A Unified Global Framework for Indoor Air Quality

GO AQS

GLOBAL OPEN AIR QUALITY STANDARDS

Addressing Submicron Particles and Standardizing Universal Health Metrics

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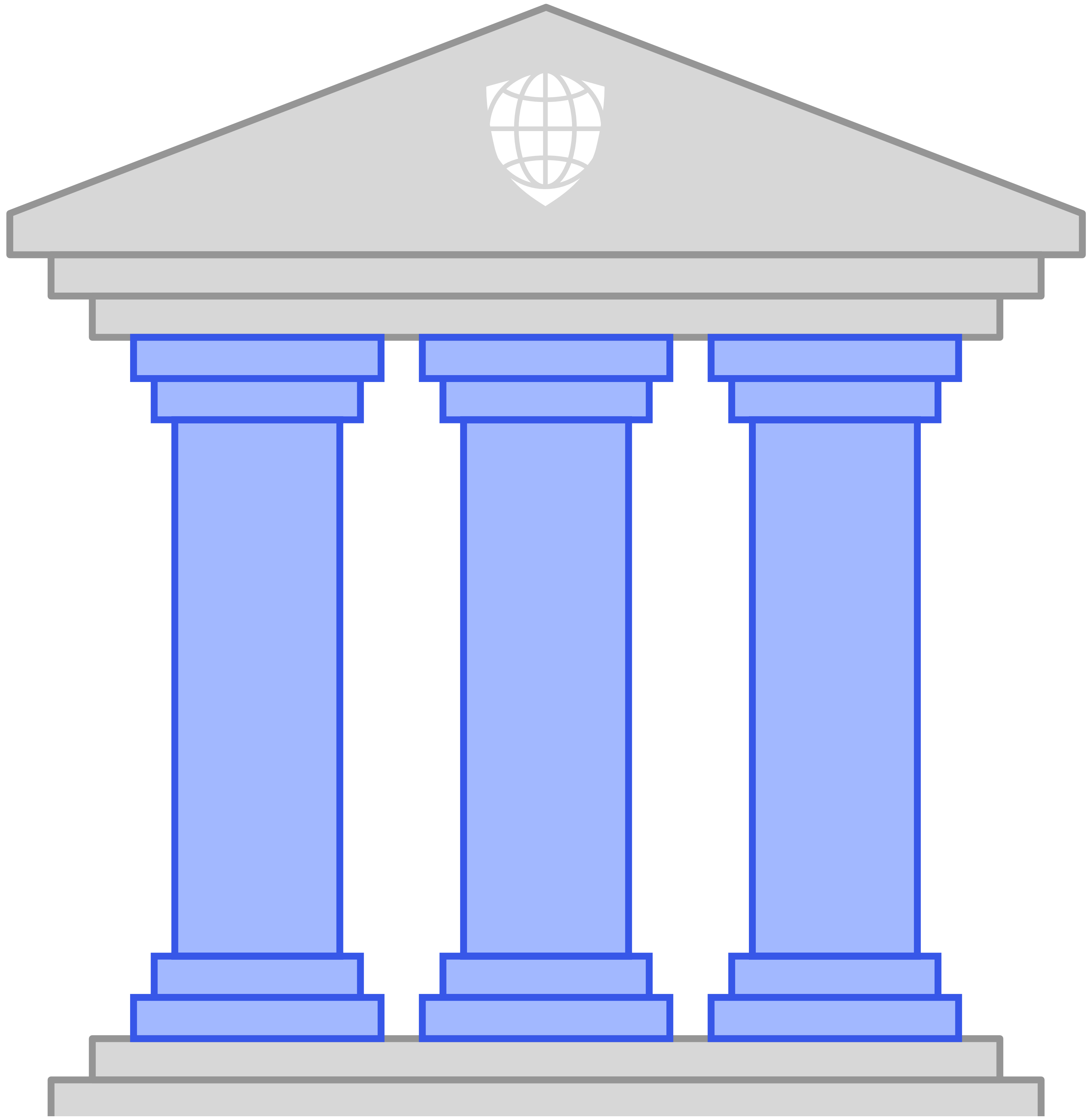
Agenda

- GO AQS Pillars
- GO IAQS Overview
- Ultrafine Particles (UFP) Findings
- GO AQS Recommendations for UFP

IAQ PILLARS



Air Pollution Limits

Establishes health-protective thresholds for indoor pollutants.

Indoor Air Quality Score

Provides a universal metric for understanding air quality in a proactive manner.

IAQ Policies

Develops universally-accepted regulatory frameworks for implementing air quality standards.

A TWO-TIER IAQ STANDARD

GO IAQS proposal is a two-tier system that provides simplicity and relevance to our ecosystem of individuals and technology integrators.

GO IAQS Starter

Provides accessible entry-level AQ guidance

GO IAQS Ultimate

Provides a complete guidance for more complex AQ conditions

GO IAQS STARTER

The GO IAQS Starter offers an accessible point for those who may currently lack the financial or technical resources for stricter protocols. It is a thoroughly investigated compliance framework, based on robust scientific knowledge that requires minimal resources for achieving a positive impact.

GO IAQS Starter Guidelines	$PM_{2.5}$	CO_2
24-hour	25 µg/m^3	
Threshold		1000 ppm

GO IAQS ULTIMATE

The GO IAQS Ultimate is a detail AQ framework, developed for complex buildings environments that seek to offer the highest performance and health protection to their occupants. Based on comprehensive emerging research, it accounts for critical pollutants that have been identified as detrimental to human health.

GO IAQS Ultimate Guidelines	$PM_{2.5}$	CO_2	O_3	CH_2O	CO	NO_2	Radon
1-hour	15 μg/m^3				31 ppm	106 ppb	
8-hour			51 ppb		9 ppm	21 ppb	
Threshold		800 ppm		27 ppb			100 Bq/m^3

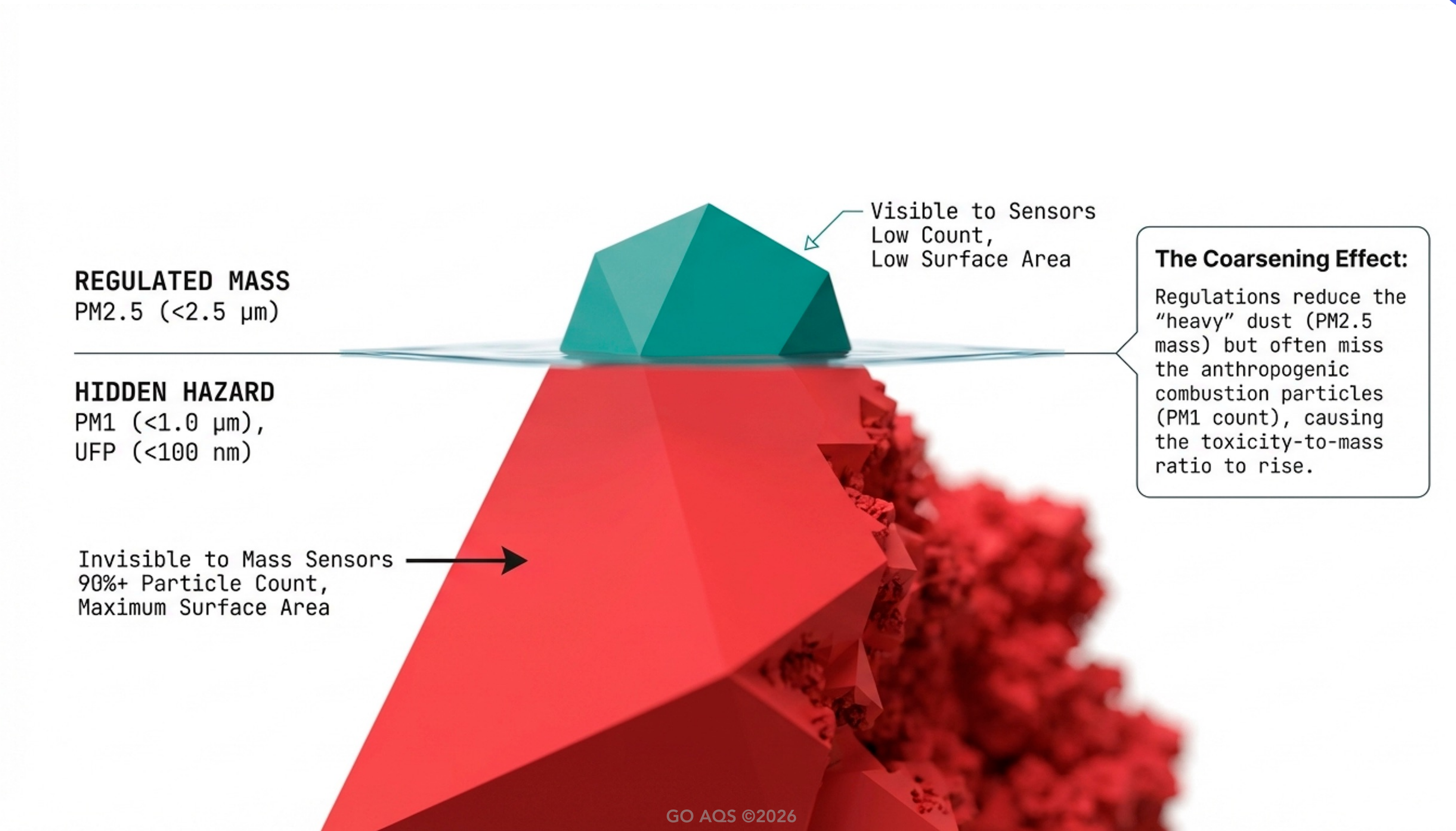
GO IAQS AIR QUALITY SCORE

Our IAQ Score is single-tier scoring measurement system that translates complex air pollution data into a user-friendly score. It consolidates measurements of various pollutants, including gases and particulate matter into a single and intuitive value, ranging from 10 (**Good**) to 0 (**Unhealthy**).

Description	Number Score	Letter Score	Health advice
Good	10 - 8	A	Ideal air quality. Enjoy activities.
Moderate	7- 5	B	Reduce sources of pollution. Cut back or reschedule strenuous activities indoors. Ventilate and/or filtrate.
Unhealthy	4 - 0	Z	Leave the room. Avoid all physical activities indoors. Wear N95/FFP3 masks and use personal or central air filtration systems in case of particle pollution or high carbon dioxide levels. Ventilate.

Ultrafine Particles Working Group

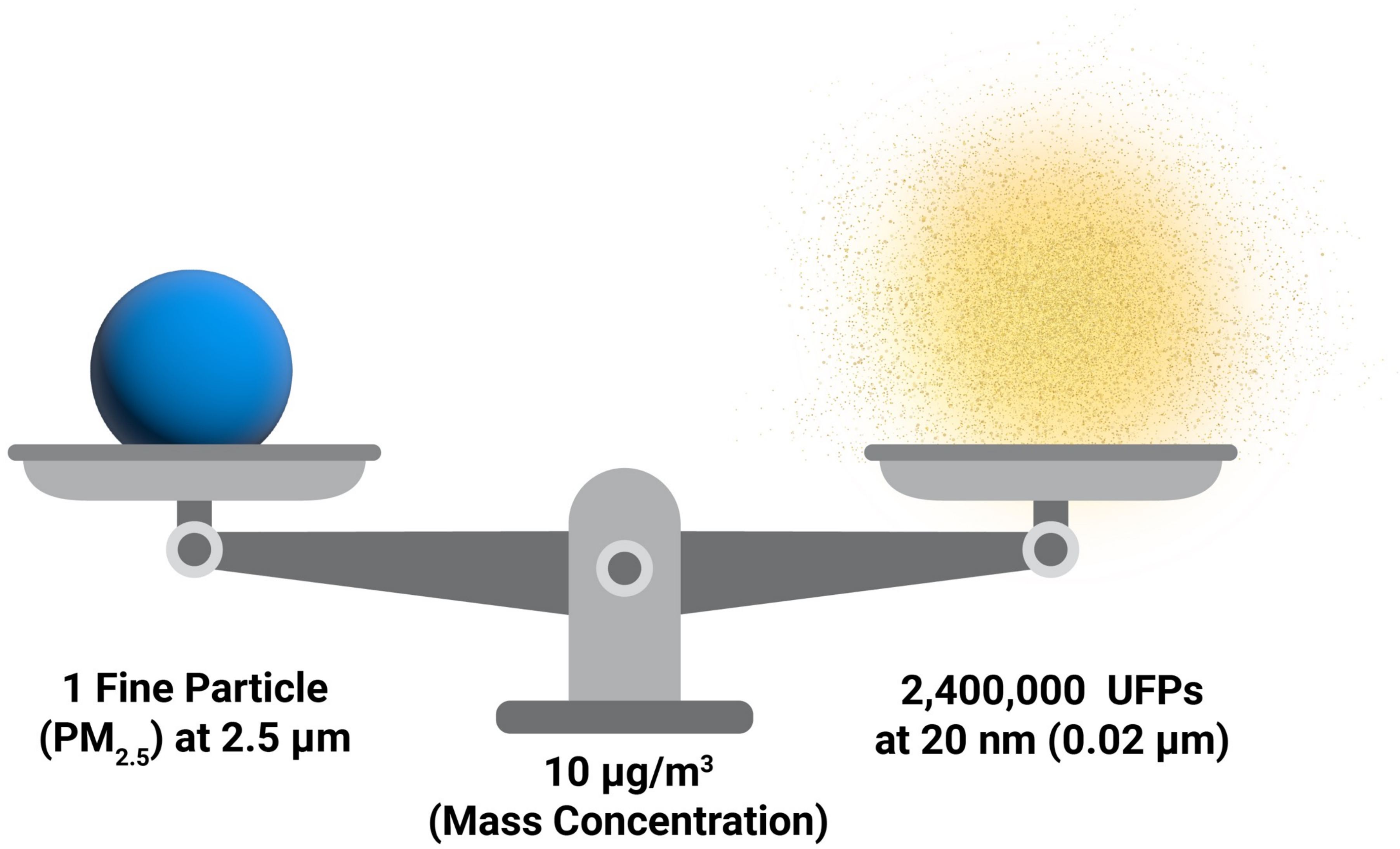
Ultrafine Particles



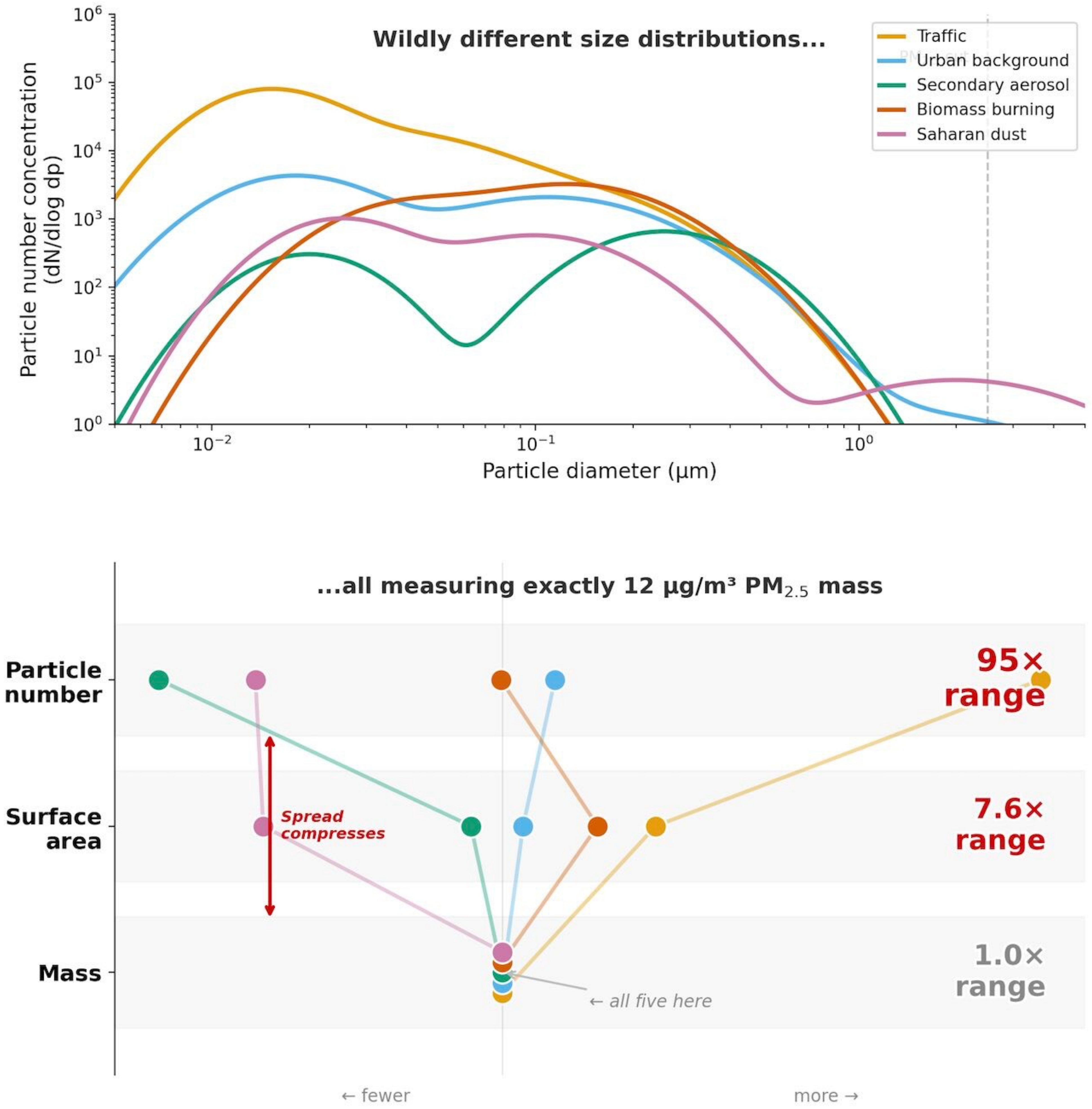
Ultrafine Particles

One vs. 2.4 Million: The Scaling Paradox

Same Mass, Massive Difference in Count



The 1-to-2,400,000 Ratio



Schraufnagel, D. E. (2020b). The health effects of ultrafine particles. Experimental & Molecular Medicine, 52(3), 311–317. https://doi.org/10.1038/s12276-020-0403-3

Size distribution parameterized from published sources profiles (Morawska et al. 2008; Seinfeld & Pandis 2016; others) All constrained to 12 µg/m³ $PM_{2.5}$ mass.

Ultrafine Particles

Importance and Necessity: The majority of the GO AQS Particulate Matter working group considers submicron and ultrafine particle monitoring important. They emphasize that mass-based sensors (like $PM_{2.5}$) often fail to detect major spikes in particle counts from indoor sources like 3D printers, laser printers, or woodsmoke.

Health Risk versus $PM_{2.5}$: 74% of respondents agree that ultrafine particle counts provide a more accurate health diagnostic than $PM_{2.5}$. *Experts highlighted that standard $PM_{2.5}$ detectors often have no sensitivity for particles smaller than 300 nanometers.*

Technological Readiness: 53% of the group feels that technology for ultrafine particles is not yet advanced enough for mass-market use or continuous monitoring indoors. The high cost of specialized monitors (often ranging from 5,000 to 15,000 Euros) is cited as a significant barrier.

Preferred Metrics: The dominant recommendation (68%) is particles per cubic centimeter (p/cm^3). Some experts also advocate for Lung-Deposited Surface Area (LDSA) as a more relevant metric for assessing toxicological impact.

Ultrafine Particles

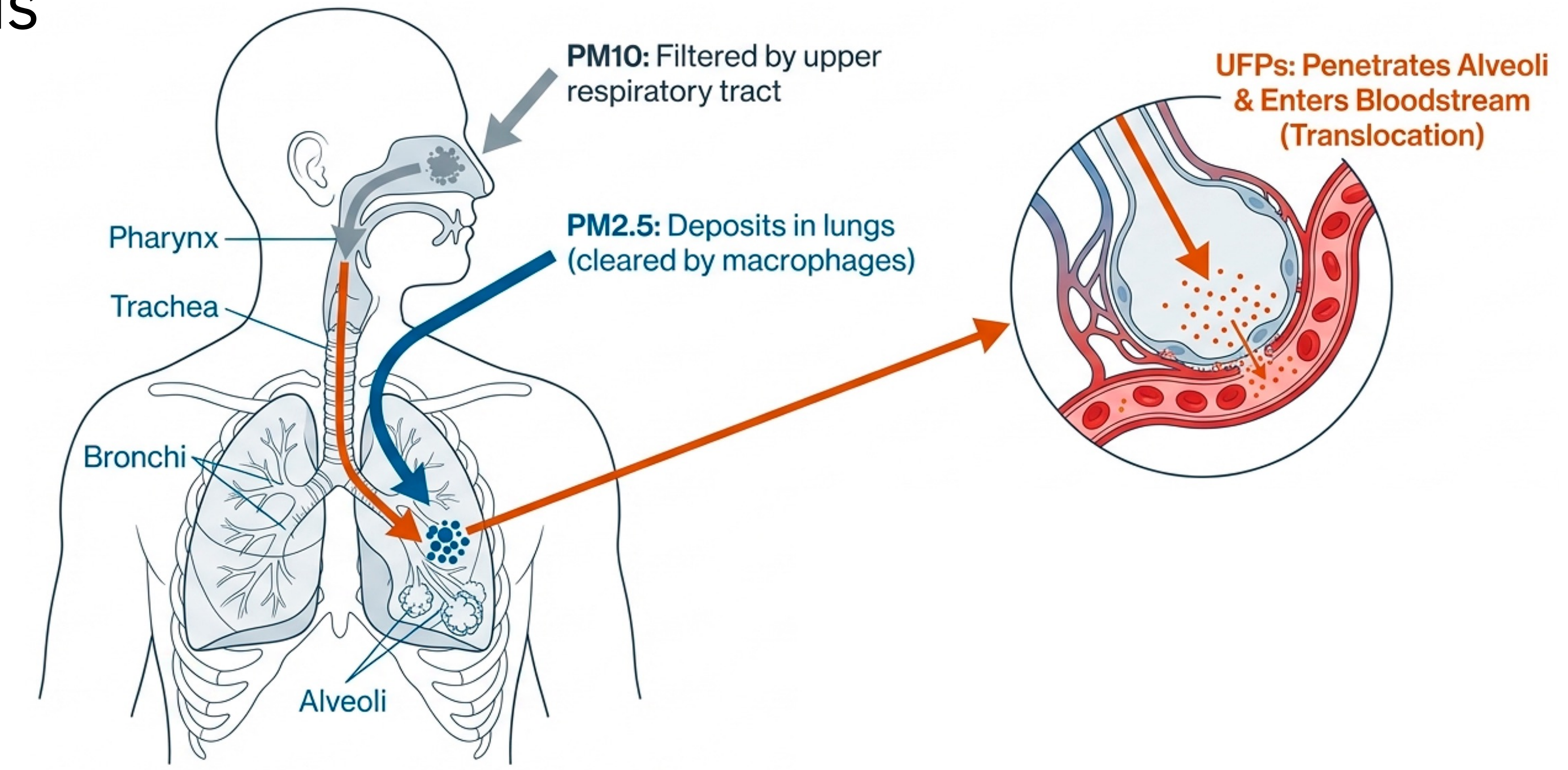
Severe Inflammation: Chronic exposure to UFPs induces severe lung inflammatory responses, massive macrophage infiltration, and tissue remodeling, such as the thickening of alveolar walls and the formation of cystic lesions[1].
Higher Sensitivity: Cell models representing asthma and COPD show a higher inflammatory response and more significant gene deregulation when exposed to UFPs compared to healthy cells[2].

Translocation: Once inhaled, a fraction of UFPs can cross the alveolar-capillary barrier and travel to major organs, including the brain via the olfactory nerves. Chronic exposure is linked to pulmonary inflammation, ischemic cardiovascular disease, hypertension, diabetes, and lower birth weights[3].

90% of traffic-related UFPs are deposited in the respiratory system, with a preference for the alveolar region. Due to nanoscale size, they evade macrophage clearance.

Source: Ali et al.; Hsiao

Cancer Risk: UFP-induced Excess Lifetime Cancer Risk (ELCR) far exceeds that of coarse particles. Nine-year-old children were found to have the highest simulated cancer risk due to higher inhalation doses and lung deposition efficiencies compared to adults[4, 5].



1. https://doi.org/10.3390/ijerph16071210
2. https://doi.org/10.1016/j.envres.2019.108538
3. https://doi.org/10.1038/s12276-020-0403-3
4. https://doi.org/10.1016/j.jhazmat.2026.141024
5. https://doi.org/10.1016/j.jaerosci.2017.10.006

Ultrafine Particles

Indoor domestic activities can produce UFP concentrations that reach levels well above those encountered in typical urban outdoor environments[1].

Highest Indoor Sources: Grilling food and using hair dryers lead to the highest levels of indoor exposure, with hair dryers yielding the highest average peak concentrations of any domestic process. Other significant indoor sources include toasting bread, frying, burning candles or incense, and using laser printers[2].

Hospital Environments: In operating rooms, smaller UFPs exhibit lower air exchange rates due to stronger Brownian motion, making them more difficult to remove than larger particles[3].

1. https://doi.org/10.1038/s12276-020-0405-1
2. https://doi.org/10.1016/j.scitotenv.2023.166947
3. https://doi.org/10.1016/j.buildenv.2023.110870

Ultrafine Particles

The research highlights a fundamental distinction between measuring particles by mass concentration and number concentration, particularly regarding ultrafine particles (UFPs). While traditional air quality standards for larger particles rely on mass, the sources argue that particle number concentration (PNC) in p/cm^3 is the essential metric for characterizing UFPs.

Instead of proposing a single safety threshold, the researchers discuss why current standards are insufficient and suggest technical improvements for future regulations. Regulating $PM_{2.5}$ mass may not significantly reduce UFP levels, as the two are often not well-correlated.

Reference Values: In the absence of regulatory limits, some researchers recommend that background concentrations (levels measured just before an activity starts) should be systematically reported as a reference value to make measurements more meaningful[1].

1. https://doi.org/10.1016/j.scitotenv.2023.166947

Ultrafine Particles

Rural Background[1]: Approximately 2,610 p/cm^3.

Global Urban Mean[1]: Approximately 10,760 p/cm^3.

Roadside Hotspots[1]: Concentrations often reach 48,180 p/cm^3 and can be more than 10x higher than background levels.

Extreme Indoor Events[2]: Certain domestic activities, such as candle burning, have been recorded at levels as high as 2.3 million p/cm^3.

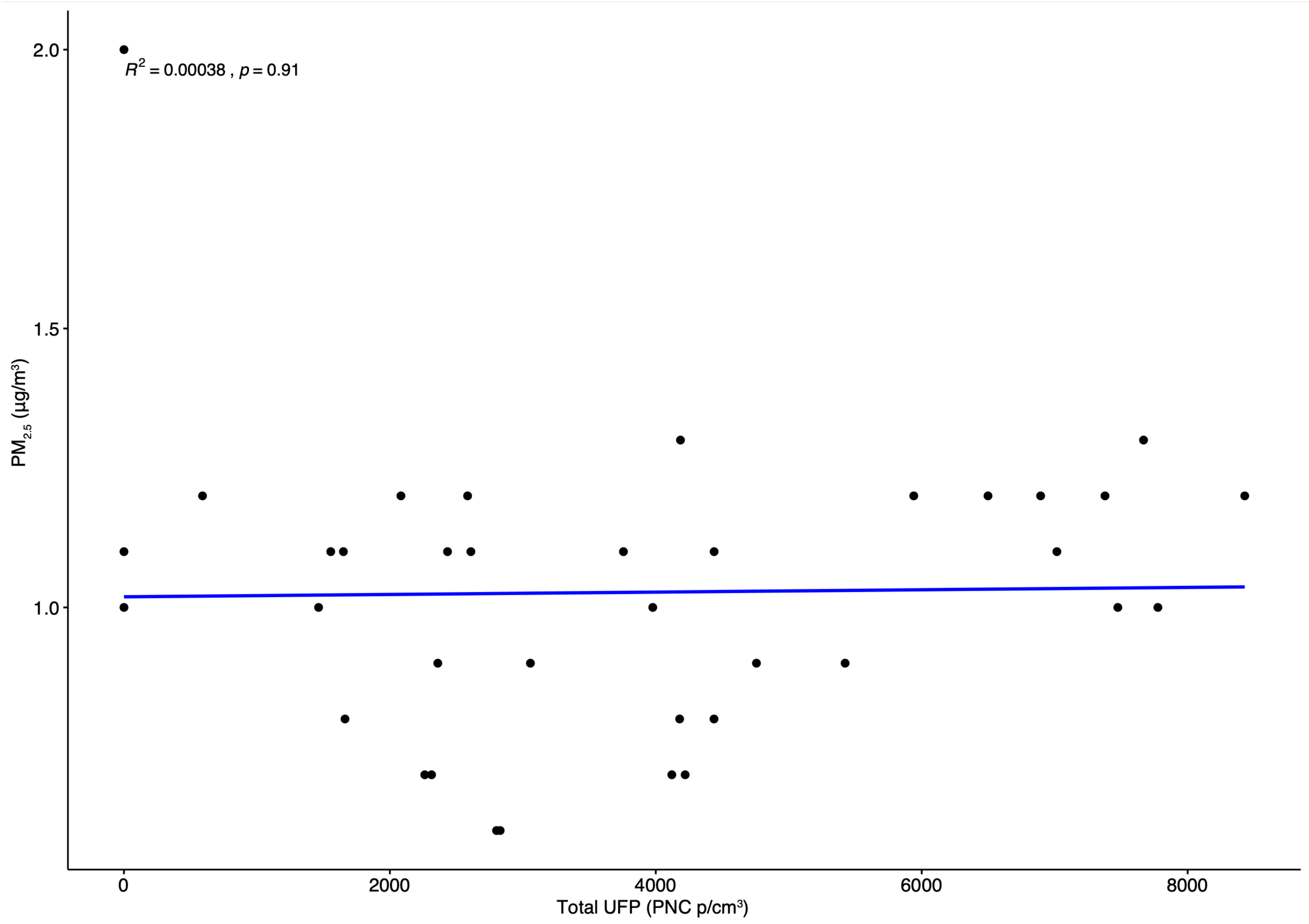
WHO good practice recommendations:

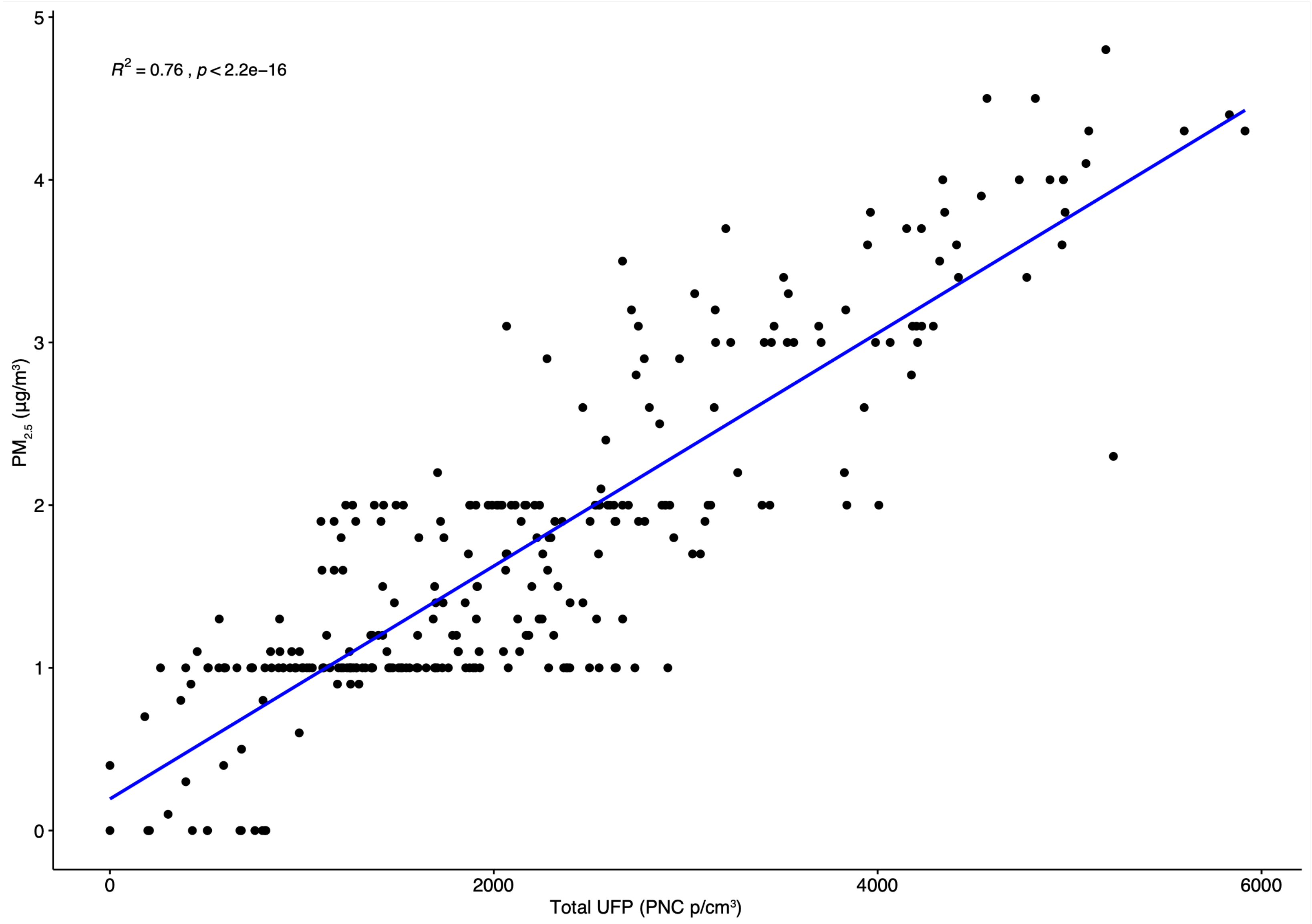
- Low PNC: $<$ 1,000 p/cm^3 (24-hour mean)
- High PNC: $>$ 10,000 p/cm^3 (24-hour mean)
- High PNC: $>$ 20,000 p/cm^3 (1-hour mean)

1. https://doi.org/10.1038/s12276-020-0403-3
2. https://doi.org/10.1080/10643389.2020.1831359

Ultrafine Particles

Indoors



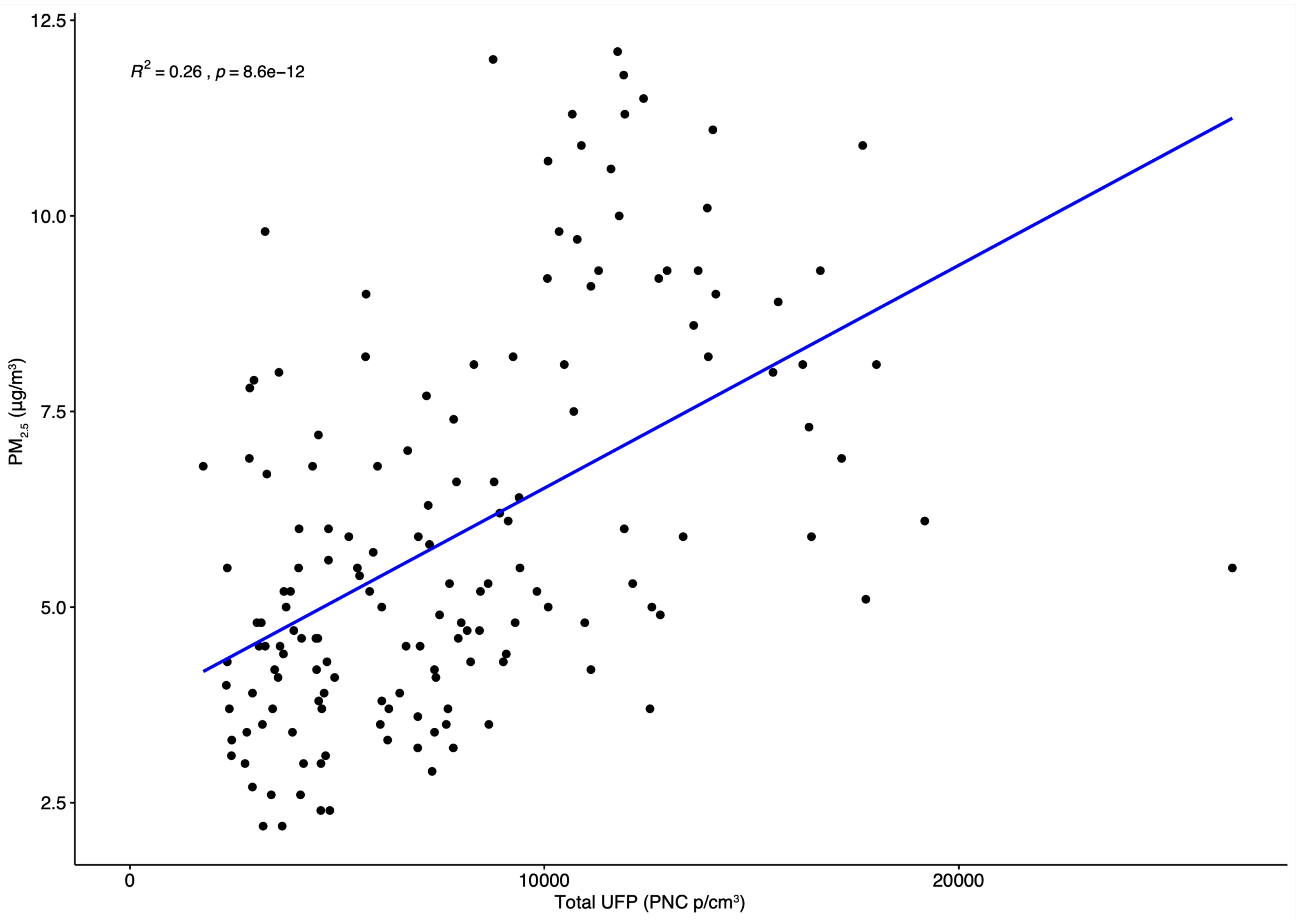


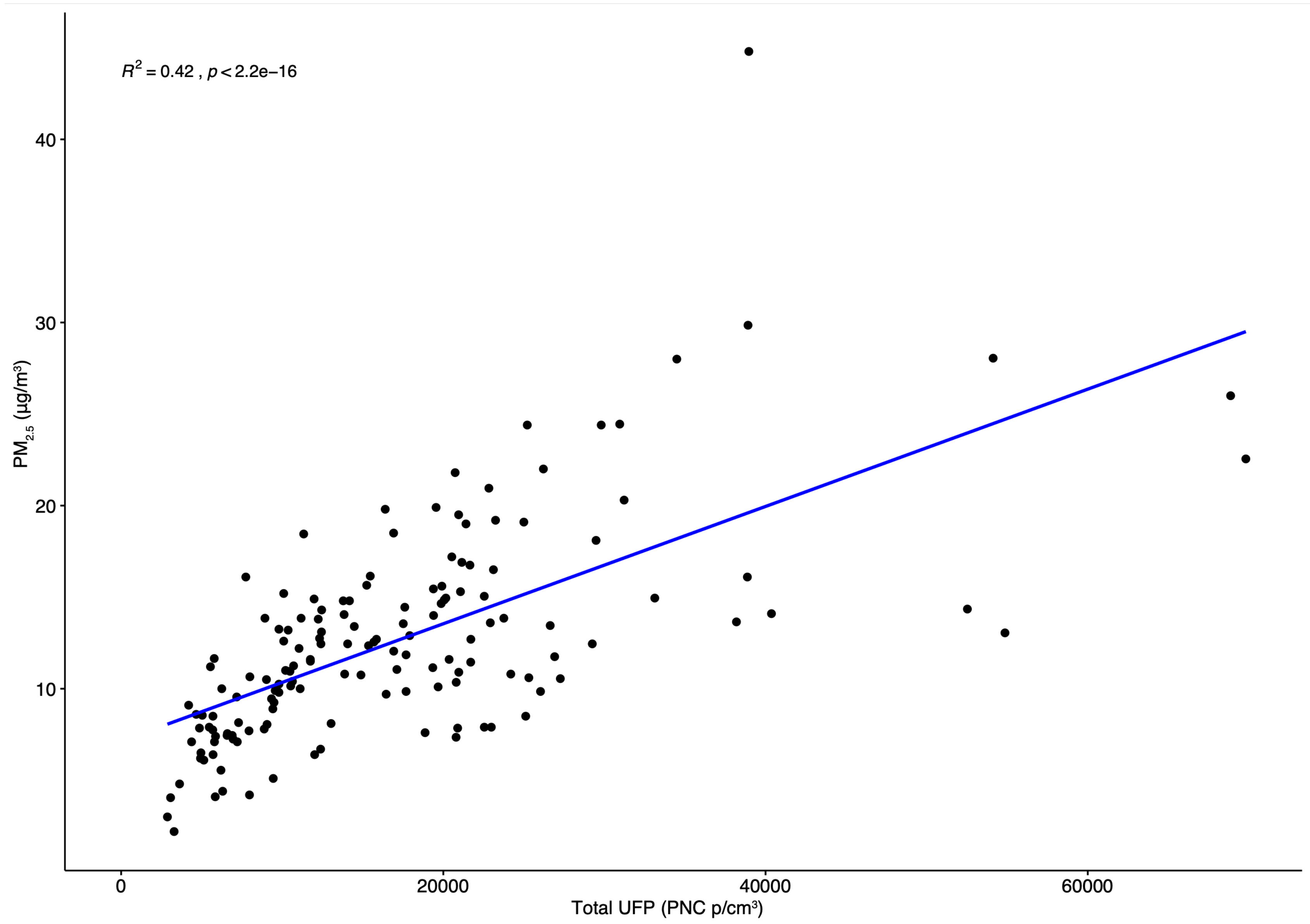
Unpublished data tell us that the correlation (r^2 = 0.00038) between UFP and $PM_{2.5}$ is non-existent in indoor environments that rely on natural ventilation as they have a complex world of influence of atmospheric conditions and sources of particulates.

In another experiment where the indoor space got unoccupied for 72h and the HVAC system was turned off there was a strong correlation (r^2 = 0.76) between UFP and $PM_{2.5}$ due to the fact that there was barely any air movement and source of particulates.

Ultrafine Particles

Outdoors





Unpublished data tell us that the correlation (r^2 = 0.26 - 0.42) between UFP and $PM_{2.5}$ in two Spanish cities is weak due to the complex world of atmospheric conditions and sources of particulates outdoors.

GO AQS Recommendations for UFP

Roadmap for Monitoring

Technology: Use existing technologies, from low-cost and reference-grade CPC to diffusion charging solutions.

Unit of Measurements: Use (p/cm^3) as the primary metric for both submicron and ultrafine particles. Additionally, adopt Lung Deposited Surface Area (LDSA) when possible as a more toxicologically relevant metric that combines particle size and deposition fraction in the lungs (Alveolar LDSA and Total Lung LDSA).

Terminology: Avoid confusion with mass-based “PM” standards, use “Particle Number Count (PNC)” to be explicit about what is being measured.

Particle Size Range: In general, when we refer to UFP we generally talk about particles with a diameter of less than 0.1µm (100 nm). However, in some cases instruments can measure bigger size particles but they won’t add up significant more particles in the total particle number concentration. The lower detection limit should be 10 nm which aligns with modern automotive and atmospheric monitoring standards.

Collaborative Data Collection: The group invites the research community to share measurements from diverse indoor environments (schools, offices, homes) to help us and epidemiologists determine safe levels if any.

We share the same air;
Let's share the same standards.

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Thank you!

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