# Health Effects of Fine Particulate Matter, Ultrafine Particle Exposure and Co-Benefits of SAF

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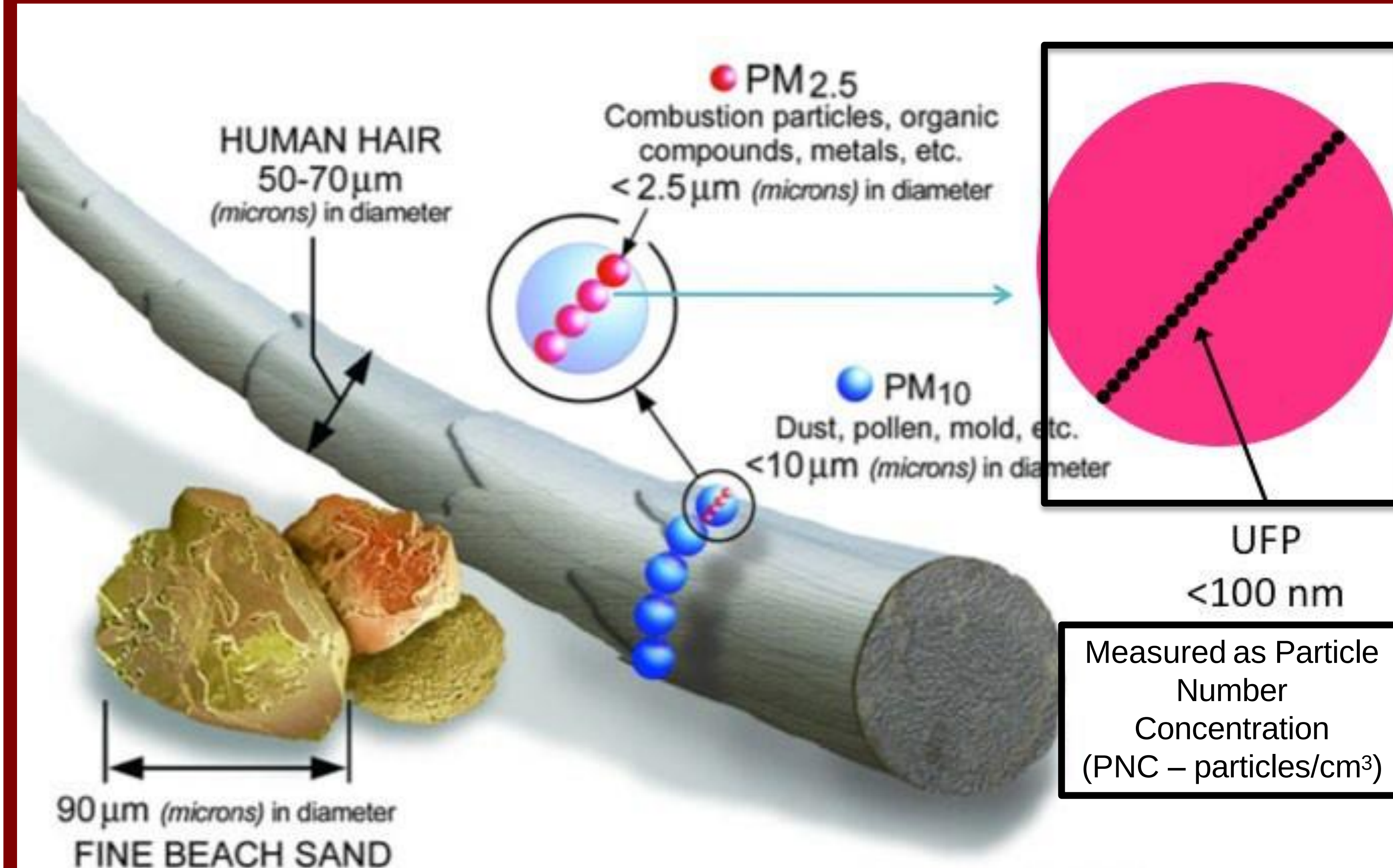
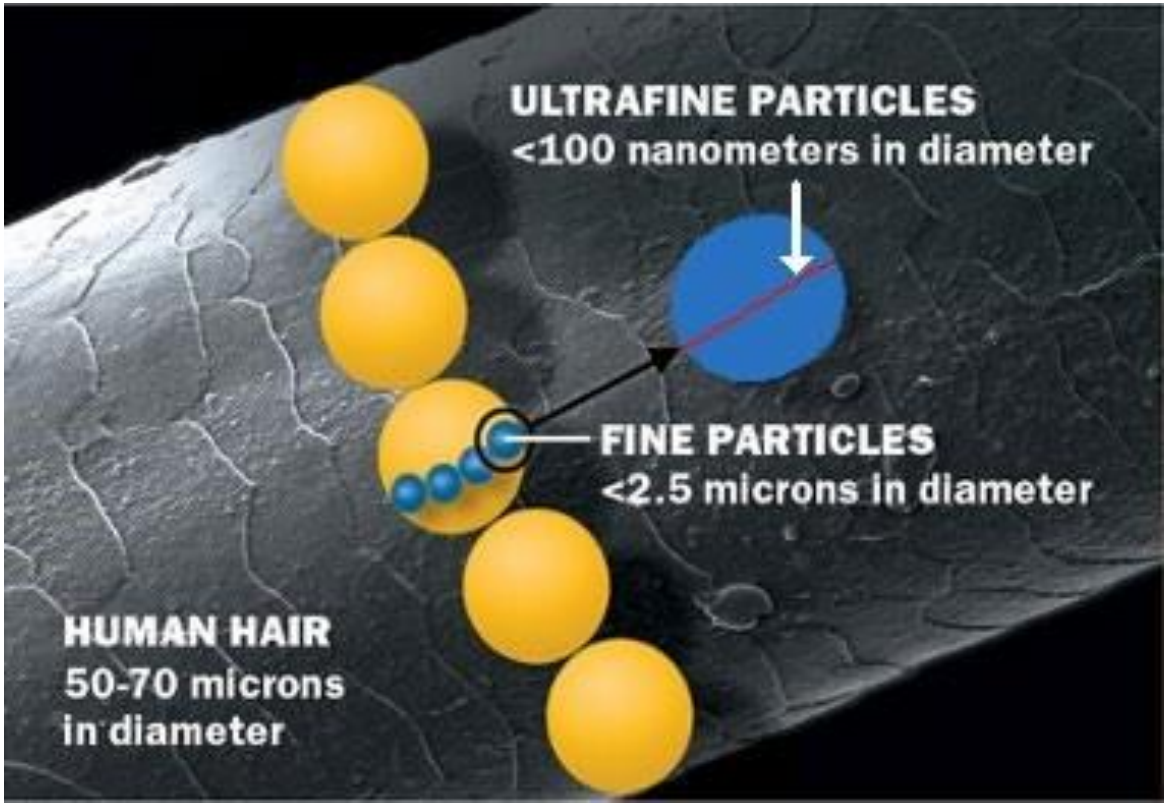
# Particle Matter Pollution




Measured as Particle Number Concentration (PNC – particles/cm³)

# PM 2.5 Health Impacts




- Aggravates asthma
- Decrease lung function
- Lung cancers
- Heart attacks
- Strokes
- COPD
- Cognitive delays and decline

PM2.5 Health Studies inform concentration response functions to calculate burden of disease.

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# Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021

| Leading risks 2021 | 95% UI for Ranking | Percentage of total DALYs, 2021 | Percentage change in number of DALYs, 2000–2021 | Percentage change in age-standardised rate of DALYs, 2000–2021 |
|---|---|---|---|---|
| 1 Particulate matter pollution | (1 to 2) | 8·0 (6·7 to 9·4) | –17·2 (–25·9 to –6·2) | –41·9 (–47·2 to –35·6) |
| 2 High systolic blood pressure | (1 to 2) | 7·8 (6·4 to 9·2) | 34·3 (26·7 to 42·3) | –24·3 (–28·4 to –20·0) |
| 3 Smoking | (3 to 6) | 5·7 (4·7 to 6·8) | 10·8 (3·2 to 19·9) | –34·8 (–39·2 to –29·7) |
| 4 Low birthweight and short gestation | (3 to 6) | 5·6 (4·8 to 6·3) | –32·4 (–41·2 to –22·3) | –33·0 (–41·6 to –22·8) |
| 5 High fasting plasma glucose | (3 to 6) | 5·4 (4·8 to 6·0) | 88·2 (80·5 to 96·4) | 7·9 (3·3 to 12·9) |
| 6 High body-mass index | (3 to 10) | 4·5 (1·9 to 6·8) | 96·5 (87·1 to 105·8) | 15·7 (9·9 to 21·7) |
| 7 High LDL cholesterol | (7 to 10) | 3·0 (1·9 to 4·2) | 27·0 (20·8 to 33·6) | –26·1 (–29·6 to –22·4) |
| 8 Kidney dysfunction | (6 to 10) | 3·0 (2·6 to 3·4) | 49·5 (42·7 to 57·0) | –12·4 (–16·5 to –7·9) |
| 9 Child growth failure | (6 to 14) | 2·6 (1·4 to 3·5) | –69·8 (–77·5 to –62·4) | –71·5 (–78·8 to –64·4) |
| 10 High alcohol use | (7 to 11) | 2·5 (2·1 to 3·1) | 12·4 (2·6 to 20·9) | –25·8 (–32·0 to –20·4) |
| 11 Unsafe sex | (11 to 17) | 1·5 (1·4 to 1·7) | –35·0 (–44·6 to –20·1) | –52·4 (–58·9 to –42·3) |
| 12 Diet low in fruits | (11 to 22) | 1·5 (0·6 to 2·3) | 22·5 (15·5 to 34·0) | –26·6 (–30·9 to –20·5) |
| 13 Unsafe water source | (11 to 24) | 1·5 (0·8 to 2·0) | –60·1 (–67·1 to –53·2) | –66·3 (–72·0 to –60·2) |
| 14 Diet high in sodium | (8 to 36) | 1·4 (0·3 to 3·2) | 27·6 (1·3 to 41·2) | –26·8 (–40·9 to –19·1) |
| 15 Diet low in whole grains | (12 to 23) | 1·4 (0·6 to 2·1) | 30·1 (24·0 to 36·6) | –23·3 (–26·9 to –19·5) |
| 16 Secondhand smoke | (11 to 26) | 1·2 (0·6 to 1·8) | –16·0 (–22·0 to –6·5) | –45·3 (–48·9 to –40·3) |

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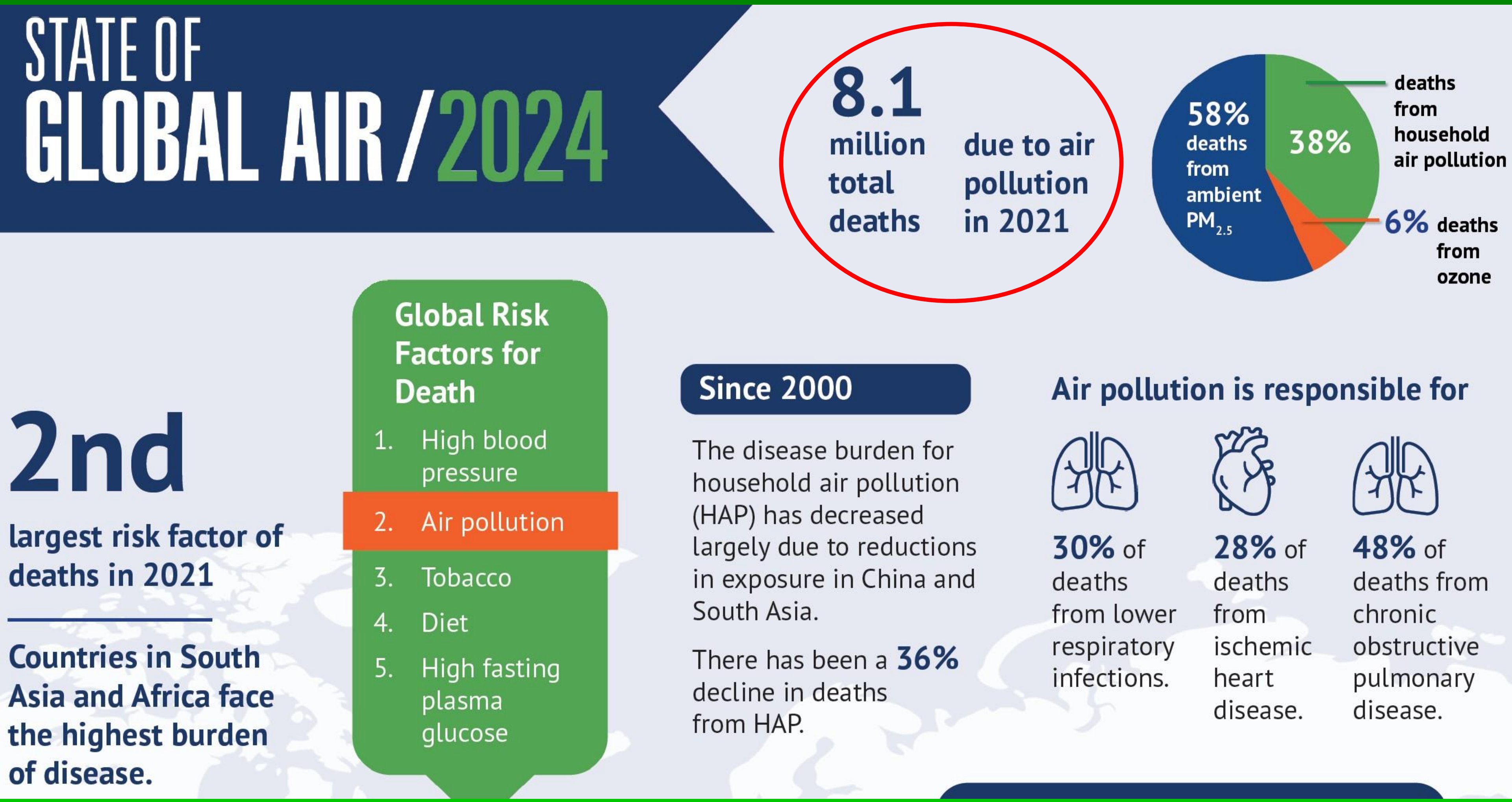
*Lancet* 2024; 403: 2162–203

# Health Effects Institute estimates



# EPA ISA for PM2.5 compared to UFP Evidence

**Table 1-1 "Causal" and "likely to be causal" causality determinations for short- and long-term PM exposure.**

| Size Fraction | Health Effects Category | Exposure Duration | Causality Determination | Section |
|---|---|---|---|---|
| $PM_{2.5}$ | Respiratory | Short-term | Likely to be causal | 1.4.1.1.1 |
| | | Long-term | Likely to be causal | 1.4.1.1.2 |
| | Cardiovascular | Short-term | Causal | 1.4.1.2.1 |
| | | Long-term | Causal | 1.4.1.2.2 |
| | Nervous System | Long-term | Likely to be causal | 1.4.1.3.1 |
| | Cancer | Long-term | Likely to be causal | 1.4.1.4.1 |
| | Mortality | Short-term | Causal | 1.4.1.5.1 |
| | | Long-term | Causal | 1.4.1.5.2 |
| UFP | Nervous System | Long-term | Likely to be causal | 1.4.3.1 |

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# Background

- Ultrafine particulate matter: Particles < 100 nm in aerodynamic diameter
  - Typically combustion products
  - Large reactive surface area
  - Limited removal in lung
  - Potential to translocate ➔ effects beyond respiratory system

- UFP epidemiological evidence fairly limited 10 years ago, growing rapidly
  - Ohlwein 2019: 85 studies 2011-2017, including long-term studies

**Recent EPA Integrated Science Assessment reports have consistently stated that improved exposure monitoring and health studies are needed**

# UFP Exposure Modeling

- High spatiotemporal variability
- Multiple contributing sources/source sectors
  - Mobile sources – automobiles and aircraft
  - Restaurants, wood burning, construction operations
- Lack of ambient monitoring infrastructure
  - Challenges in developing dispersion models
  - Imprecise exposure assessment for epidemiological studies

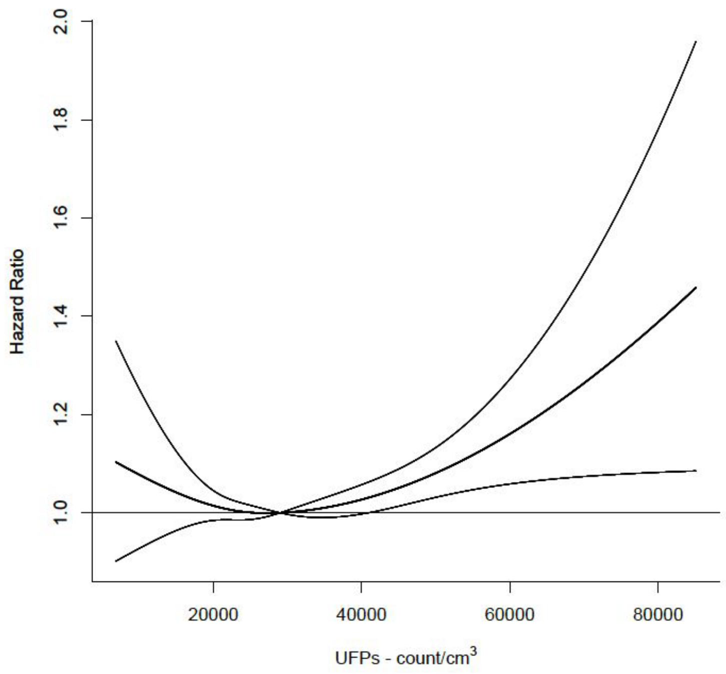
# UFP Cardiovascular effects

- Increases in biomarkers of inflammation related to cardiovascular disease (Lane et al. 2016; Devlin et al. 2014)
- Changes in heart rhythm and vasomotor function (Vora et al. 2014)
- Decreased microvascular function (Karottki et al. 2014)
- Recurrent myocardial infarction (Wolf et al. 2015)
- Systolic blood pressure and hypertension (Corlin et al. 2018), though with mixed evidence (Magalhaes et al. 2018)
- Cardiovascular and cerebrovascular disease in a prospective cohort study (Downward et al. 2018)
- Cardiovascular mortality (Ostro et al. 2015; Hennig et al. 2018)

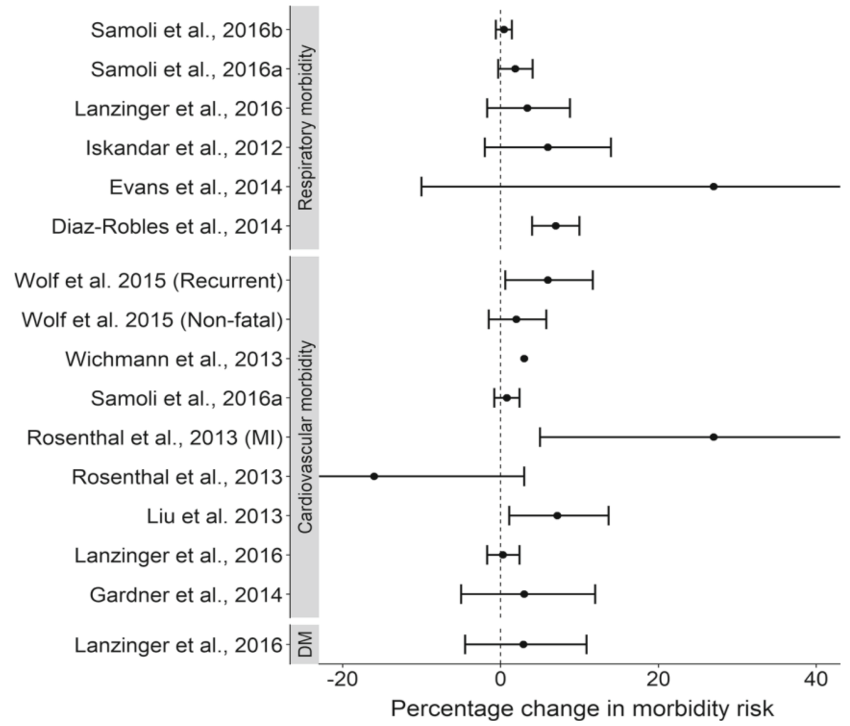
Cardiovascular epidemiology fairly consistent and generally positive, ranging from pre-clinical outcomes to mortality

# UFP Respiratory effects

UFP during second trimester of pregnancy vs. childhood asthma incidence (Lavigne 2019)



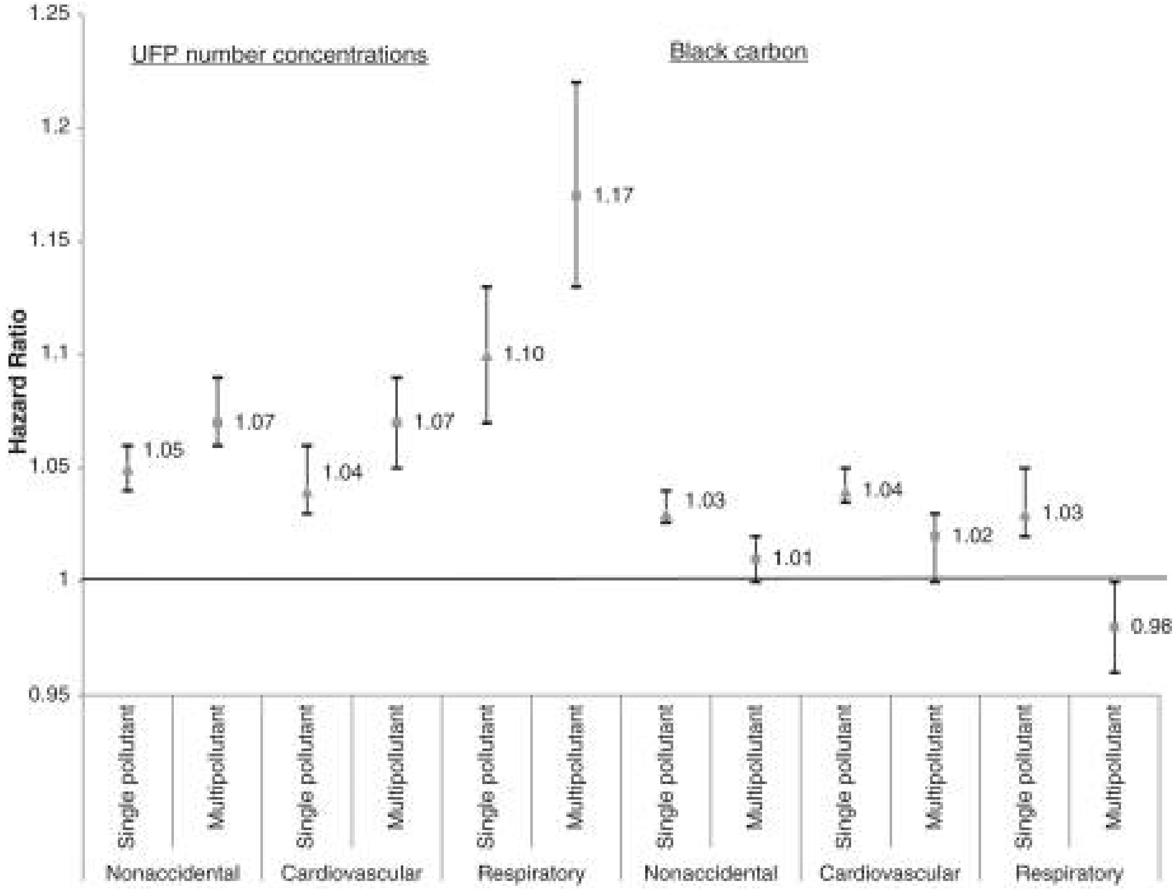

Cause-specific emergency department visits or hospital admissions (Ohlwein 2019)




Respiratory epidemiology has some inconsistencies (i.e., associations with lung function) but with robust indication of effects on individuals with lung disease

# UFP Health – Mortality Studies (Weichenthal et al. 2024)

Statement Figure: Adjusted hazard ratios for UFP number concentrations (per 10,000 particles/cm3) and black carbon (per 500 ng/m3) and selected mortality outcomes using the combined exposure model with backcasting.




Weichenthal S, Lloyd M, Ganji A, Simon L, Xu J, Venuta A, Schmidt A, Apte J, Chen H, Lavigne E, Villeneuve P, Olaniyan T, Tjepkema M, Burnett RT, Hatzopoulou M. Long-Term Exposure to Outdoor Ultrafine Particles and Black Carbon and Effects on Mortality in Montreal and Toronto, Canada. Res Rep Health Eff Inst. 2024 Jul;2024(217):1-63. PMID: 39392111; PMCID: PMC11480997.

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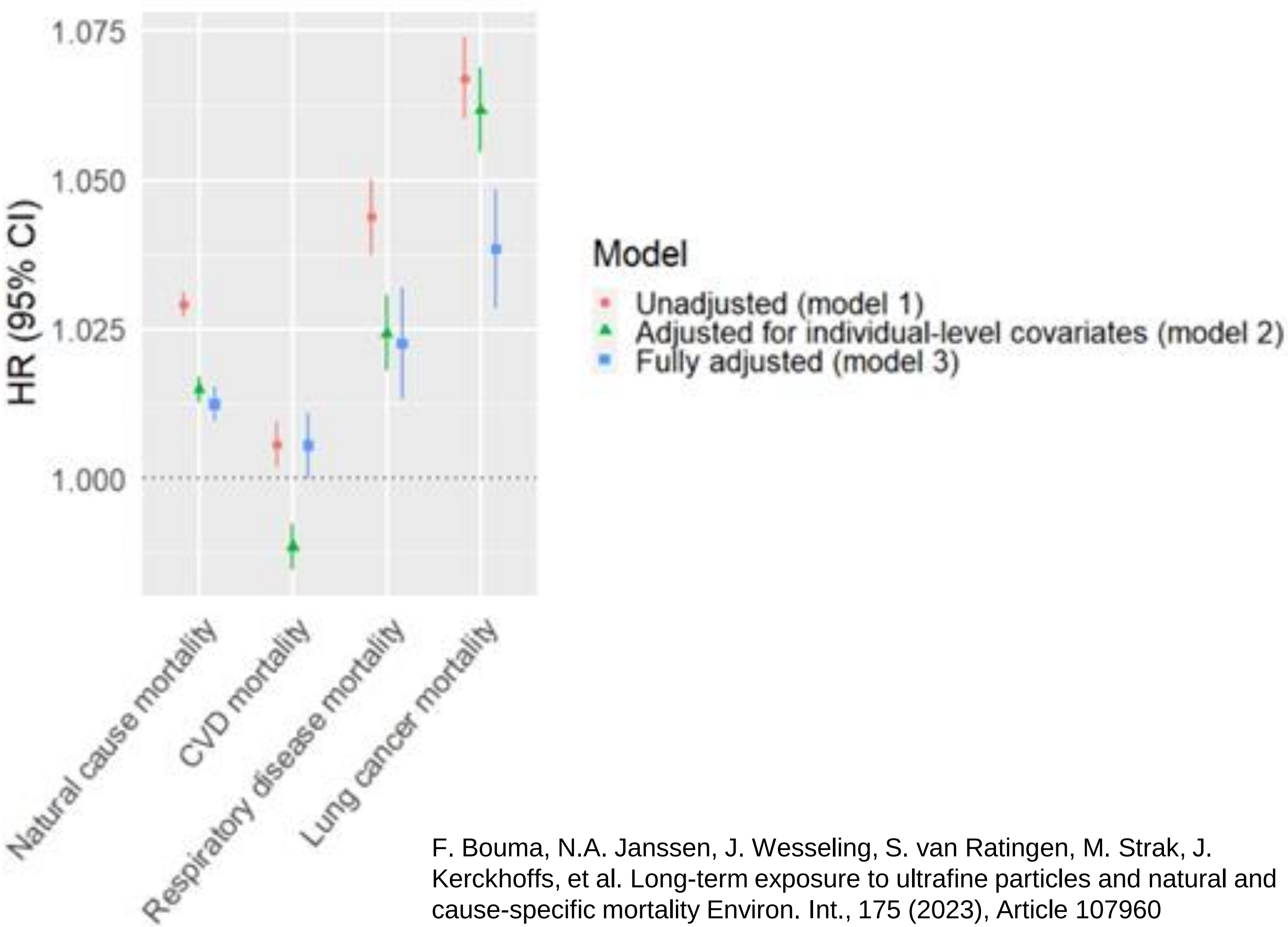
# UFP Health – Mortality Studies (Bouma et al. 2023)

Figure 1. Association of annual average UFP exposure and natural cause and cause-specific mortality per IQR of **2723 particles/ cm³**.




F. Bouma, N.A. Janssen, J. Wesseling, S. van Ratingen, M. Strak, J. Kerckhoffs, et al. Long-term exposure to ultrafine particles and natural and cause-specific mortality Environ. Int., 175 (2023), Article 107960

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# Sustainable Aviation Fuel (SAF) Co-Benefits

"Currently, **a 50 % SAF blend**, such as those using Hydroprocessed Esters and Fatty Acids (HEFA) or Fischer-Tropsch (FT) fuels, **can reduce particulate matter, including UFP, emissions by roughly 50 %**, depending on the aromatic content and fuel properties. (Beyersdorf et al., 2014; Corporan et al., 2010; Durdina et al., 2021; Harlass et al., 2024; Schripp et al., 2022)"

– Blanco et al. 2025

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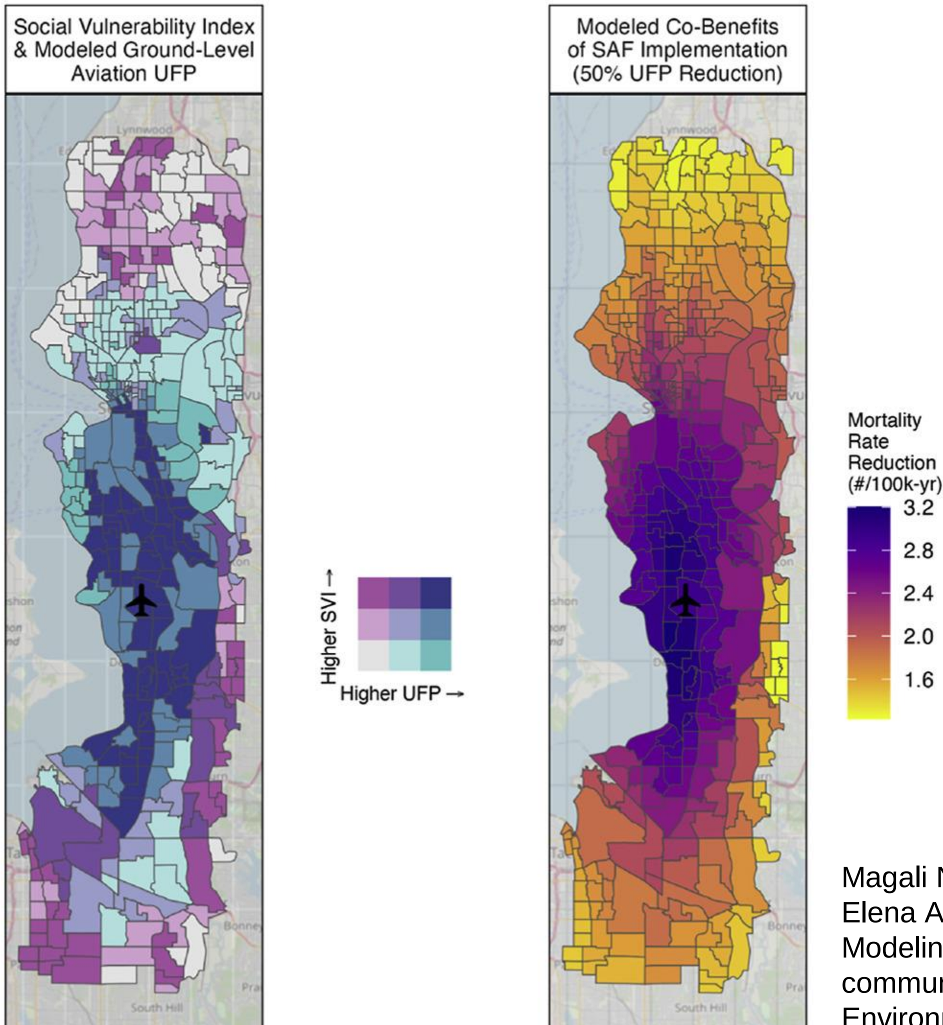
# Quantifying health benefits of sustainable aviation fuels: Modeling decreased ultrafine particle emissions and associated impacts on communities near the Seattle-Tacoma International Airport

Magali N. Blanco [a,*], Melissa Sui-hui Louie [b], Ningrui Liu [a], Shruti Khadka Mishra [b], Elena Austin [a]




- Ultrafine particles (UFP) are linked to adverse outcomes, including mortality.
- Sustainable aviation fuel (SAF) has the potential to reduce aviation-related UFP.
- Lower UFP from SAF adoption was associated with mortality reductions near SEA-TAC.
- The method is adaptable for evaluating aviation-related health impacts elsewhere.

Magali N. Blanco, Melissa Sui-hui Louie, Ningrui Liu, Shruti Khadka Mishra, Elena Austin. Quantifying health benefits of sustainable aviation fuels: Modeling decreased ultrafine particle emissions and associated impacts on communities near the Seattle-Tacoma International Airport. Atmospheric Environment, Volume 355, 2025, 121280, ISSN 1352-2310,

# Health Impact Assessment Methods

1) **Define the Exposure Area**: Establish a geographic study area centered around the airport that is defined using atmospheric dispersion modeling (AERMOD) estimated non-zero ground-level CO air quality concentrations from aircraft landing and take-off activities.

2) **Use Census to Obtain Population Data**: Using Census and American Community Survey (ACS) counts on relevant demographic data for census tracts in the exposure area as well as baseline mortality information from CDC Wonder to allow for spatially granular assessments.

3) **Generate Baseline and Control Scenario Exposure Surfaces**: Using an aviation-related UFP exposure surface calibrated from CO using a combination of AERMOD, flight count information, and ground-level UFP measurements. You can develop UFP control scenarios that could result from SAF adaptation.

4) **Estimate Risk**: Can use a concentration-response function from the literature to estimate mortality reductions resulting from control scenarios for the overall population as well as disadvantaged groups.

Adapted from Blanco et al. 2025

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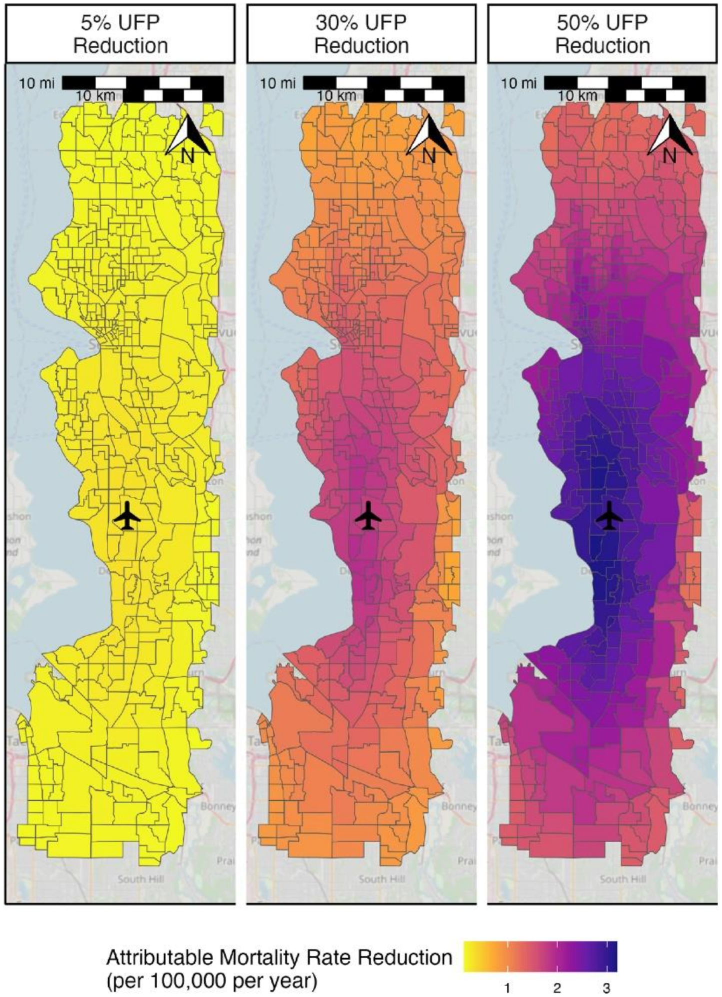


- 5% UFP reduction: Mortality case reductions averaged 3.1/100,000 persons (95 % range: 2.5–3.7)
- 50% UFP reduction: Mortality Case Reduction 31.0/100,000 per year (24.6–37.4) for a 50 % reduction

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# Improve SAF Health Co-Benefits Analysis

**Monitoring Near Airports**

- Empirical validation of air quality reductions in communities.
- Collection of UFP and other air quality data in communities near airports where SAF integration is occurring at different levels could improve modeling.

**SAF Reduction Modeling**

- Areas with UFP monitored data (BOS, LAX) would be able to also conduct UFP reduction scenarios for SAF.
- Development of a UFP AERMOD capability would allow for national expansion.

**Aviation-Specific Health Benefit Calculations**

- Aviation specific air quality health analyses could improve the concentration response functions and allow for more direct understanding of health benefits.

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