Short- and long-term effects of air pollution on people's health. Special focus on children, the elderly, and population with respiratory problems.

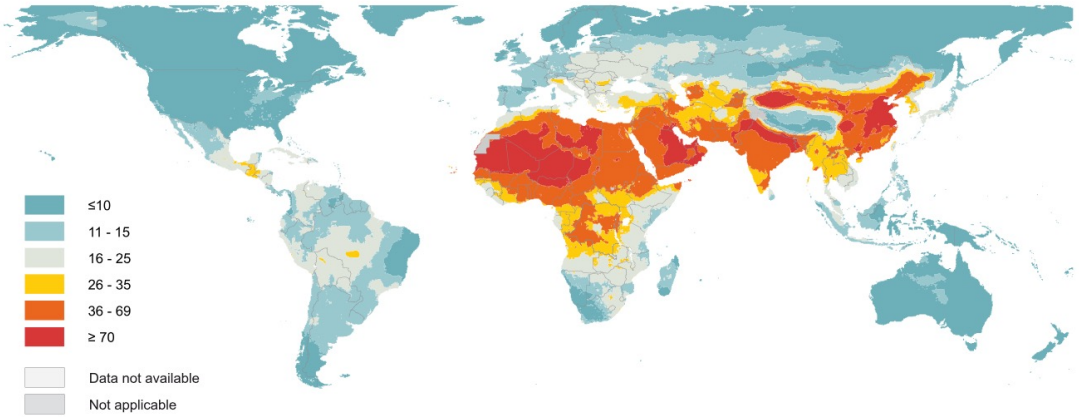
Antonio J. Signes Pastor

Co-funded by the European Union

Why this matters

- Air pollution is nearly universal exposure
- $PM_{2.5}$ & NO_2 drive major cardiorespiratory burdens
- High-risk groups bear disproportionate harm

Figure 9: Global map of modelled annual median concentration of $PM_{2.5}$, in µg/m³



$PM_{2.5}$: Fine particulate matter of 2.5 microns or less.

@who2016_global_air_pollution

Objectives & flow

- Define pollutants & pathways
- Acute responses in vulnerable groups
- Lifecourse effects on asthma/COPD
- Early-life lung & immune development
- SES/comorbidity modifiers in older adults
- Benefits of pollution reduction & policies



Key pollutants: $PM_{2.5}$

- Particles ≤2.5 μm reach alveoli & bloodstream
- Sources: combustion, traffic, industry, biomass
- Outcomes: inflammation, oxidative stress, vascular dysfunction

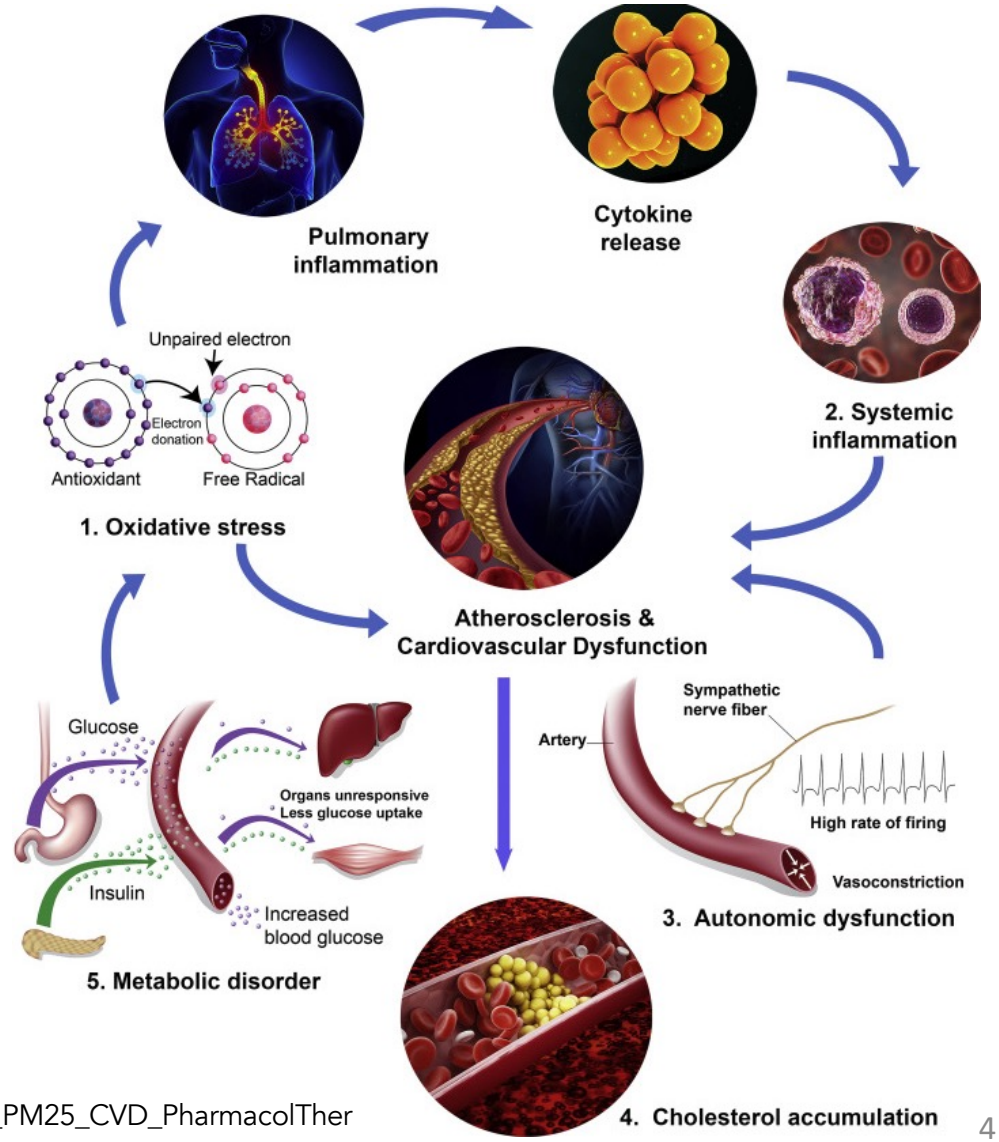
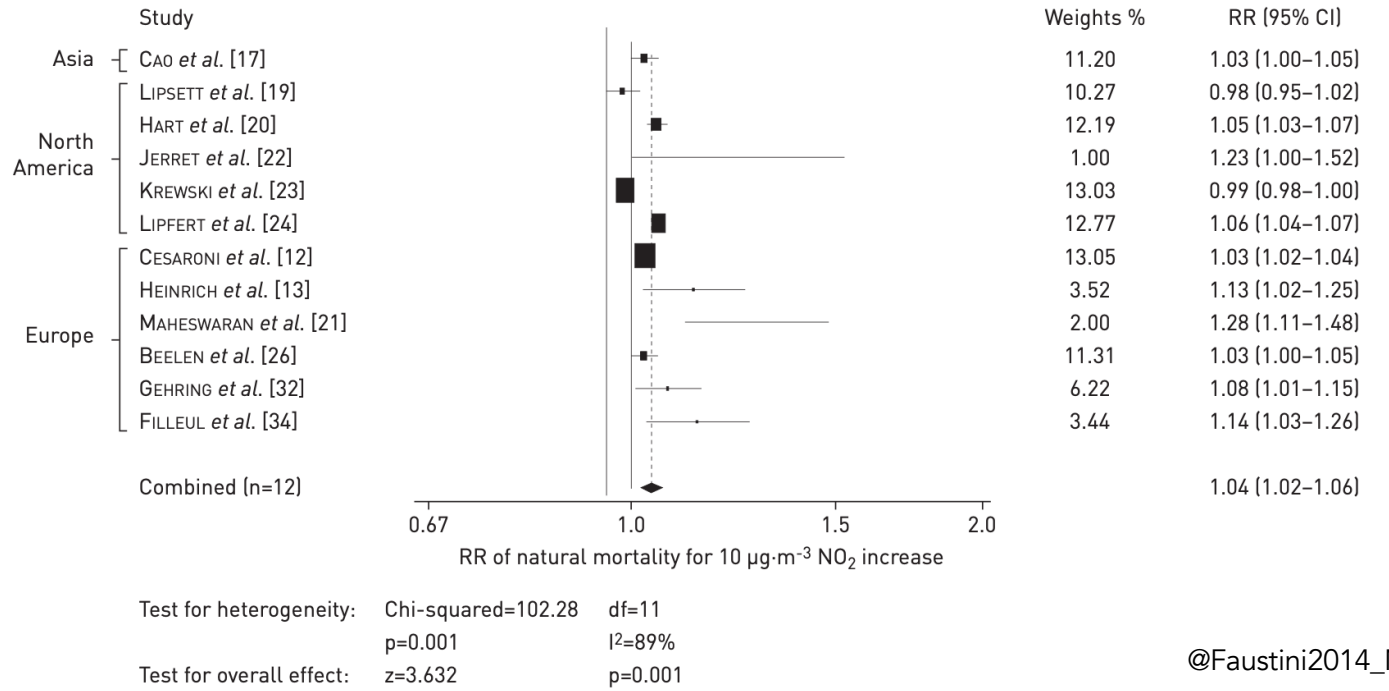


Fig. 1. Schematic representation of the mechanisms contributing to particulate matter (PM)-associated cardiovascular diseases, including 1) oxidative stress and decreased pulmonary barrier function, 2) pulmonary and systemic oxidative stress, 3) autonomic dysfunction, 4) cholesterol accumulation, and 5) metabolic disorder.

@Aryal2021_PM25_CVD_PharmacolTher

Key pollutants: NO_2

- Traffic-related gas; marker for near-road mixtures
- Potent airway irritant; amplifies allergic responses
- Often co-occurs with PM exposure

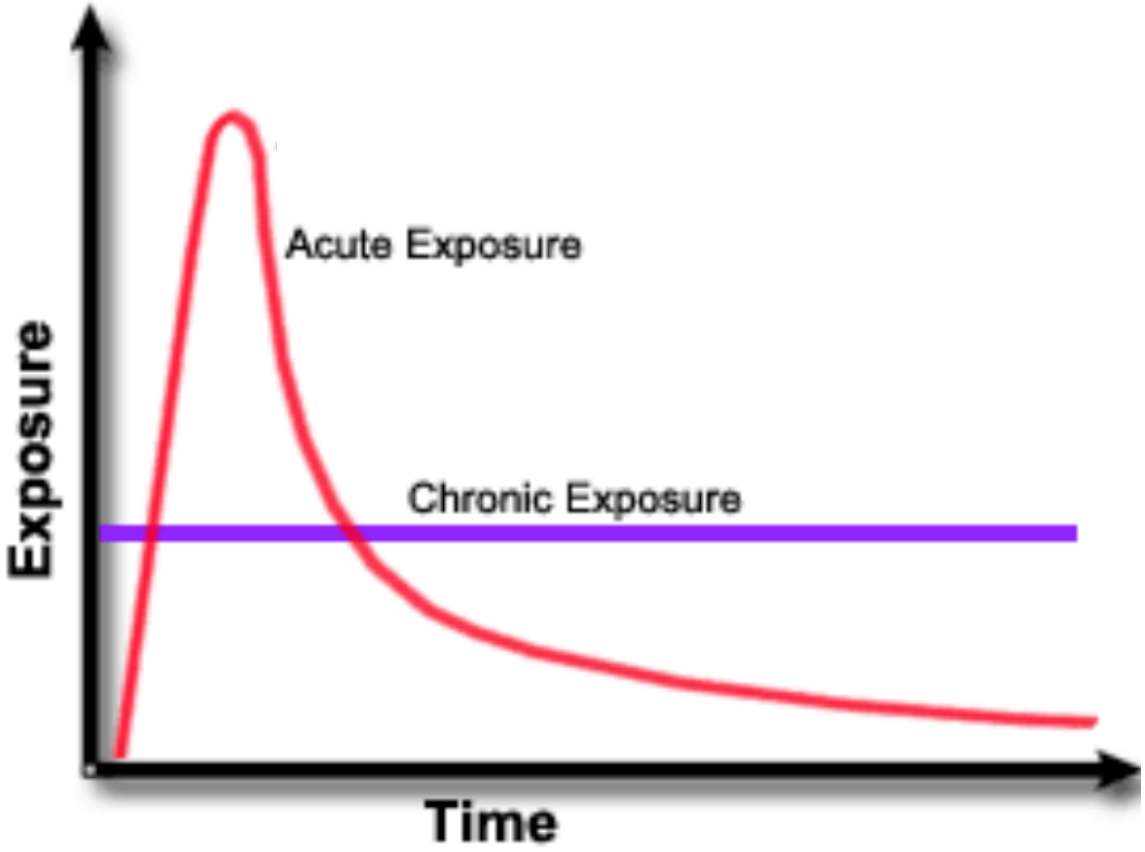


@Faustini2014_NO2_Mortality

FIGURE 1 Relative risks (RR) of natural mortality with increasing chronic exposure to nitrogen dioxide (NO_2). df: degrees of freedom; I^2: inconsistency.

Acute *vs.* chronic exposure

- Acute: hours–days → symptoms, triggers, ER visits
- Chronic: years → incidence/progression, mortality
- Interact: repeated acute hits accelerate chronic decline



Vulnerable groups at a glance

- Children
- Older adults
- People with chronic respiratory disease (asthma, COPD – Chronic Obstructive Pulmonary Disease)



https://www.who.int/health-topics/children-environmental-health#tab=tab_1

Acute responses: Children

- Higher dose per kg (higher minute ventilation)
- Transient lung-function drops; wheeze/asthma flares
- Increased risk of acute lower respiratory infections (ALRI)



@Sly2008_Children_EnvironmentalPollutants

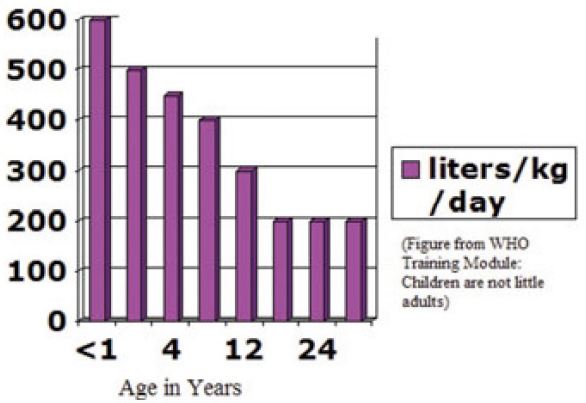


Figure 3. Minute ventilation in liters per kilogram body weight versus age in years. (In color in *Annals* online.)

Children's Health and the Environment: Public Health Issues and Challenges for Risk Assessment

Philip J. Landrigan,[1] Carole A. Kimmel,[2] Adolfo Correa,[3] and Brenda Eskenazi[4]

[1]Department of Community and Preventive Medicine, Mount Sinai School of Medicine, New York, New York, USA; [2]National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, USA; [3]National Center on Birth Defects and Developmental Disabilities, Centers for Disease Control and Prevention, Atlanta, Georgia, USA; [4]Maternal and Child Health and Epidemiology, Berkeley School of Public Health, University of California, Berkeley, California, USA

@Landrigan2004_ChildHealth_Environment

Acute responses: Older adults

- Lower physiologic reserve; endothelial dysfunction
- Greater dyspnea, cough; more persistent decrements
- Short-term upticks in ischemic/arrhythmic & cerebrovascular events



Review

The aging lung: Physiology, disease, and immunity

Jaime L. Schneider,[1,2,3] Jared H. Rowe,[4] Carolina Garcia-de-Alba,[5] Carla F. Kim,[5,6,7,*] Arlene H. Sharpe,[8,9,10,*] and Marcia C. Haigis[1,*]

[1]Department of Cell Biology, Blavatnik Institute, Harvard Medical School, Boston, MA 02115, USA
[2]Dana Farber Cancer Institute, Boston, MA 02115, USA
[3]Massachusetts General Hospital Cancer Center, Boston, MA 02114, USA
[4]Division of Hematology Boston Children's Hospital and Division of Pediatric Oncology Dana-Farber Cancer Institute, Boston, MA 02115, USA
[5]Stem Cell Program and Divisions of Hematology/Oncology and Pulmonary Medicine, Boston Children's Hospital, Boston, MA 02115, USA
[6]Department of Genetics, Harvard Medical School, Boston, MA 02115, USA
[7]Harvard Stem Cell Institute, Cambridge, MA 02138, USA
[8]Department of Immunology, Blavatnik Institute, Harvard Medical School, Boston, MA 02115, USA
[9]Evergrande Center for Immunologic Disease, Harvard Medical School and Brigham and Women's Hospital, Boston, MA 02115, USA
[10]Department of Pathology, Brigham and Women's Hospital, Boston, MA 02115, USA
*Correspondence: carla.kim@childrens.harvard.edu (C.F.K.), arlene_sharpe@hms.harvard.edu (A.H.S.), marcia_haigis@hms.harvard.edu (M.C.H.)
https://doi.org/10.1016/j.cell.2021.03.005

@Diaz2021_Respiratory_OlderAdults

Mechanistic bridge (acute)

- Airway irritation → cytokines, oxidative stress
- Systemic spillover → endothelial dysfunction, coagulability
- Autonomic dysregulation → arrhythmia risk

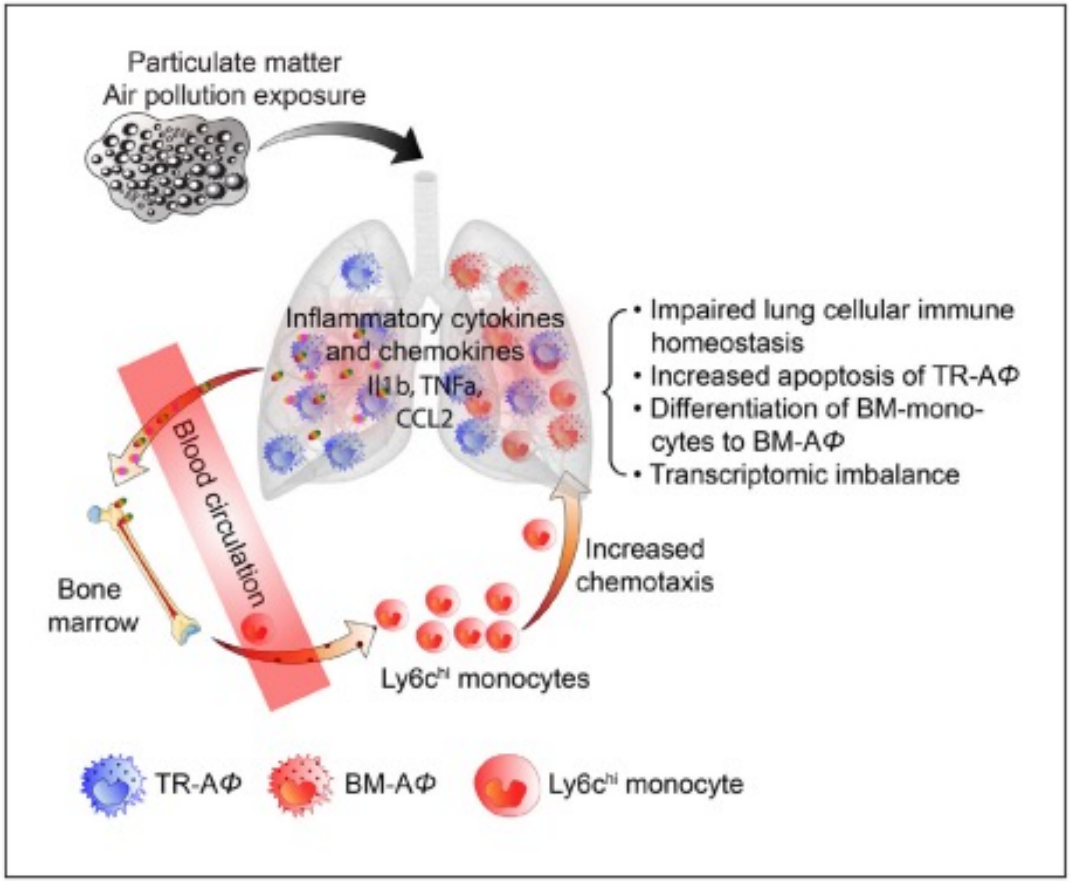


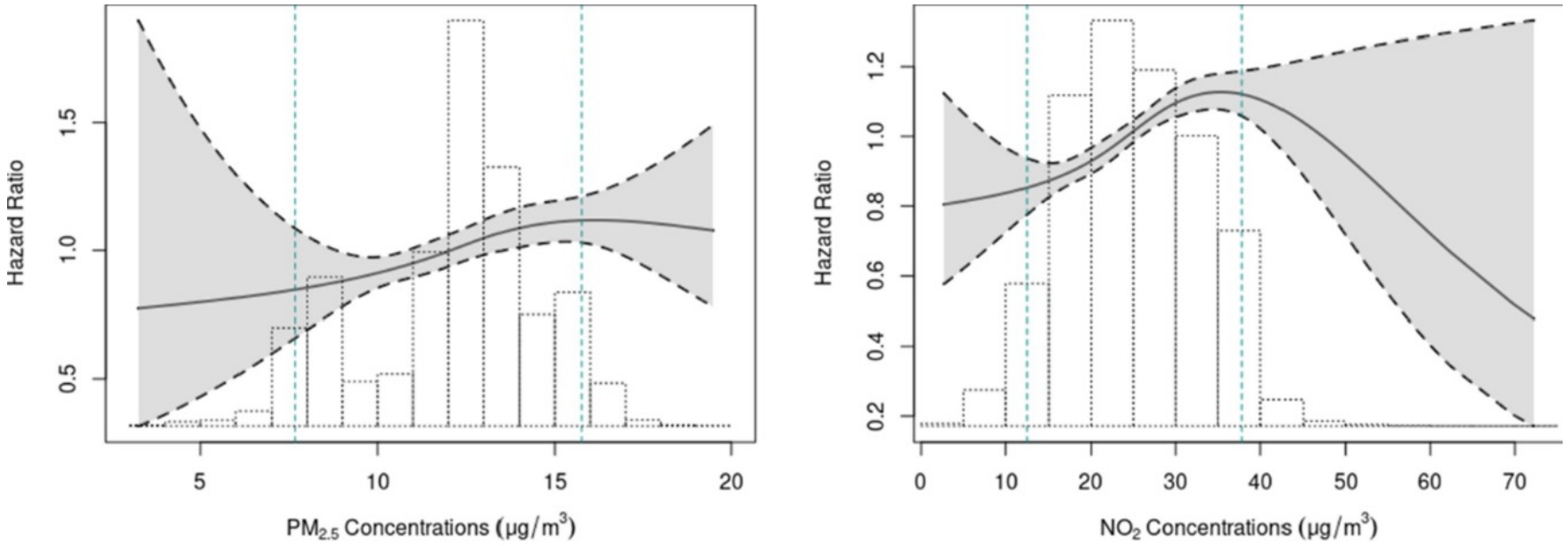
Fig. 2. Schematic illustration of key changes in the lung inflammation in chronic $PM_{2.5}$ exposure. Chronic exposure to $PM_{2.5}$ results in release of inflammatory cytokines and chemokines in the blood circulation that leads to infiltration of $Ly6c^{hi}$ monocytes in the lungs from bone marrow. Continual exposure to $PM_{2.5}$ cause persistent inflammatory environment in the lungs that resulted in increased apoptosis of tissue resident alveolar macrophage and differentiated of recruited BM-monocytes into BM-alveolar macrophages.

@Gangwar2020_OxidativeStress_AirPollution

Lifecourse lens: Chronic exposure

- Cumulative $PM_{2.5}/NO_2$ worsens asthma control
- Accelerates COPD decline & exacerbations
- Increases cardiorespiratory mortality

Fig. 2. Concentration-response curves for the association between long-term exposure to air pollution ($PM_{2.5}$, NO_2, BC, and O_3) and first-ever COPD hospitalization. Natural cubic splines with three degrees of freedom were fit for air pollutants to evaluate the linearity of the associations based on Model 3. Solid lines indicate hazard ratio values and dashed lines indicate their 95% confidence intervals. Green dashed lines indicate 5th and 95th percentiles of air pollutants' concentrations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

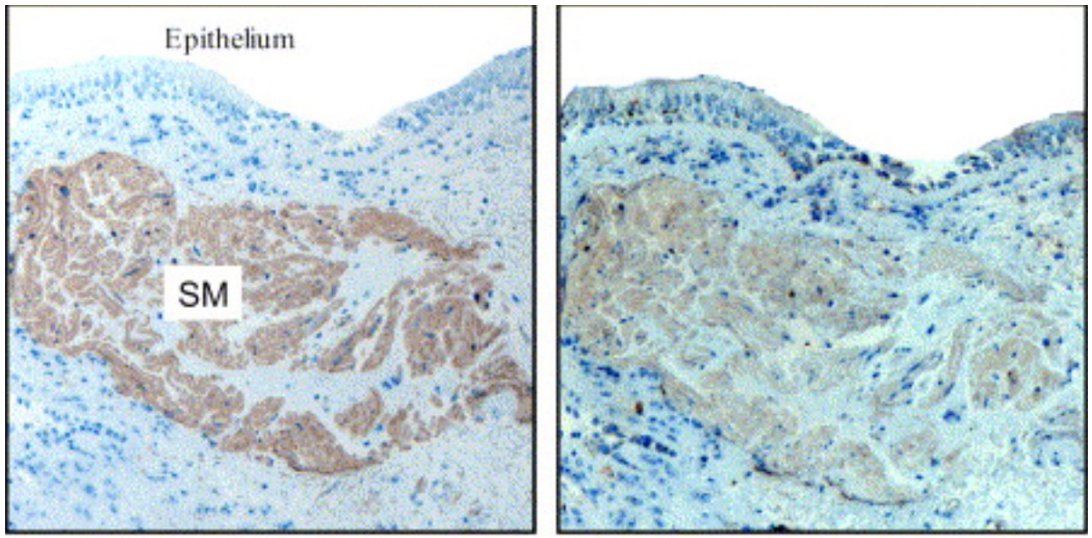


Liu2021_LowLevelAirPollution_COPD_EnvInt

Asthma across the lifespan

- Early-life exposure → higher onset risk
- Persisting exposure → more exacerbations & steroid reliance
- Potential airway remodeling over time

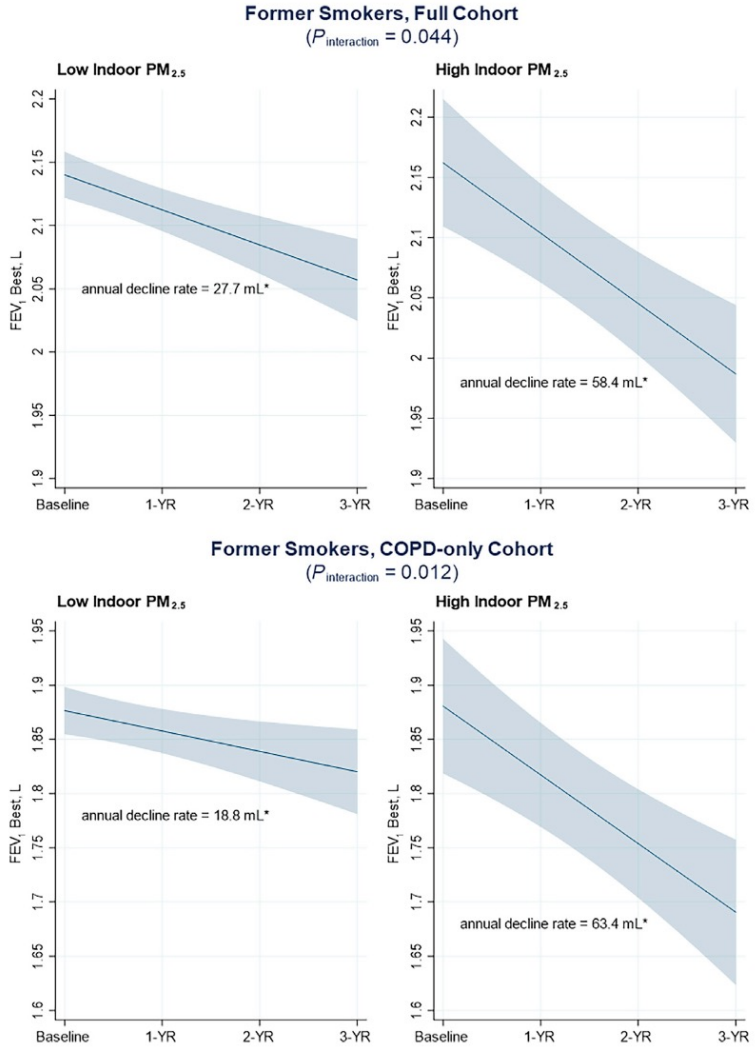
Fig 3 Localization of ADAM33 protein to airways smooth muscle *(SM)* in a bronchial biopsy specimen from a patient with severe asthma. Reprinted with permission from Haitchi et al.[116] Official Journal of the American Thoracic Society. © American Thoracic Society.



Holgate2006_SevereAsthma_Pathophysiology

COPD progression

- Faster FEV_1 decline with long-term $PM_{2.5}/NO_2$
- More frequent exacerbations → stepwise lung-function loss
- Higher hospitalizations & mortality

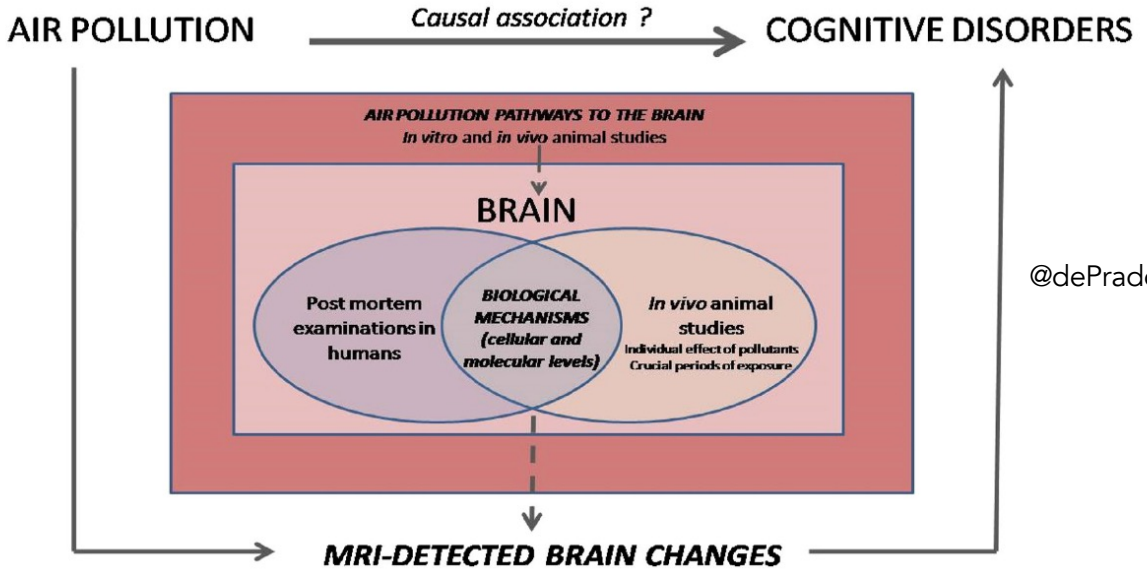


@Hansel2023_IndoorPollution_SPIROMICS_AJRCCM

Figure 1. Among former smokers, decline in FEV_1 is steeper for those residing in homes with higher indoor particulate matter ≤2.5 μm in aerodynamic diameter ($PM_{2.5}$) concentration. The chart compares the FEV_1 progression over time for those residing in homes with indoor $PM_{2.5}$ concentration at the 5th percentile (1.7 μg/m^3) versus the 95th percentile level (31.3 μg/m^3). * = annual decline rate was statistically significant; COPD = chronic obstructive pulmonary disease.

Biological plausibility (chronic)

- Persistent oxidative stress & mucus hypersecretion
- Small-airway fibrosis; emphysematous changes
- Immune modulation sustaining inflammation



@dePradoBert2018_AirPollution_Brain

Fig. 2 Understanding the link between air pollution and cognition: the central role of studies interfacing environmental epidemiology and neuroimaging in humans

Early-life: critical windows

- In utero & first 1–5 years: rapid lung growth
- Pollution can blunt peak lung function attainment
- Sets lower baseline for adulthood

@Miller2010_EnvironmentalChemicals_LungDevelopment

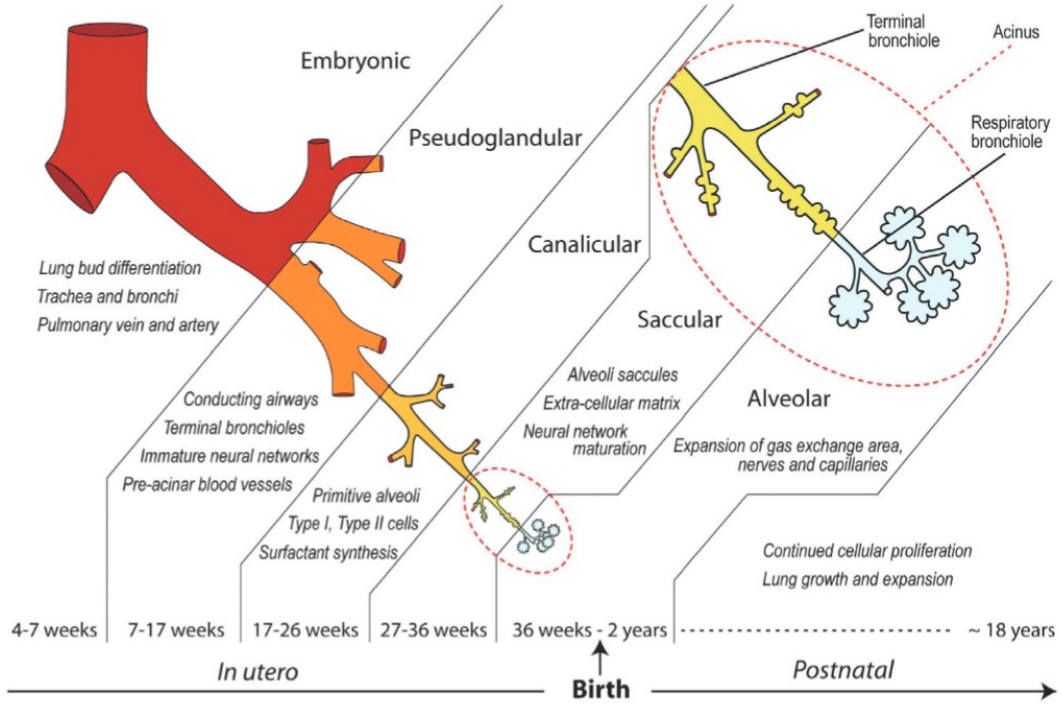
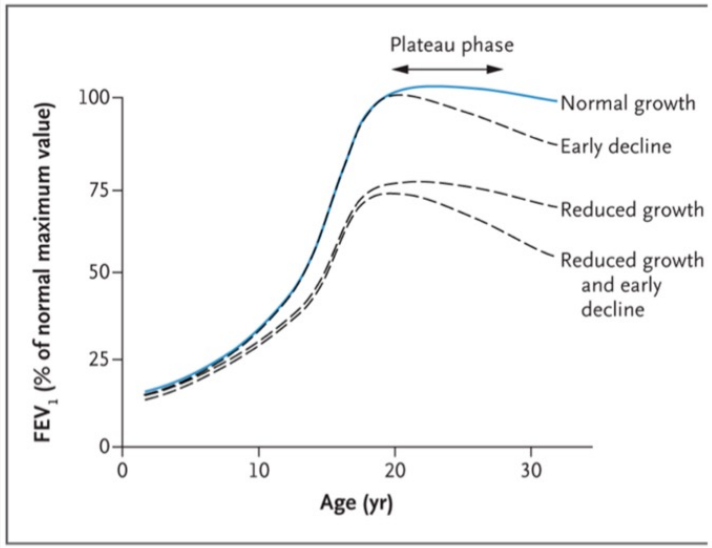


Figure 2. Principal stages of lung development in humans: diagrammatic representations of the timeline and developmental organization of trachea, primary bronchi, intrapulmonary bronchi, and acinus in the mammalian respiratory system. Reprinted from *Pharmacology and Therapeutics*, Vol 114 (Kajekar R. 2007. Environmental factors and developmental outcomes in the lung. Pharmacol Therap 114:129–145), copyright (2007), with permission from Elsevier.

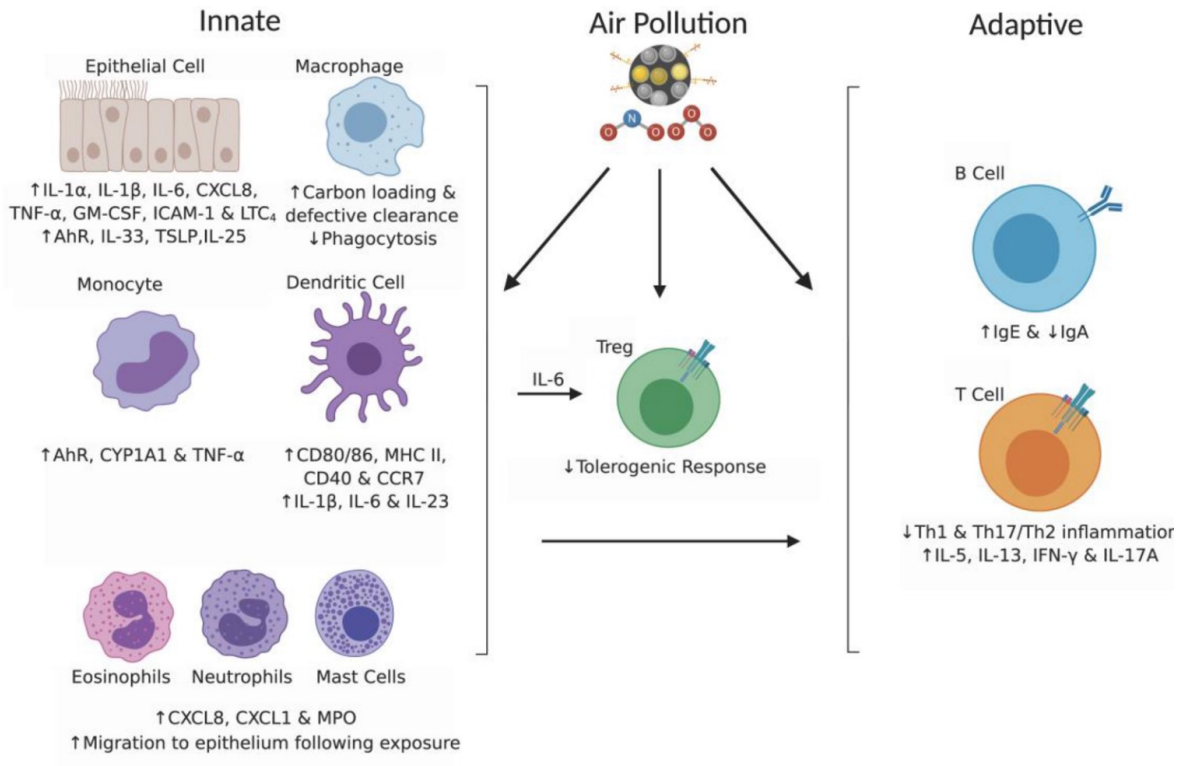
Figure 3. Longitudinal lung-function trajectories reproduced with permission from McGeachie et al. [70].



@Deolmi2023_EarlyOrigins_COPD_IJERPH

Early-life: immune development

- Skewed immune maturation; altered mucosal defenses
- Higher infection susceptibility; atopic tendencies
- Microbiome–host interactions disrupted



@Glencross2020_AirPollution_ImmuneSystem

Long-term child outcomes

- Increased wheeze/asthma prevalence
- Lower spirometric indices into adolescence
- Potential elevated risk for adult COPD

Poor airway function in early infancy and lung function by age 22 years: a non-selective longitudinal cohort study

Debra A Stern [a] · Prof Wayne J Morgan, MD [a,b] · Anne L Wright, PhD [a] · Stefano Guerra, MD [a,c] · Prof Fernando D Martinez, MD [a]

@Stern2007_AirwayFunction_Lancet

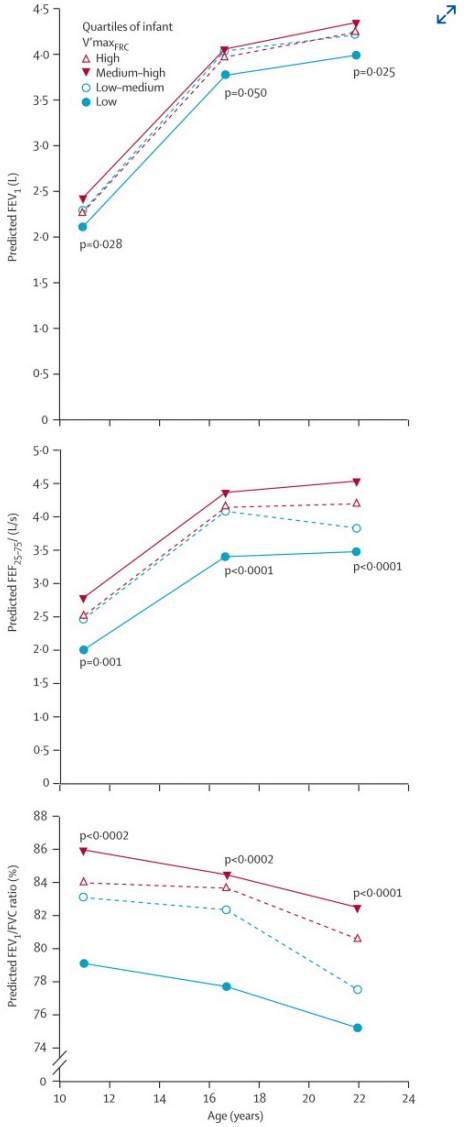
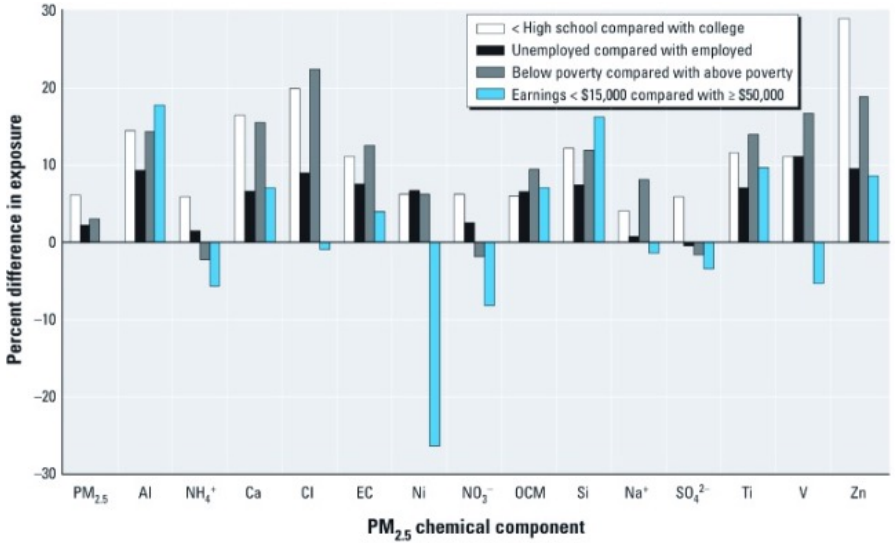


Figure Predicted mean values for lung function in males at ages 11, 16, and 22 years by length-adjusted infant Vmax$_{FRC}$

SES as an effect modifier

- Higher exposure: roads/industry, housing quality
- Lower mitigation capacity: filtration, relocation
- Reduced access to timely care

Figure 3 Percentage differences in exposure by category of socioeconomic indicators (education, unemployment, poverty, earnings).



@Bell2012_EnvironmentalInequality_AirborneParticulateMatter_EHP

Socioeconomic Disparities and Air Pollution Exposure: a Global Review

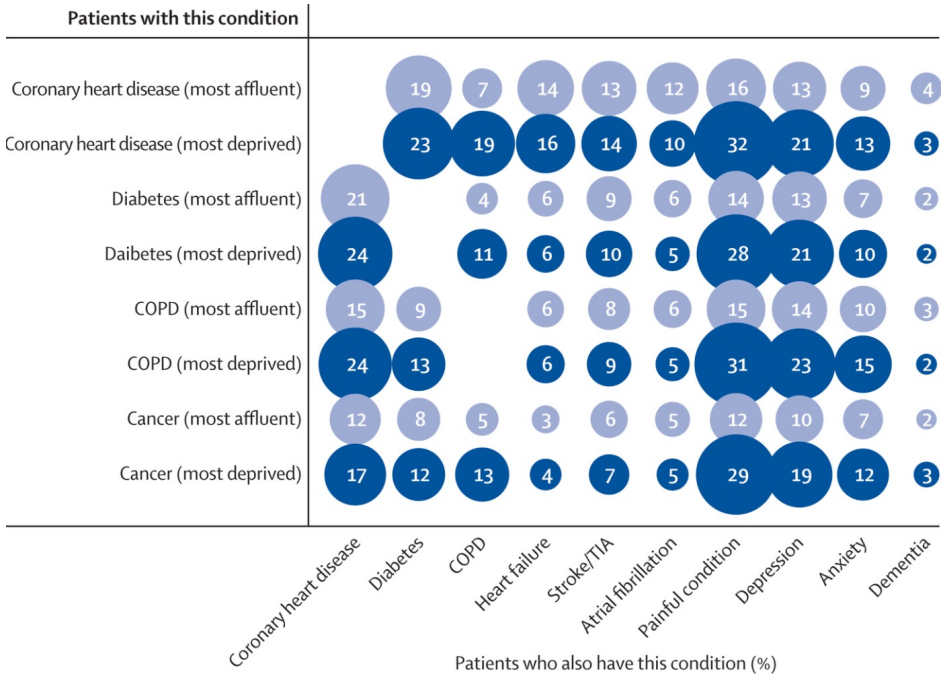
Anjum Hajat[1] · Charlene Hsia[2] · Marie S. O'Neill[3]

@Hajat2015_SES_AirPollution_Review

Older adults & multimorbidity

- Coronary Artery Disease, diabetes, hypertension, COPD common
- Multimorbidity magnifies pollution sensitivity
- Highest absolute risks: low-SES, high-exposure settings

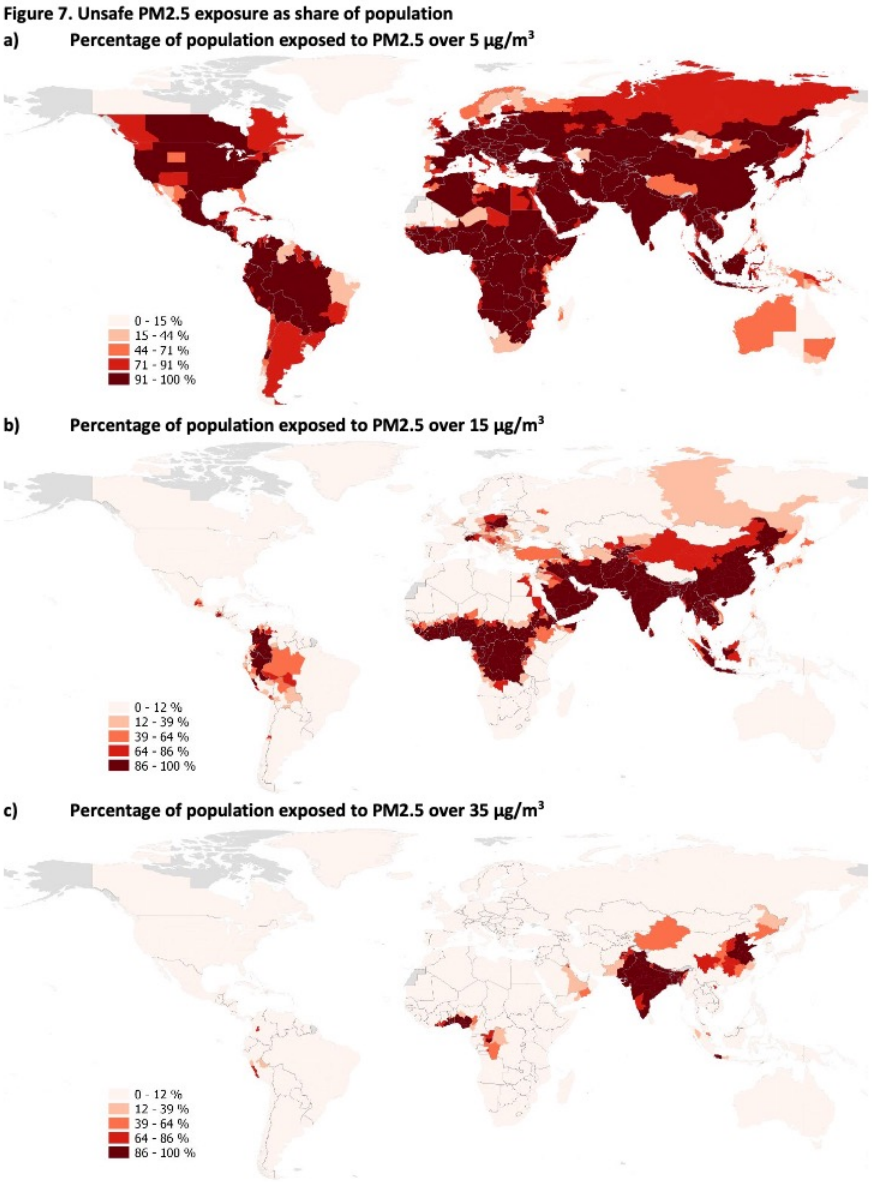
Figure 4 Selected comorbidities in people with four common, important disorders in the most affluent and most deprived deciles



@Barnett2012_Multimorbidity_Lancet

Equity lens & geography

- LICs/MICs: higher exposures, weaker standards
- Urban poor: indoor + outdoor double burden
- Children, pregnant people, elders most impacted



@Rentschler2022_AirPollutionPoverty_WorldBank

What improves when air gets cleaner?

- Fewer exacerbations & hospitalizations
- Lower cardiovascular & respiratory mortality
- Gains in life expectancy and HALE (Health-Adjusted Life Expentacy)





@Brauer2021_AirPollution_CardiovascularHealth_GlobalHeart

Policy levers: Transport & industry

- Tight vehicle emission standards; low-emission zones
- Electrify fleets; optimize freight logistics
- Industrial emissions controls & fuel switching





Policy levers: Energy & buildings

- Clean power generation; retire high-sulfur fuels
- Clean cooking/heating to cut household PM
- Ventilation + filtration standards in schools/elder care





Urban planning & co-benefits

- Transit-oriented development; green corridors
- Reduce heat-island effects; enable active transport
- Climate mitigation aligned with health gains

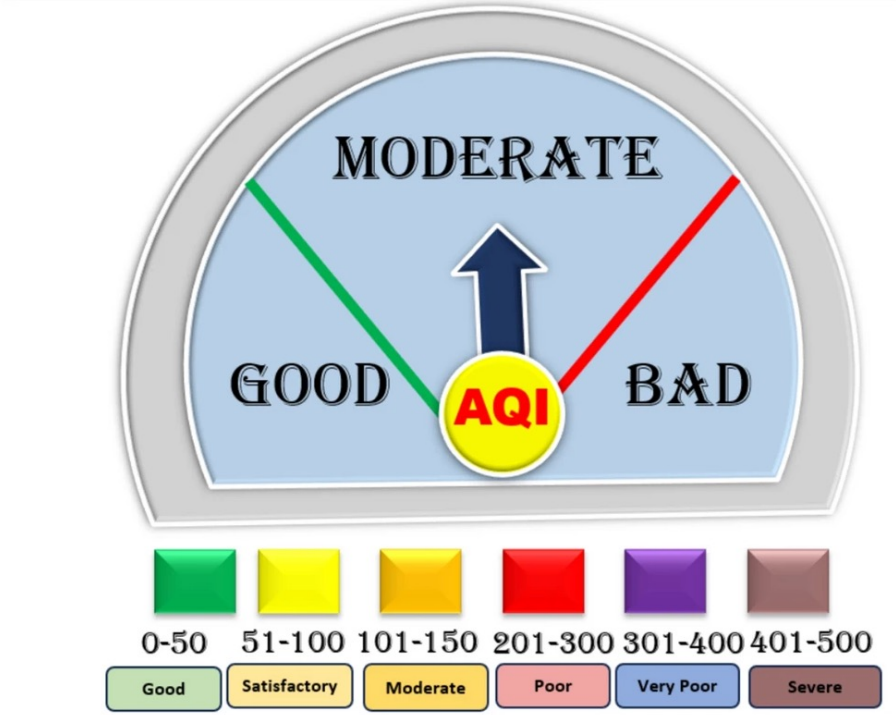
Table 3. Field figures of different roadside green belt types.

Types of roadside green belt	Onsite picture	Schematic
Trees (TRs)		
Shrubs (SHs)		
Trees+Shrubs (TRs+SHs)		

@Xi2023_NatureBasedSolution_UrbanTrafficHeat_AppliedEnergy

Health-system actions

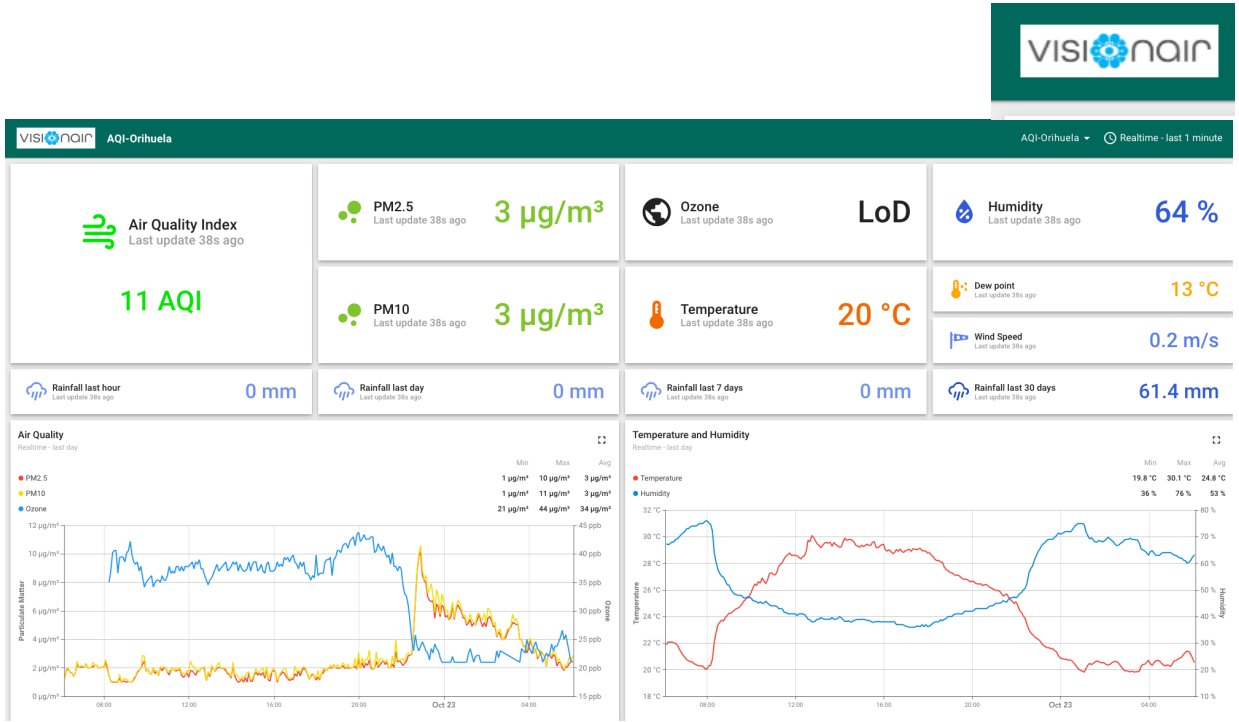
- Air-quality alerts integrated into care plans
- Seasonal pre-emptive therapy optimization
- Stock rescue meds; rapid escalation protocols



Communication & community

- Tailored messages for high-risk groups
- Empower schools & elder facilities with action plans
- Transparent air-quality data to build trust

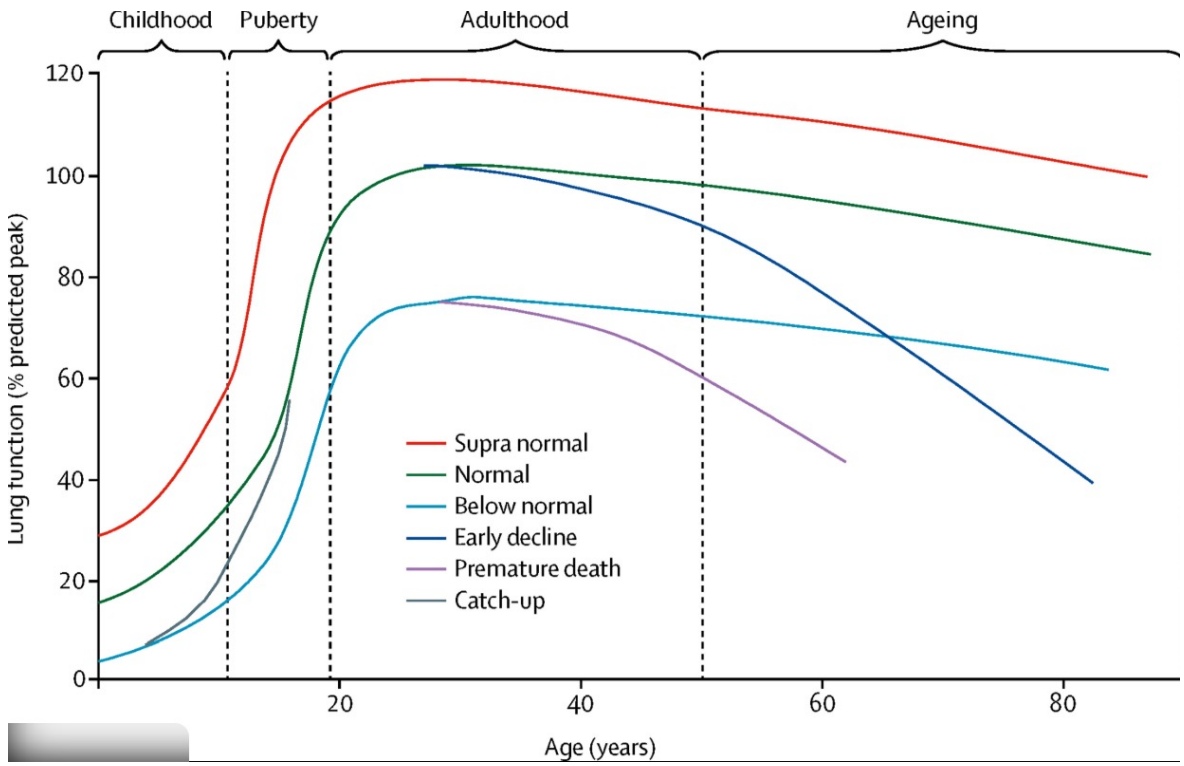




https://eu.thingsboard.cloud/dashboard/e6aaec70-60af-11f0-9559-935bf62f36a1?publicId=5e78d560-609b-11f0-b4ed-29e316672b3e

Research priorities

- Lifecourse cohorts for exposure windows & lung growth
- Component-specific toxicity (ultrafines, metals)
- Interventional trials: filtration, low-emission zones



Key Takeaways



- Air pollution is a widespread global health threat with both immediate and lifelong impacts.
- Children, older adults, and people with respiratory conditions face the greatest risks.
- Early-life exposure disrupts lung and immune development, leading to persistent health problems.
- Socioeconomic disadvantage and high-exposure environments greatly amplify health burdens.
- Cleaner air, driven by strong policy and community action, yields swift and lasting health benefits.

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