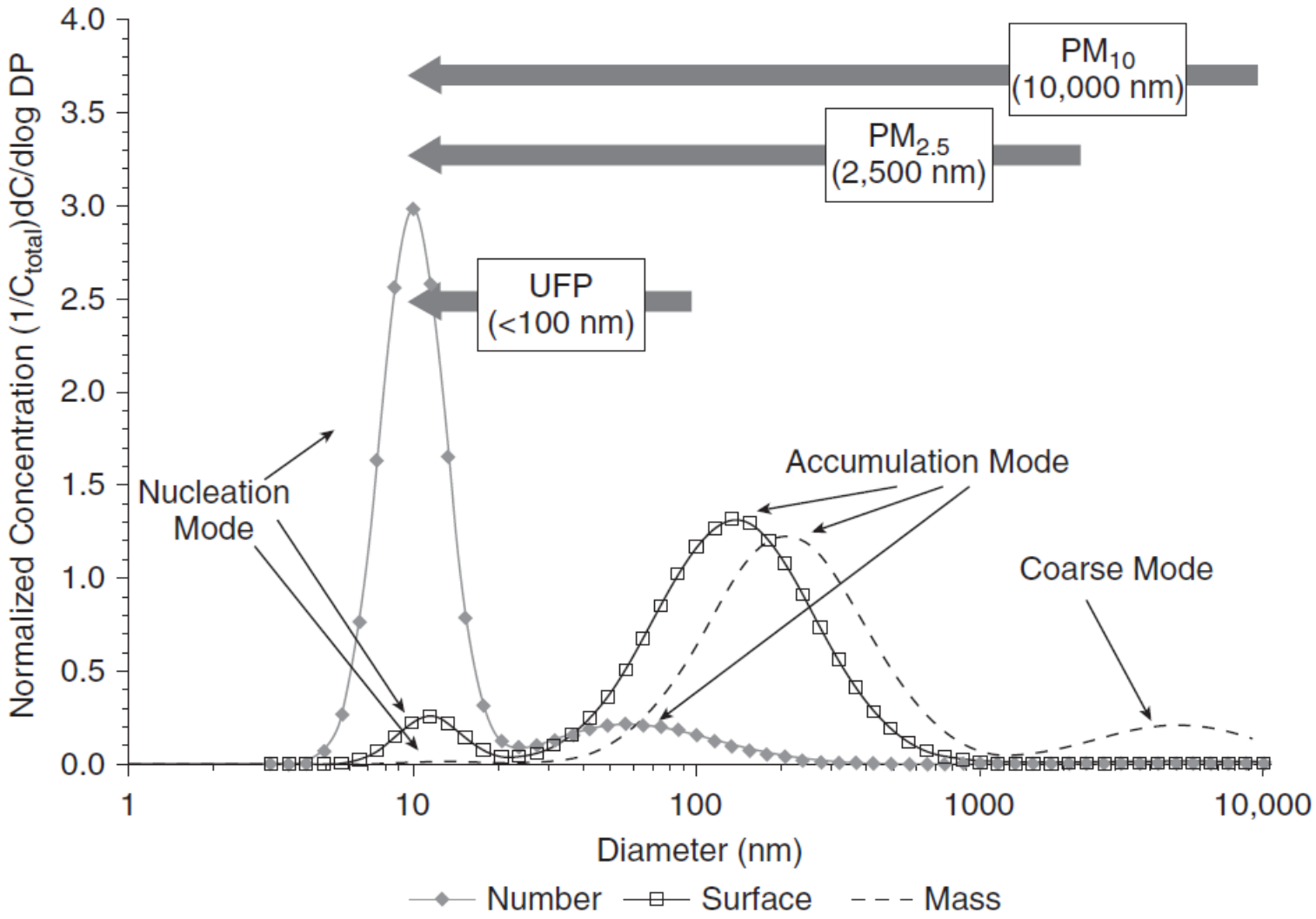
Health Impact of $PM_{2.5}$:

About 80,000 premature deaths were attributed to $PM_{2.5}$ in the U.S. in 2016

HEI

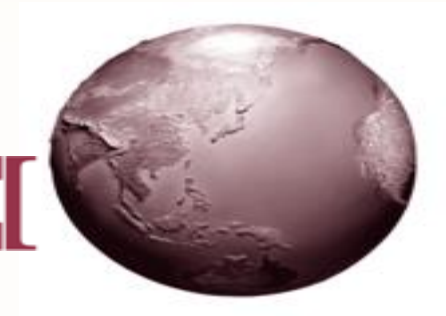
What are Ultrafine Particles (UFPs)



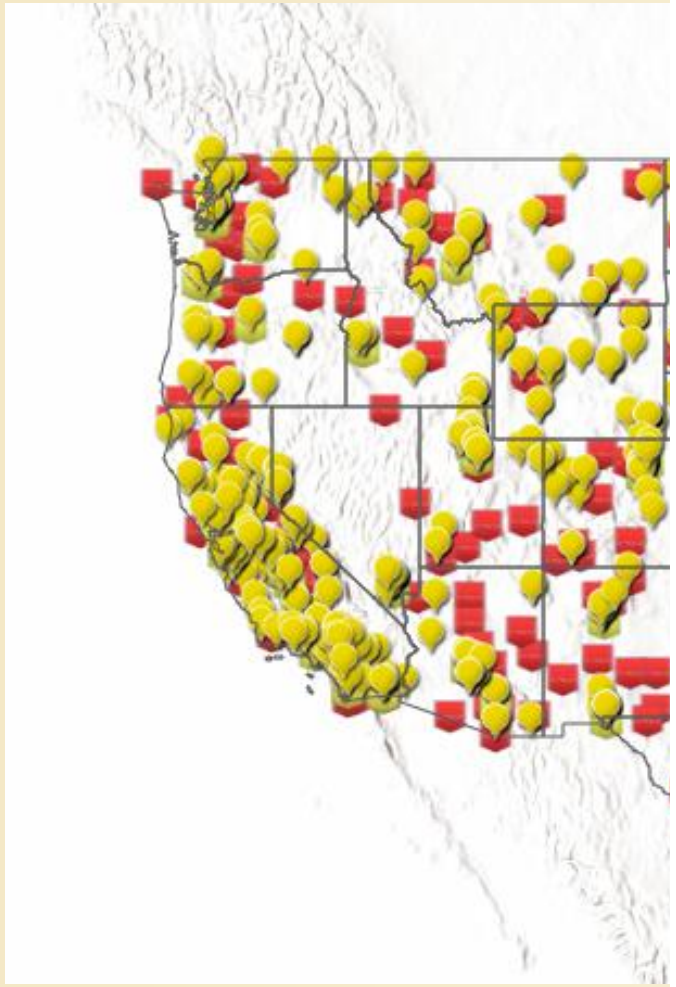


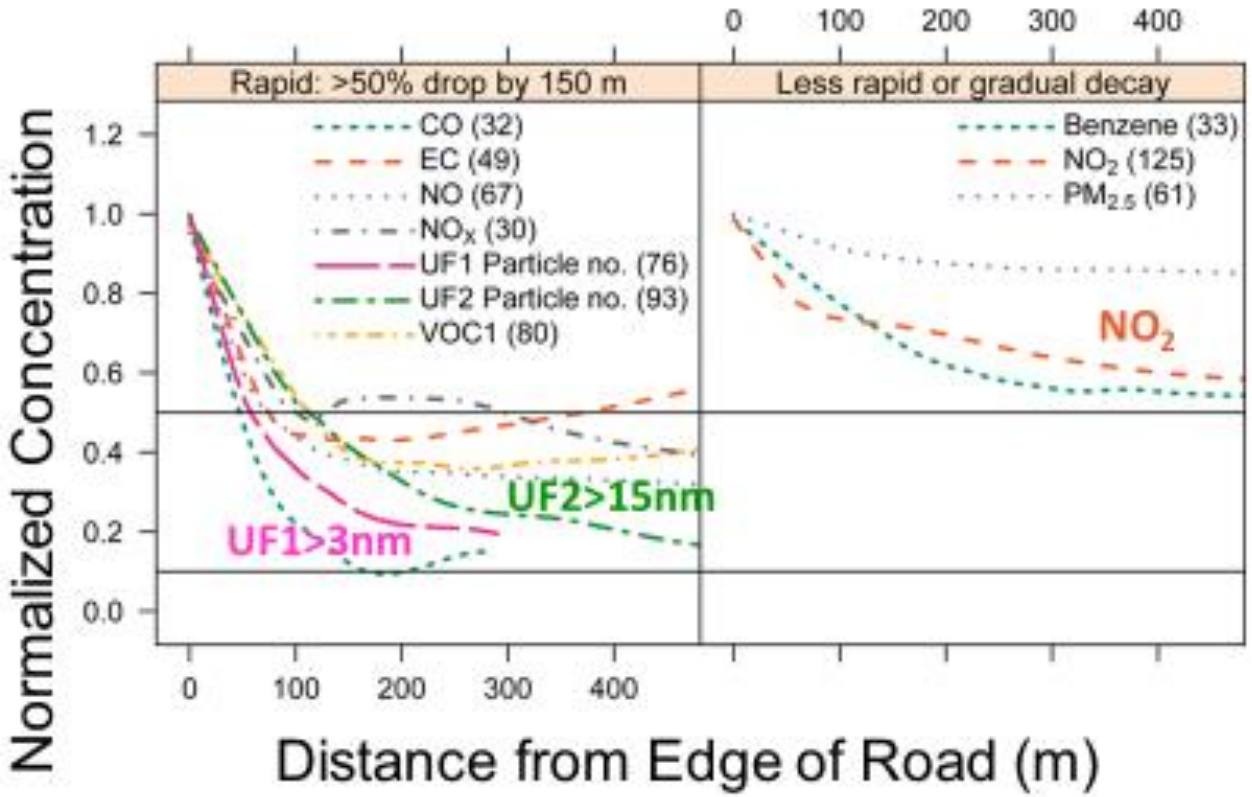
Challenges of Studying UFPs

- Characterization of ambient UFP exposures continues to be much poorer than for other pollutants
- No clear consensus on the 'right' (health-relevant) metric for UFP exposures
  - Number, size, surface area, composition?
  - Sources (Traffic, Cooking, Other)
  - High Spatial and Temporal Variability
- Health Endpoints, mechanisms



Higher air pollutant levels near busy roads



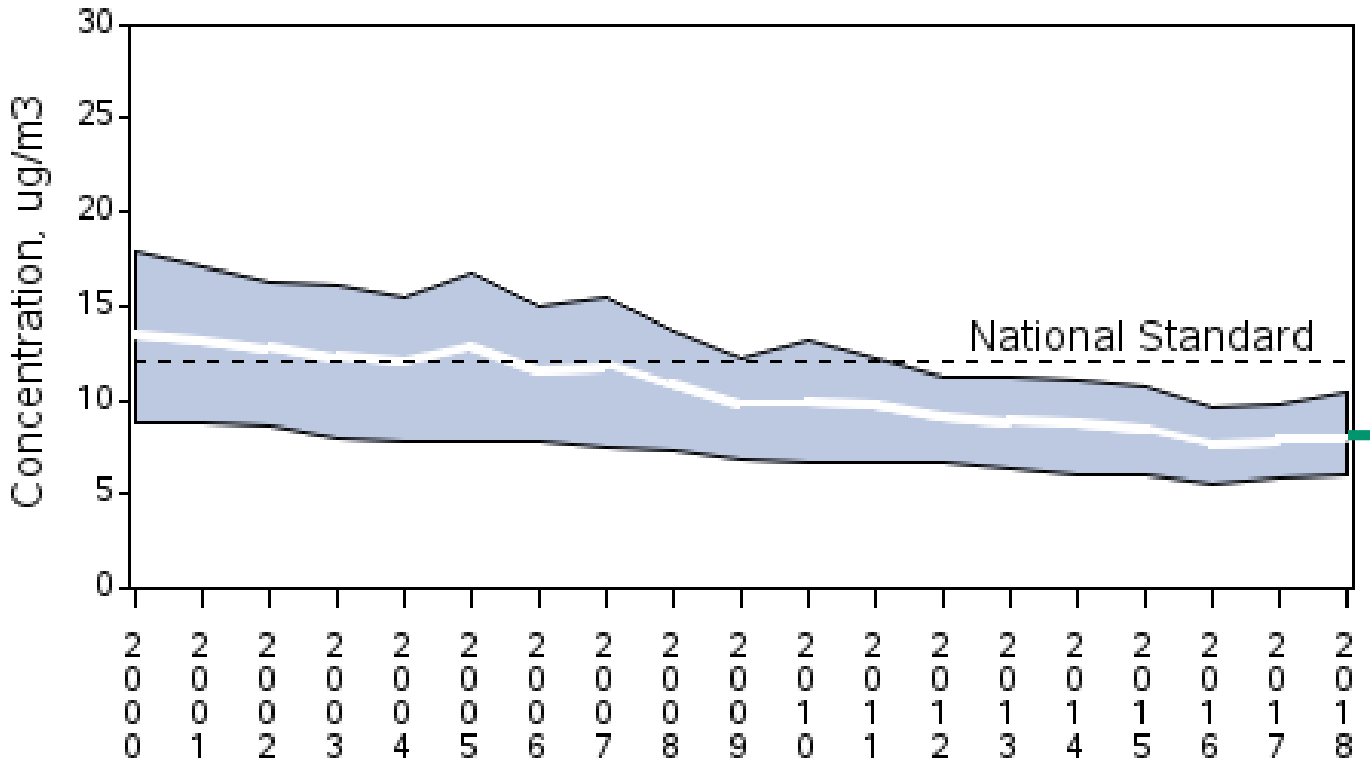


Karner et al, 2010, *ES&T*

UF1 and UF2 are ultrafine particles measured as particle number concentration (PNC).

PM2.5 Air Quality, 2000 - 2018

(Seasonally-Weighted Annual Average)
National Trend based on 412 Sites



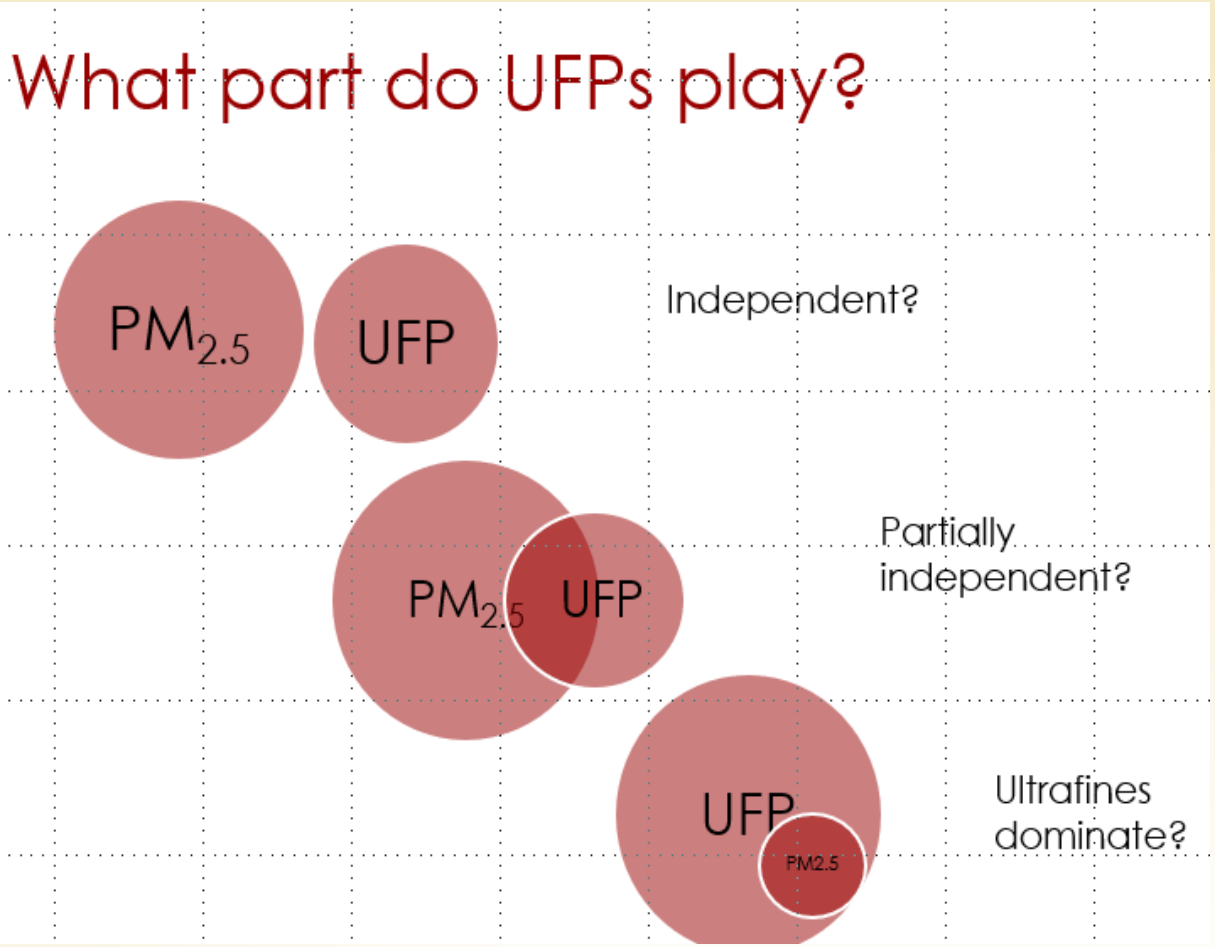
8.16

2000 to 2018 : 39% decrease in National Average

https://www.epa.gov/air-trends/particulate-matter-pm25-trends

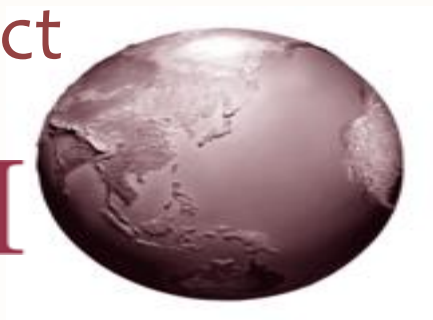
The HEI UFP Panel

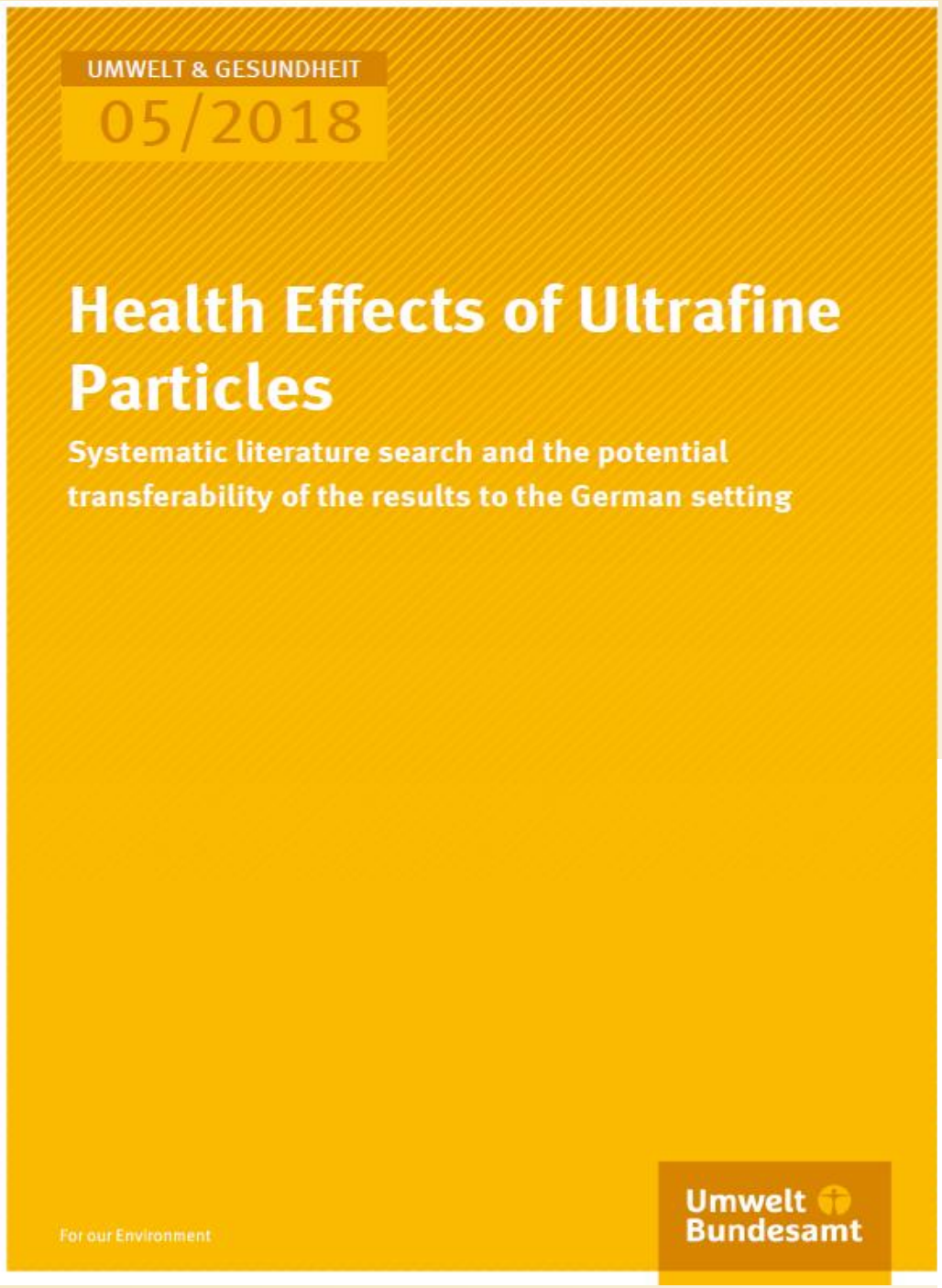
- Multidisciplinary panel to review the science on UFPs
- Do UFP affect health at ambient levels? What is the evidence from scientific studies?
- In particular: Given there is good evidence of effects of fine particles (PM2.5) on health:
  - The health effects of UFPs that are *independent* of other particle size fractions or of other components of the air pollution mixture?



HEI Panel's Overall Conclusions (2013)

- Motor vehicles have been important sources of emissions and exposures to ambient UFPs.
- UFPs differ from larger particles in their lung deposition, clearance and potential for translocation.
- Experimental and epidemiologic studies provide suggestive, but not consistent, evidence of adverse effects of short-term exposures to ambient UFP.
- Long-term studies on the effects of UFPs do not exist.
- Therefore: "The current evidence does *not* support a conclusion that "exposure to UFPs alone can account in substantial ways for the adverse effects … of $PM_{2.5}$"
- The lack of support for a substantial, independent effect "does not mean that such effects, as one part of the broader effects attributable to $PM_{2.5}$ can be entirely ruled out."





GOALS

- Investigate health effects of ultrafine particles, independent of other pollutants
- Systematic literature review
- Focus on Epidemiological studies published from 2011 to 2017
- Start with the HEI review (2013)
- Two publications

International Journal of Public Health (2019) 64:547–559
https://doi.org/10.1007/s00038-019-01202-7

REVIEW

Health effects of ultrafine particles: a systematic literature review update of epidemiological evidence

Simone Ohlwein[1] · Ron Kappeler[2] · Meltem Kutlar Joss[2] · Nino Künzli[2] · Barbara Hoffmann[1]

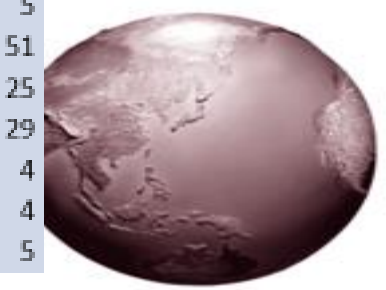
Received: 10 August 2018 / Revised: 4 January 2019 / Accepted: 9 January 2019 / Published online: 21 February 2019

Characteristics of studies included

(n=85)

World region	Number of studies	%
Africa	0	0.0%
North America	37	43.5%
Middle/ South America	1	1.2%
Western Europe	27	31.8%
Eastern Europe	2	2.4%
South-East-Asia	1	1.2%
Western-Pacific	12	14.1%
Multiple study regions	5	5.9%
Total	85	100.0%

Characteristics		short-term (N=75)	long-term (N=10)	Total (N=85)
Study design				
	Case-cohort	-	1	1
	Case-control	-	1	1
	Cohort	4	4	8
	Cross-sectional	4	4	8
	Panel	32	-	32
	Case-crossover	8	-	8
	Scripted exposure	16	-	16
	Time-series	11	-	11
Exposure assessment technique				
	Model based	2	9	11
	Measurement	73	1	74
Exposure metric				
	UFP	9	5	14
	quasi-UFP	45	5	50
	UFP + quasi-UFP	19	0	19
	Co-pollutants	32	1	33
Outcome type				
	Mortality	7	1	8
	Morbidity	7	4	11
	Emergency	11	0	11
	Subclinical	55	5	60
Outcome - organ related				
	Total mortality	4	1	5
	Cardiovascular	47	4	51
	Respiratory	24	1	25
	Inflammation	26	3	29
	Oxidative stress	4	0	4
	Neurocognitive	3	1	4
	Other	2	3	5



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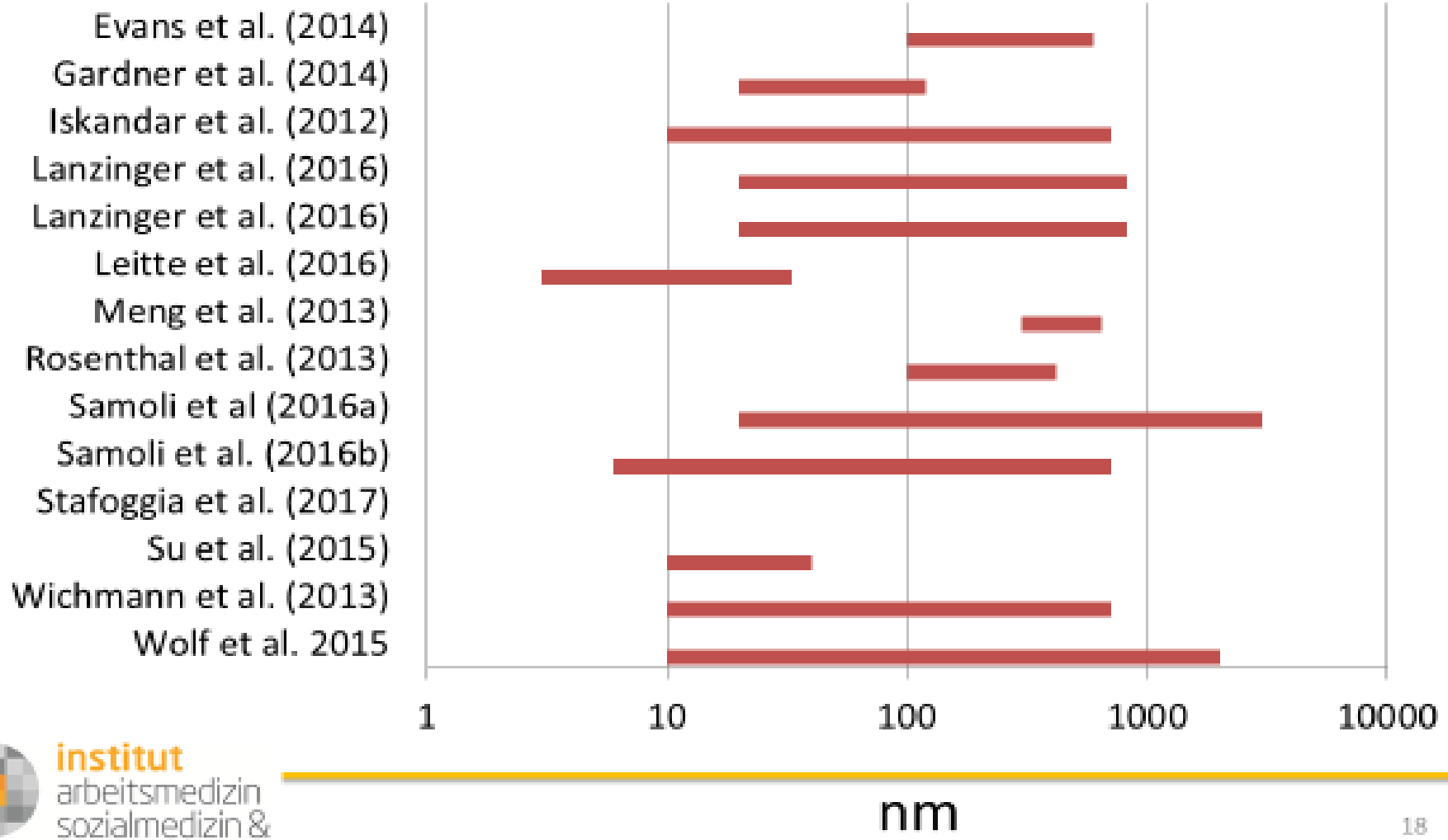
Size ranges studied vary

(mortality/morbidity studies with co-pollutant adjustment only)



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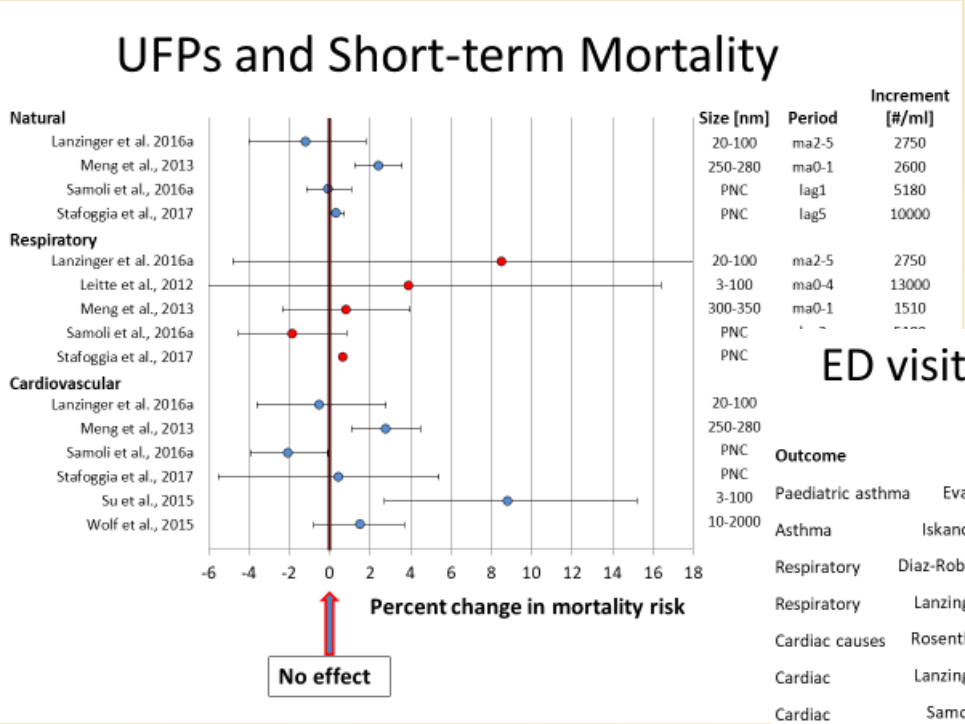
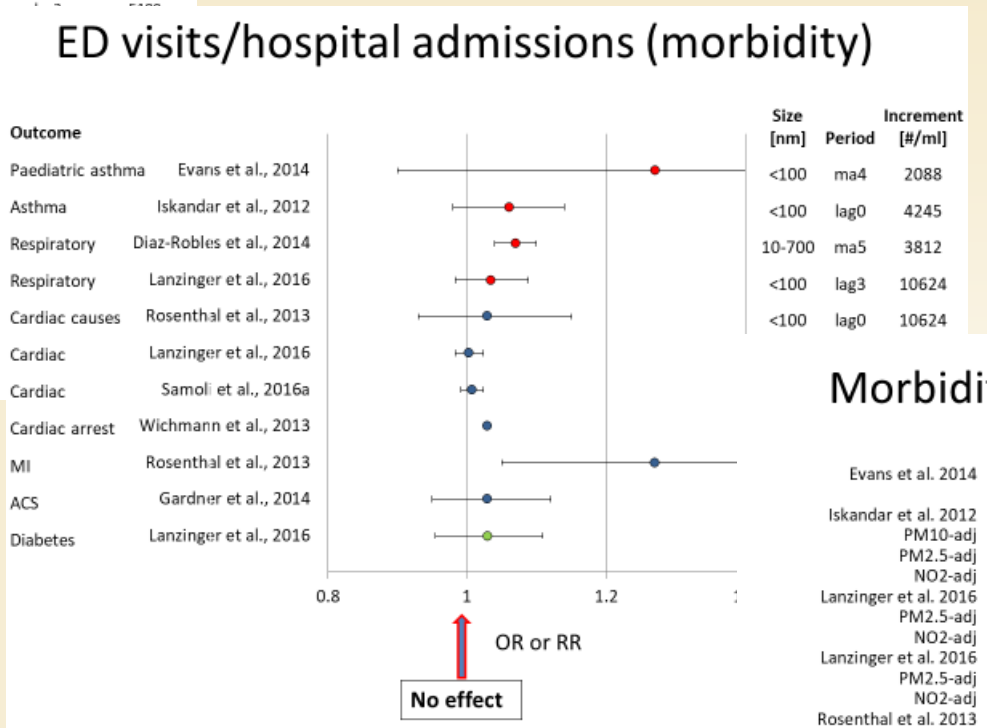
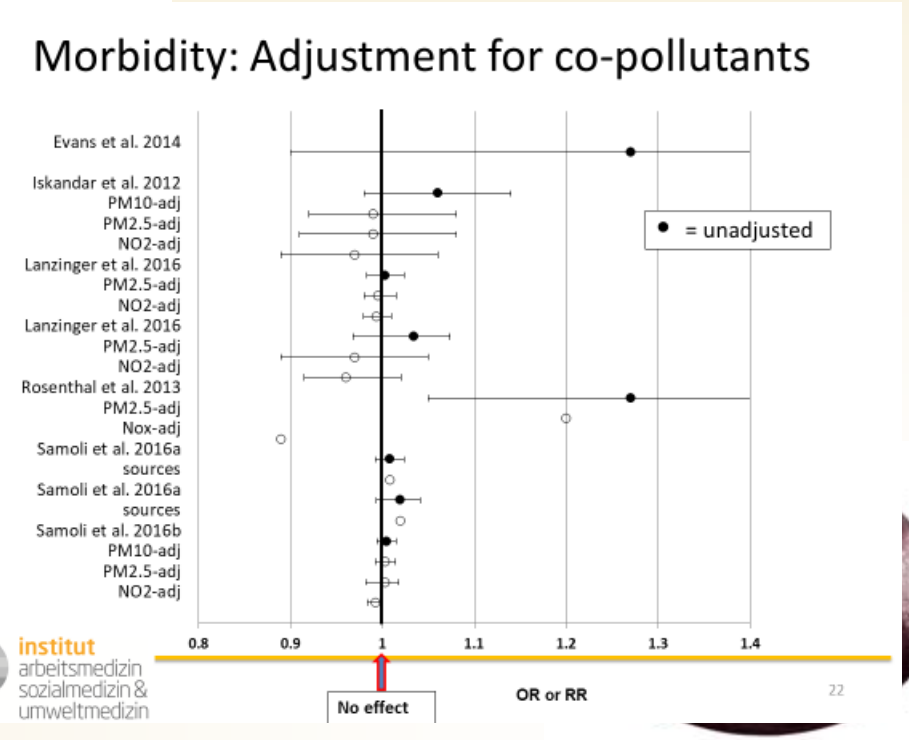
Effects of Short-Term Exposure







NEW!!: Long-term UFP studies

Outcome type/ study	Outcome	Associations w/o co-pollutant adjustment	Associations with co-pollutant adjustment
Mortality Ostro et al. 2015	- all-cause	0	nc
	- cardiovascular/ IHD	(+)/0	nc
$PM_{0.1}$ mass	- pulmonary	0	nc
Morbidity Li et al. 2017	- Cardiometabolic	(+)	nc
Laurent et al. 2014/2016b	- low birth weight	+/(+)	nc
Laurent 2016a	- preterm birth	-/+	nc
Subclinical			
Aguilera et al. 2016	- carotid-intima-media thickness (PNC/LDSA)	+/+	-/(+)
Viehmann et al. 2015	- hs-CRP/ fibrinogen/ WBC	(+)/+/(+)	nc
Lane et al. 2015	- hs-CRP/ IL-6	(+)/(+)	nc
Lane et al. 2016	- hs-CRP/ IL-6/ TNRFIII/ fibrinogen	(+)/(+)/(+)/(-)	nc
Sunyer et al. 2016	- working memory,	(+)	
	- superior working memory,	+	
	- inattentiveness	+	

IHD: Ischemic heart disease, o indicates no association. (+) and (-) indicates primarily non-significant associations, + and - indicate significant associations. Nc: not conducted.

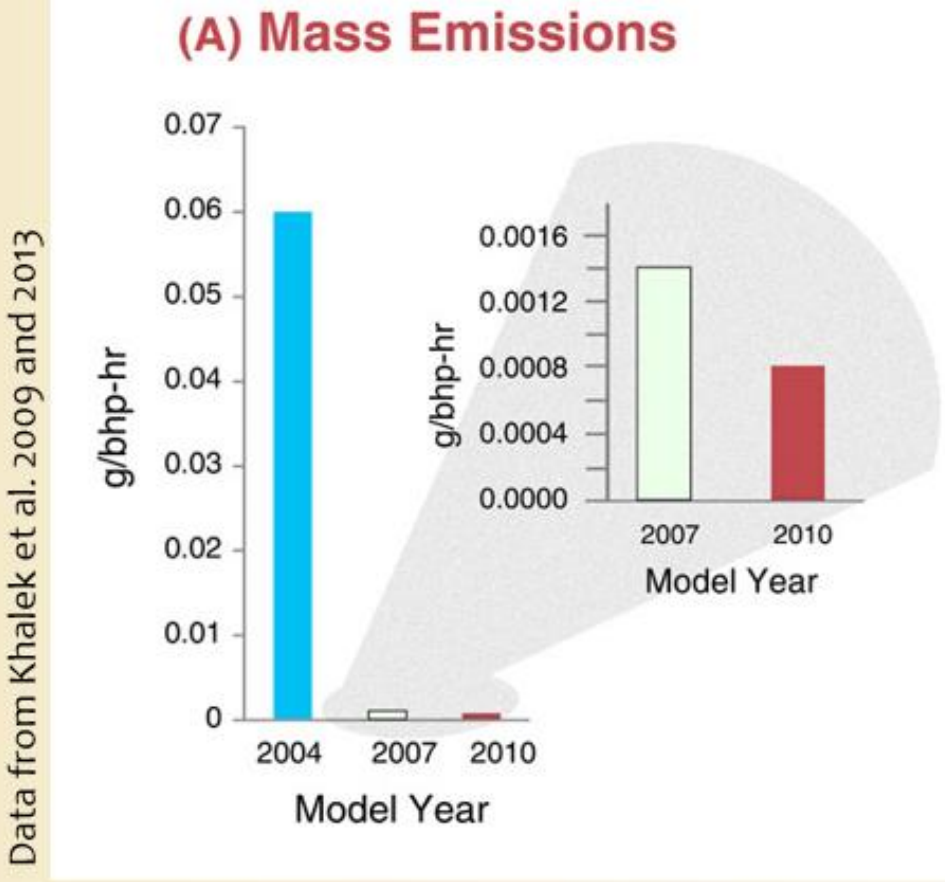
Overall Conclusions – German Review (2018)

A rapidly increasing field of research and substantial developments, but the overall conclusions have not changed substantially since publication of the HEI review

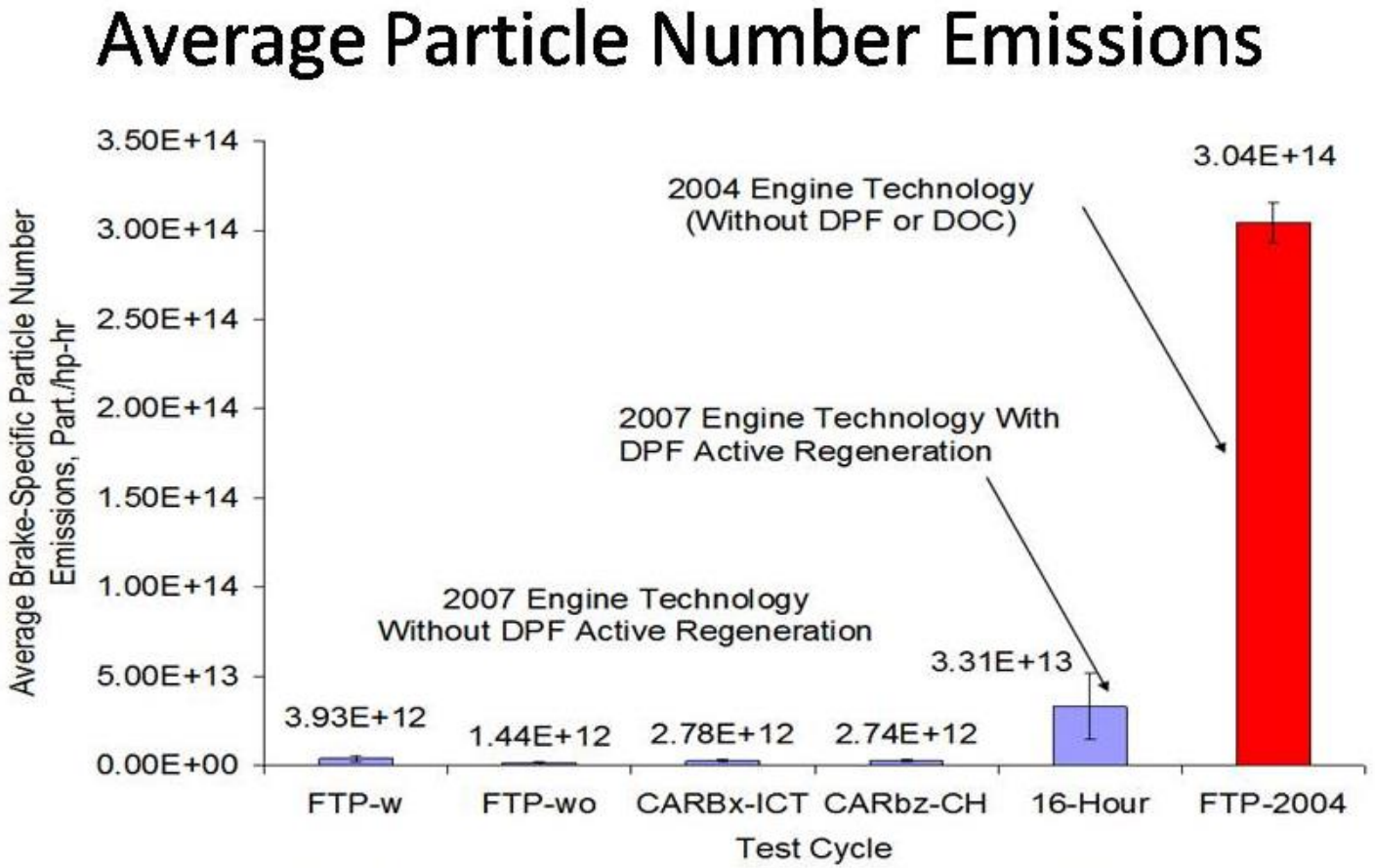
1. Exposure assessment in the population remains difficult, due to the specific characteristics of UFPs
2. The evidence on health effects remains inconclusive or insufficient for most of the studied outcomes
3. The independence of UFPs cannot be evaluated at the moment, due to the low number of studies with adjustment and other limitations to exposure assessment
4. There continues to be an urgent need for long-term studies on health effects of UFPs

US Heavy Duty Vehicle Emissions Regulations

Where does this leave us?



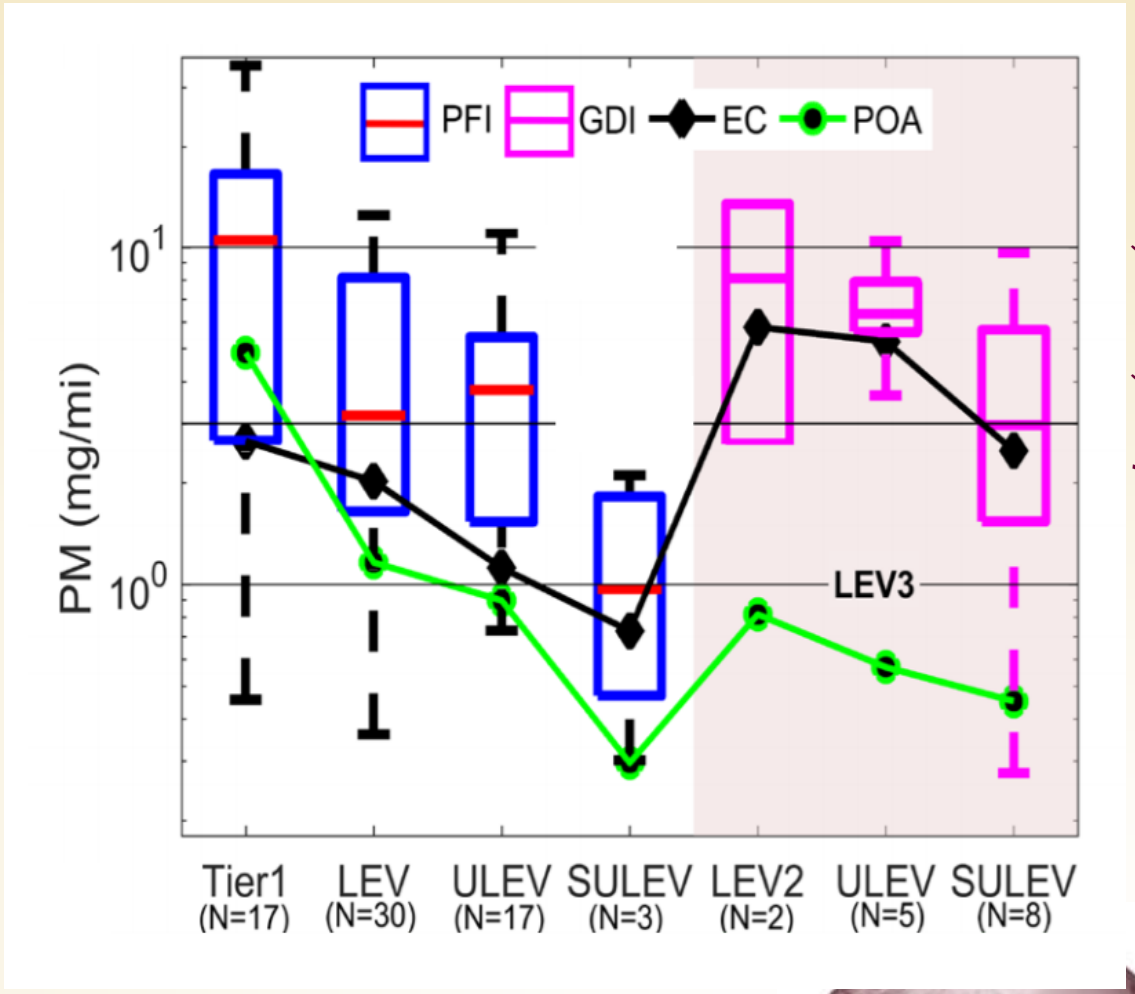
Data from Khalek et al. 2009 and 2013



- Without DPF regeneration, the particle number emissions average was 99 percent lower than the level emitted by a 2004 engine technology, and with regeneration it was 90 percent lower
- With Active DPF regeneration, the number emissions average was a factor of 10 higher than events without regeneration

Gasoline Direct Injection LDV Engines

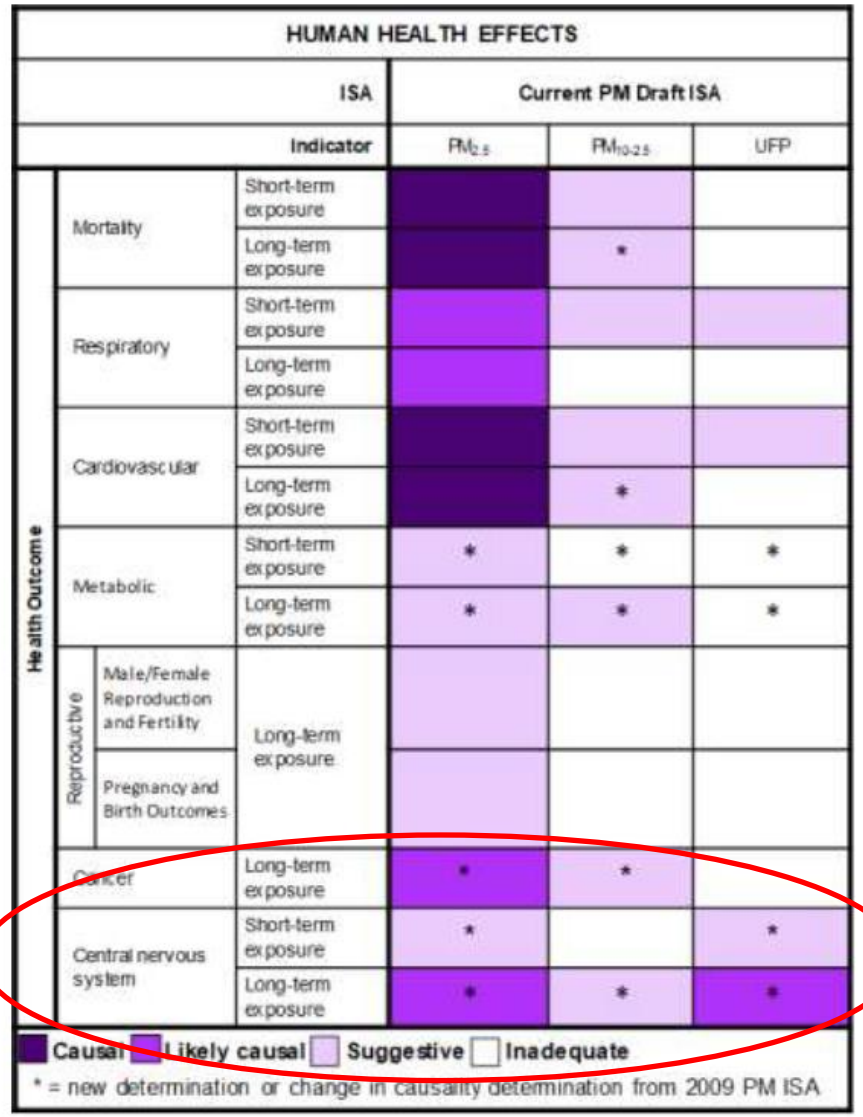
- ~ 50% of LDVs sold in the US have GDI
- More fuel efficient
- Higher UFP (and PM) emissions
- Evolving technology
- Impact on ambient concentrations?



Saliba et al., ES&T, 2017

- ➢ European PN standard (not based on health studies)
- ➢ Use of gasoline particle filter for compliance

Table 1-5. Summary of causality determinations for health outcome categories for first draft PM ISA.



Integrated Science Assessment for Particulate Matter (External Review Draft), October 2018

Where does this leave us, cont.

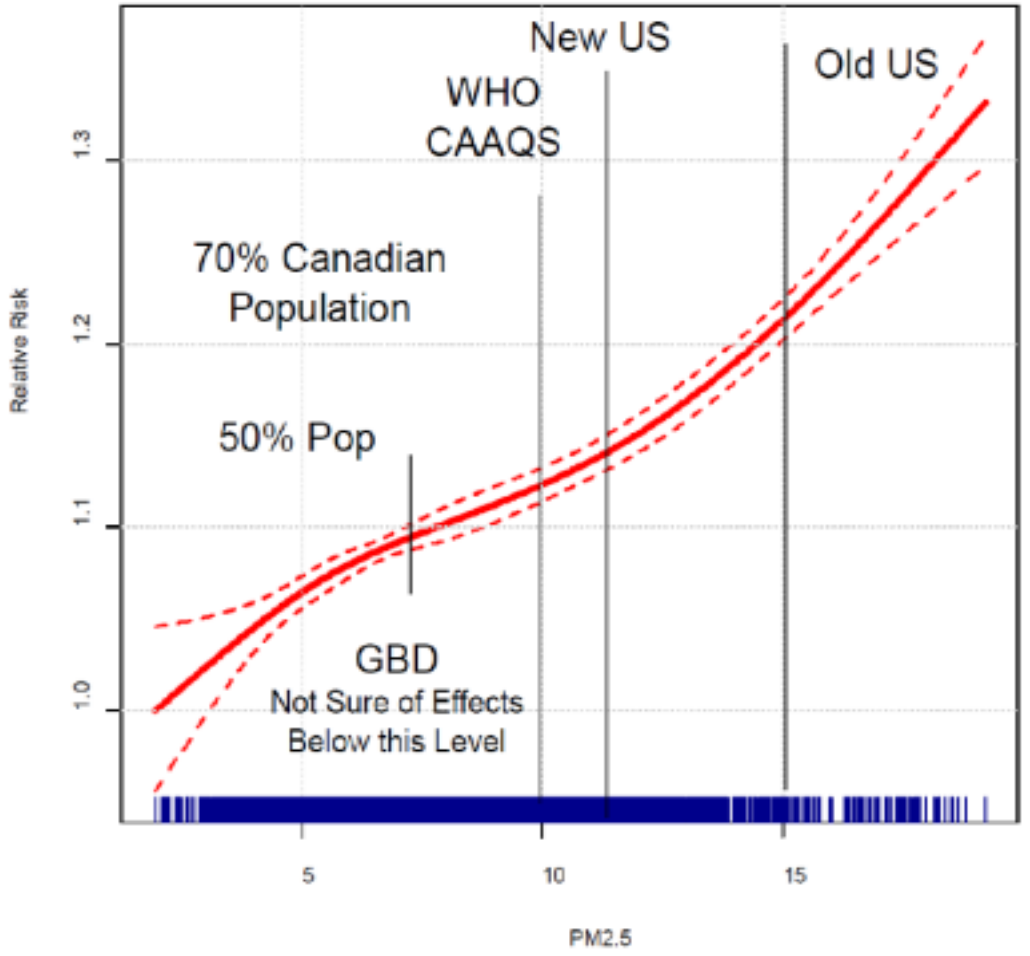
- DRAFT ISA --Changes in evaluation of UFPs
- Based on
  - Six animal studies [very high doses]
  - One epidemiology study [did not adjust for co-pollutants]
- Many comments on this point
- Will EPA re-consider this designation for UFPs ?
- Not a driver for the NAAQS

HEI

DIGRESSION: A New Challenge -- $PM_{2.5}$ Effects at Low Levels

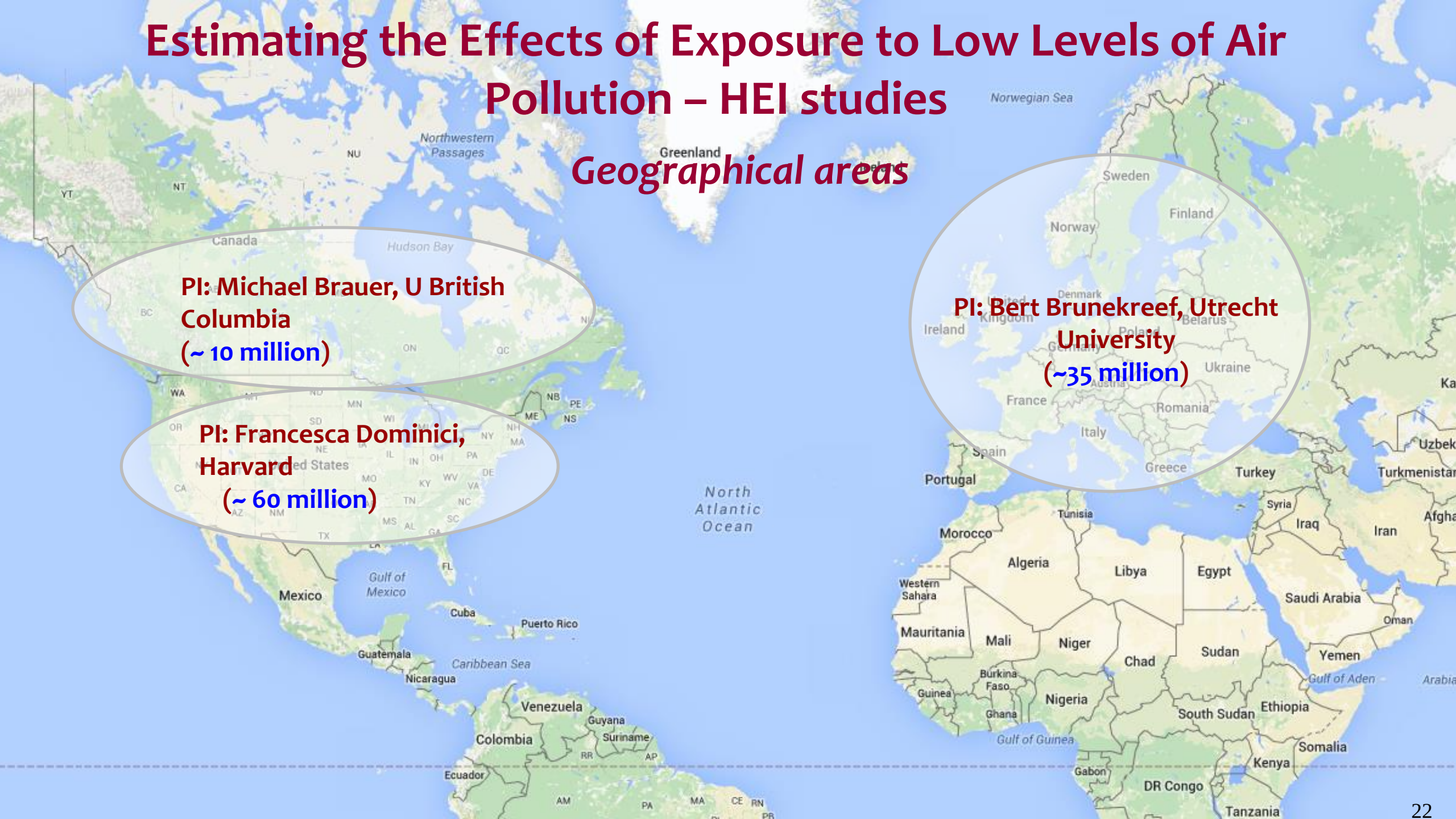
- Crouse et al. (2012) paper on effects at low levels in the Canadian Census Cohort
- Are they real? Questions include
- Exposure Estimates
- Confounders
- Analytical methods
- HEI is funding three excellent teams for this research
- Goal: rigorous testing of low-level associations

Figure 1 Shape of Canadian Concentration-Response Function
(From Burnett 2013 drawn from Crouse 2012)



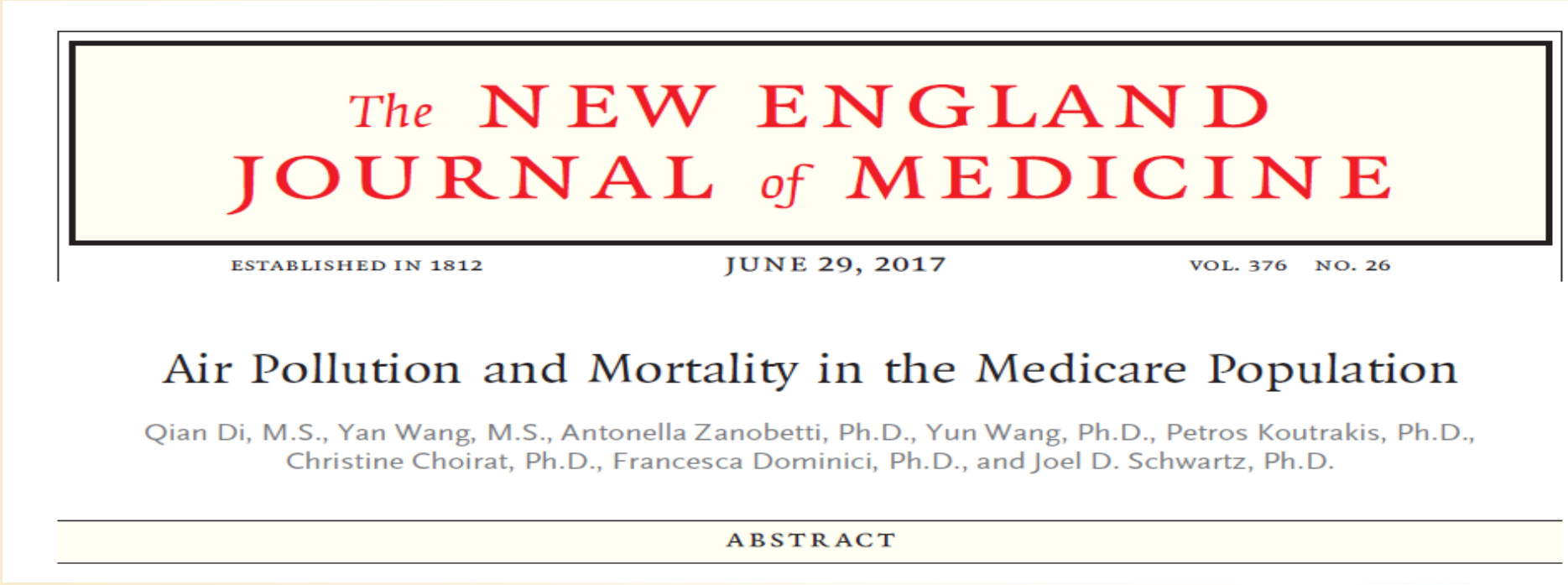
Estimating the Effects of Exposure to Low Levels of Air Pollution – HEI studies

Geographical areas



Early Results from the U.S. Medicare Cohort

- First results in 61 million Medicare enrollees
- Analyzed for PM and Ozone effects
- Traditional "Cox Proportional Hazard" Models
  - Controlled for possible confounders
  - But did not have data on smoking, some others confounders



The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 JUNE 29, 2017 VOL. 376 NO. 26

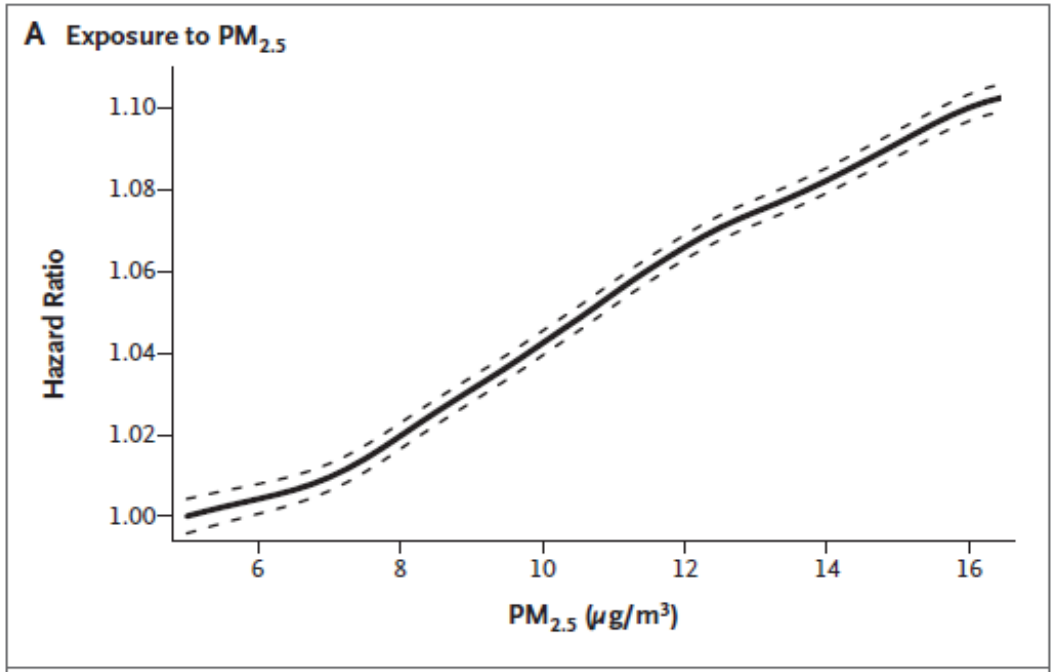
Air Pollution and Mortality in the Medicare Population

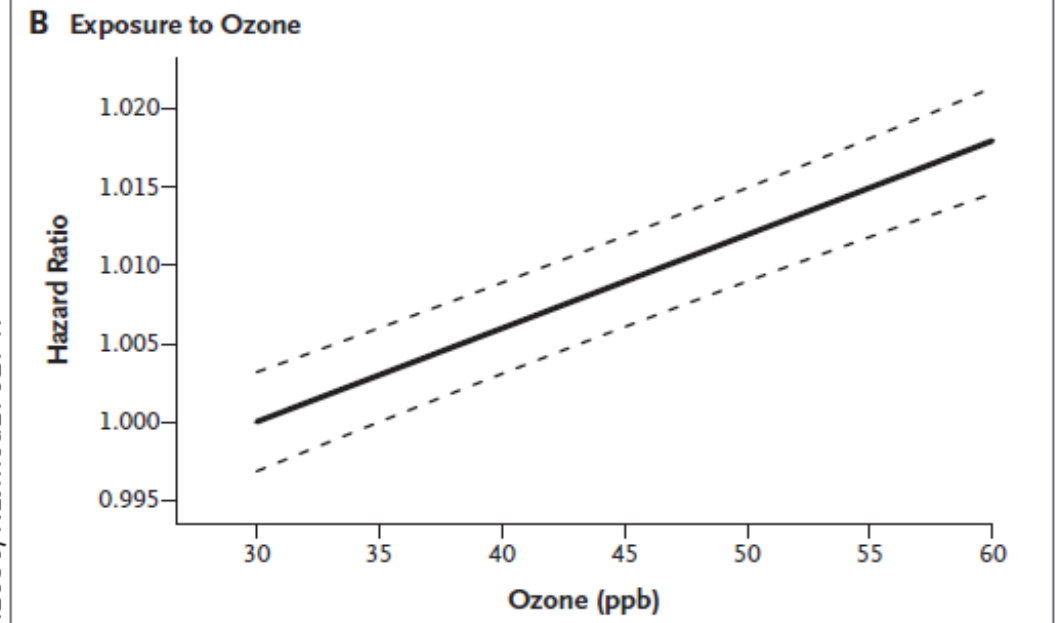
Qian Di, M.S., Yan Wang, M.S., Antonella Zanobetti, Ph.D., Yun Wang, Ph.D., Petros Koutrakis, Ph.D., Christine Choirat, Ph.D., Francesca Dominici, Ph.D., and Joel D. Schwartz, Ph.D.

ABSTRACT

Conclusions from Dominici et al

- Medicare enrollees (~65 million) [limited confounder information]
- Exposure – Satellite + ground, neural network
- Concentration– Response:
  - PM: HR 1.073; no threshold?
  - Ozone: HR 1.011, to at least 30 ppb
- Additional analyses underway
- Medicare data are public & Dominici will make all statistical codes and data available



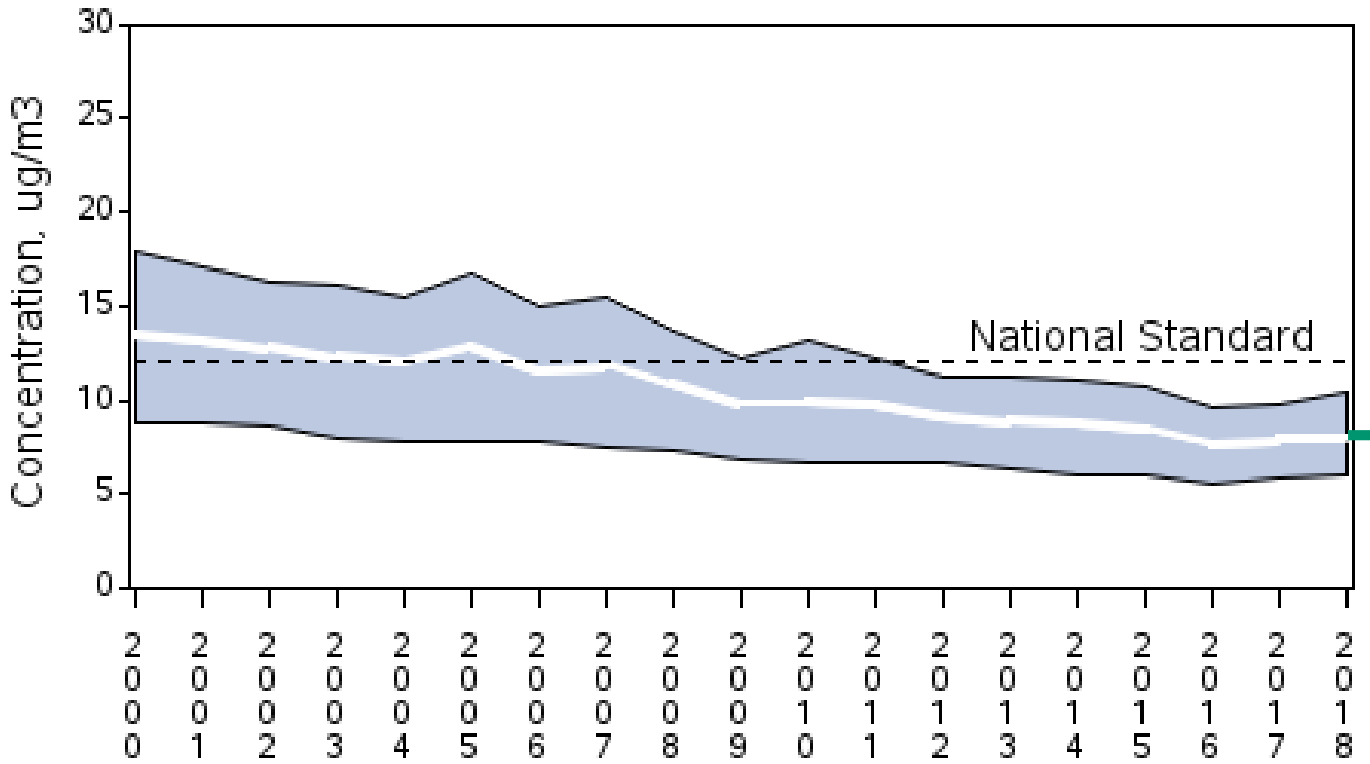


N Engl J Med 2017;376:2513-22.
DOI: 10.1056/NEJMoa1702747

Figure 3. Concentration–Response Function of the Joint Effects of Exposure to $PM_{2.5}$ and Ozone on All-Cause Mortality.

PM2.5 Air Quality, 2000 - 2018

(Seasonally-Weighted Annual Average)
National Trend based on 412 Sites



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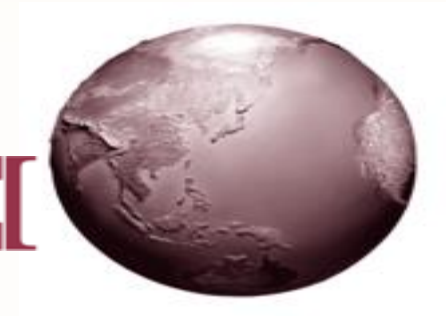
2000 to 2018 : 39% decrease in National Average

https://www.epa.gov/air-trends/particulate-matter-pm25-trends

$PM_{2.5}$: Continuing Challenges …

- If low exposure effects are confirmed by other studies
- Scientific challenges – Reducing uncertainties
  - Exposure assessment – error assessment
  - Health ascertainment and characteristics
  - Analytical challenges – Big Data; causal inference
- Policy Challenges – Reducing exposures/doses
  - Further reductions in exposures -- What would work best?
  - Averages vs "hot spots" and population and individual vulnerabilities
- Role of $PM_{2.5}$ characteristics: size, source, composition, etc.
- Other …



Thank You

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