



*EU Regional Development Funds - Interreg Central Europe AWAIR*  
Strategies and operational tools to support adaptation actions  
in vulnerable population groups during the Severe Air Pollution Episodes (SAPes)  
*Parma - APE Parma Museo, via Farini 32a, November 6<sup>th</sup>, 2019*

# Physiopathological effects of the main air pollutants: prevention techniques and strategies

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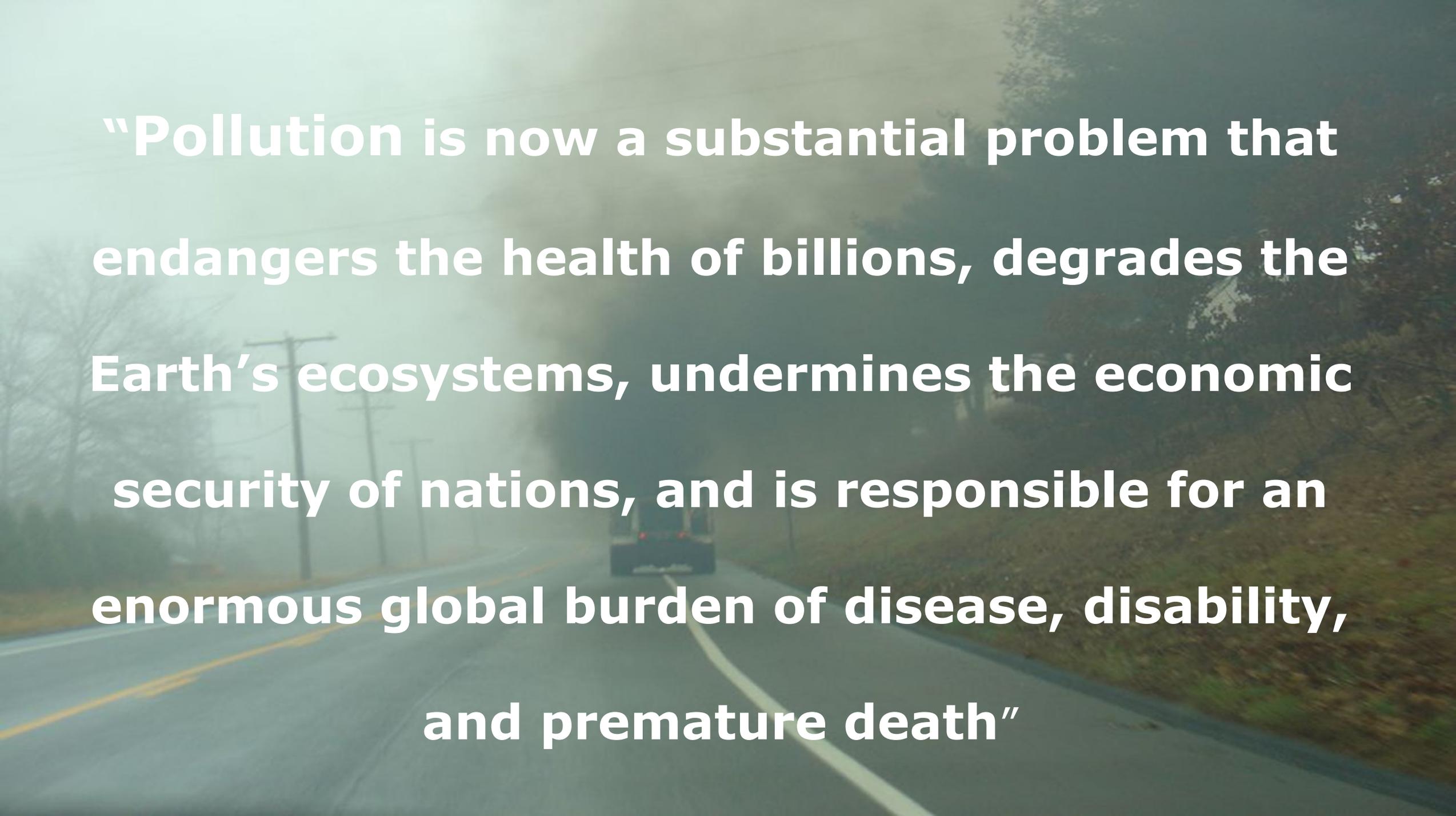
HelmholtzZentrum münchen  
German Research Center for Environmental Health

# The Lancet Commission on pollution and health

*Philip J Landrigan, Richard Fuller, Nereus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri (Nil) Basu, Abdoulaye Bibi Baldé, Roberto Bertollini, Stephan Bose-O'Reilly, Jo Ivey Boufford, Patrick N Breyse, Thomas Chiles, Chulabhorn Mahidol, Awa M Coll-Seck, Maureen L Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V Mathiasen, Maureen A McTeer, Christopher J L Murray, Johanita D Ndahimananjara, Frederica Perera, Janez Potočnik, Alexander S Preker, Jairam Ramesh, Johan Rockström, Carlos Salinas, Leona D Samson, Karti Sandilya, Peter D Sly, Kirk R Smith, Achim Steiner, Richard B Stewart, William A Suk, Onno C P van Schayck, Gautam N Yadama, Kandeh Yumkella, Ma Zhong*

**“Pollution is one of the greatest existential challenges of the Anthropocene epoch”**



A photograph of a road on a foggy day. A bus is visible in the distance, driving away from the viewer. The road has yellow and white lane markings. The fog is thick, obscuring the background. The text is overlaid on the image in white, bold font.

**“Pollution is now a substantial problem that endangers the health of billions, degrades the Earth’s ecosystems, undermines the economic security of nations, and is responsible for an enormous global burden of disease, disability, and premature death”**



Urban pollution is a complex cocktail of chemicals that can also be broadly characterized into:

- Gases: sulphur dioxide (SO<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) and monoxide (CO), ozone (O<sub>3</sub>), and nitrogen dioxide (NO<sub>2</sub>)
- Volatile organic compounds (VOCs): benzene, chlorofluorocarbons and chlorocarbons, formaldehyde, polyaromatic hydrocarbons (PAHs), and alkanes
- Particles: Particulate matter (PM), are the most relevant pollutants in medical field

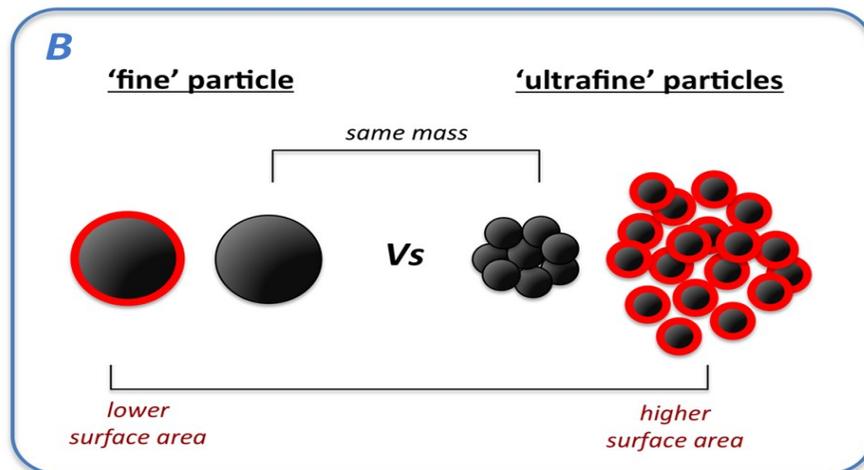
According to the World Health Organization, from a medical point of view the six major air pollutants include particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead

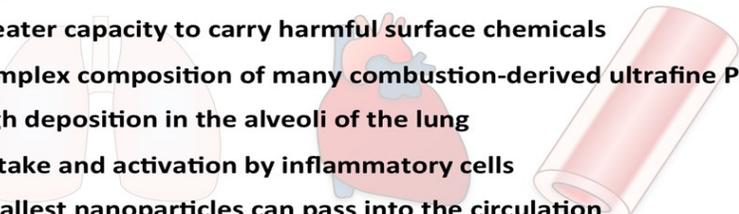


**Particulate matter (PM)** are inhalable and respirable particles composed of sulphate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. Particles with a diameter of less than 2,5 microns ( $PM_{2.5}$ ) pose the greatest risks to health, also the ultrafine particles as they are capable to reach alveolus and entering the bloodstream (the problem is that it is not possible to measure ultrafine PM using monitoring networks in the environment at present)

**A**

<u>Particle Category</u>	<u>Diameter (<math>\mu m</math>)</u>	<u>Size comparisons</u> <i>(if the PM was 100,000 times bigger):</i>
 <b>Coarse: <math>PM_{10}</math></b>	2.5 – 10.0	 football (220 mm)
 <b>Fine: <math>PM_{2.5}</math></b>	< 2.5	 golf ball (40 mm)
 <b>Ultrafine PM</b> (nanoparticles)	< 0.1	 large grain of sugar (1-2 mm)



- C** Potential factors contributing to the toxicity of ultrafine particles:
- Large reactive surface area
  - Greater capacity to carry harmful surface chemicals
  - Complex composition of many combustion-derived ultrafine PM
  - High deposition in the alveoli of the lung
  - Uptake and activation by inflammatory cells
  - Smallest nanoparticles can pass into the circulation
  - Accumulation in peripheral organs and sites of inflammation
- MRM 2019
- 

More than 90% of the global population is exposed to levels of PM exceeding  
World Health Organization air quality guidelines

*(WHO Global Health Observatory. 18 October 2018)*

The Global Burden of Disease (GBD) study  
estimates that around

**9 MILLION TOTAL DEATHS**

are directly attributed to environmental pollution  
(4.2 million to ambient air pollution and 2.9  
million to household air pollution).

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(WH



Our region and our  
city are among the  
most polluted in  
Europe

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lines

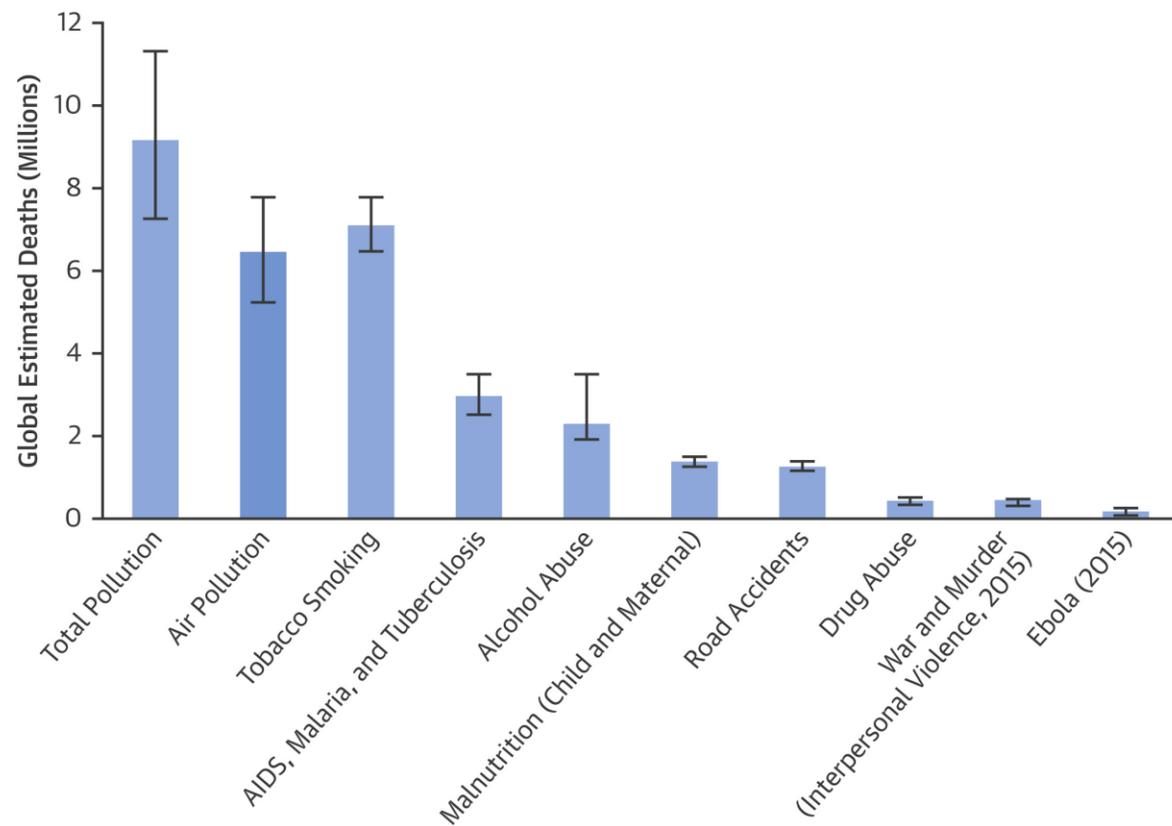
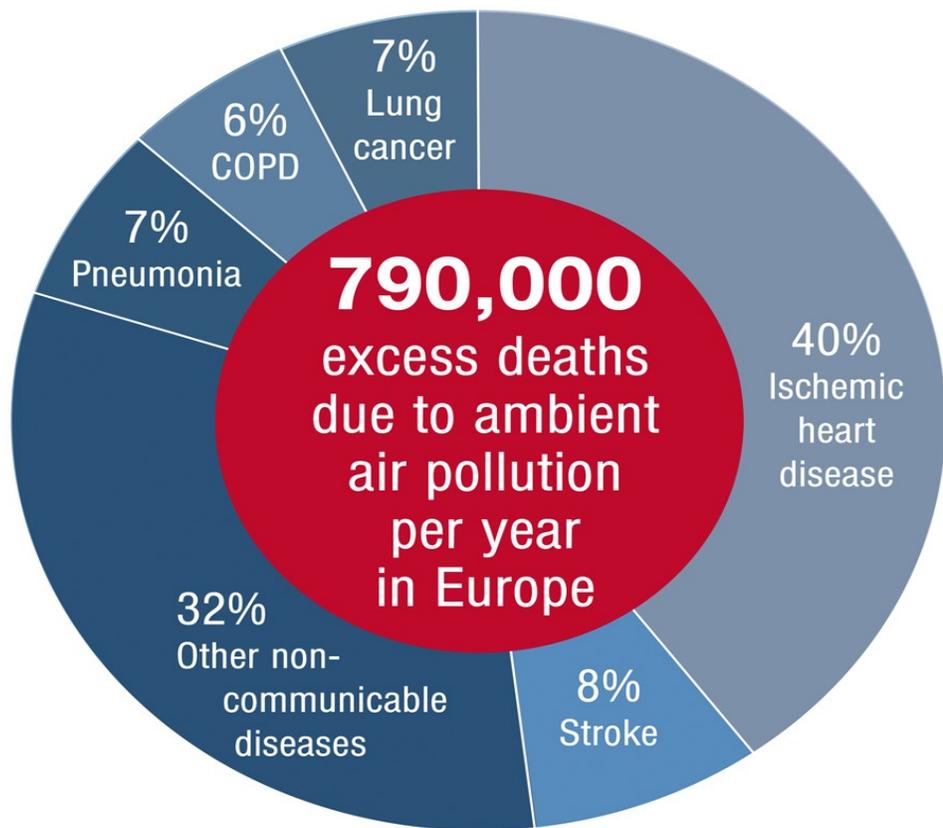
2018)

The Global Burden of Disease (GBD) study estimates that around

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are directly attributed to environmental pollution (4.2 million to ambient air pollution and 2.9 million to household air pollution).

- Environmental pollution is the largest cause of premature reversible death and disability in the world today



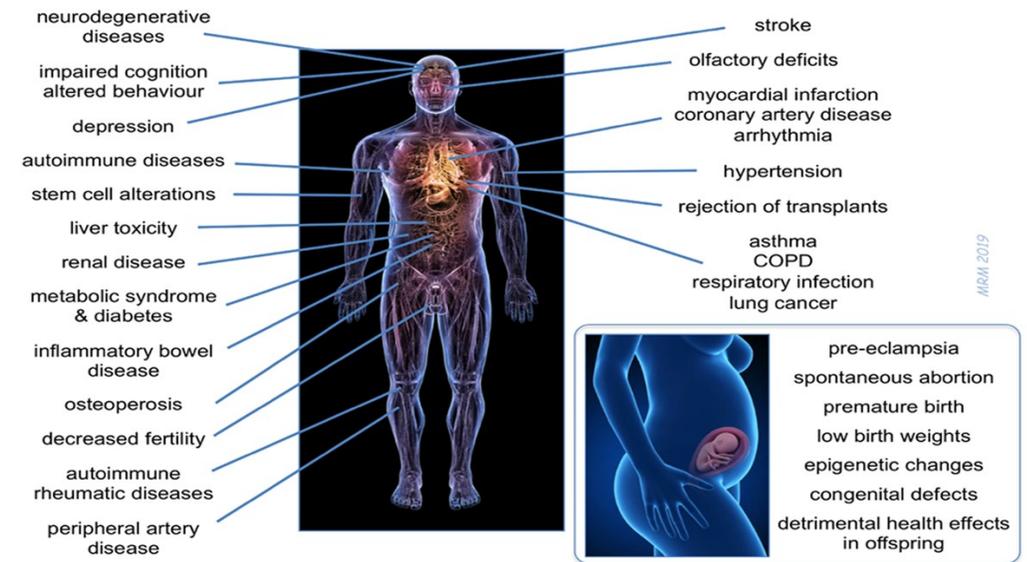
P.J.Landrigan et al. *The Lancet Commission on pollution and health Lancet 2018*

Jos Lelieveld et al. *Cardiovascular disease burden from ambient air pollution in Europe reassessed using novelhazard ratio functions. European Heart Journal, Volume 40, Issue 20, 21 May 2019, Pages 1590–1596,*

Cohen AJ et al. *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. Lancet 2017;389:1907–1918*

The strongest causal associations are seen between PM2.5 pollution and cardiovascular and pulmonary disease. But there are many other diseases related to PM 2.5 according to the latest research:

- Exacerbation of metabolic syndrome and diabetes
- chronic kidney disease
- Various cancers
- inflammatory bowel disease
- Osteoporosis
- Liver disease
- Alteration of circulating stem cell populations
- promote rejection of organ transplants
- skin diseases
- autoimmune diseases
- Infertility
- impaired cognition, dementia, antisocial behaviour, teenage psychosis, autism



As Sir Isaac Newton did when the apple fell, we ask ourselves

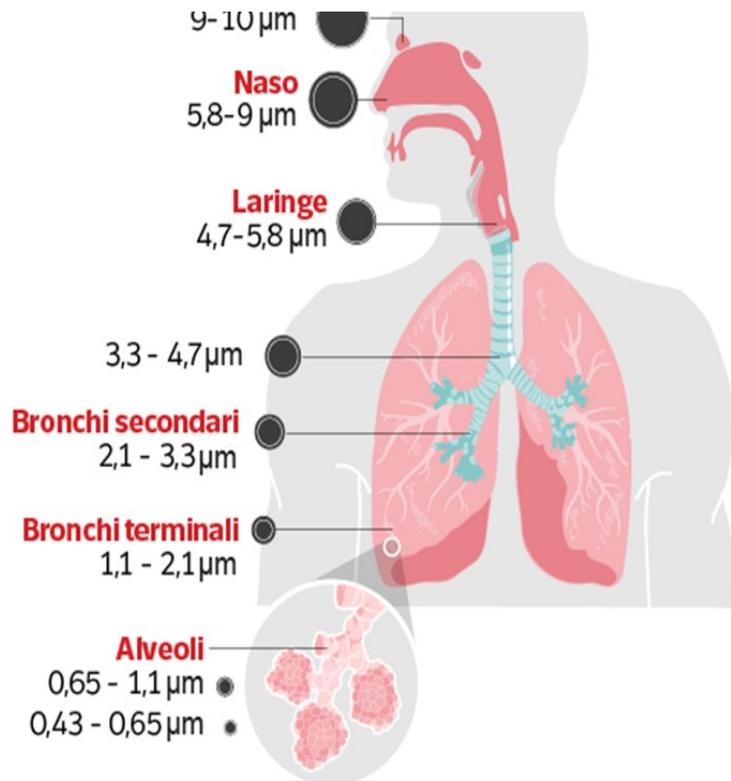


WHY??

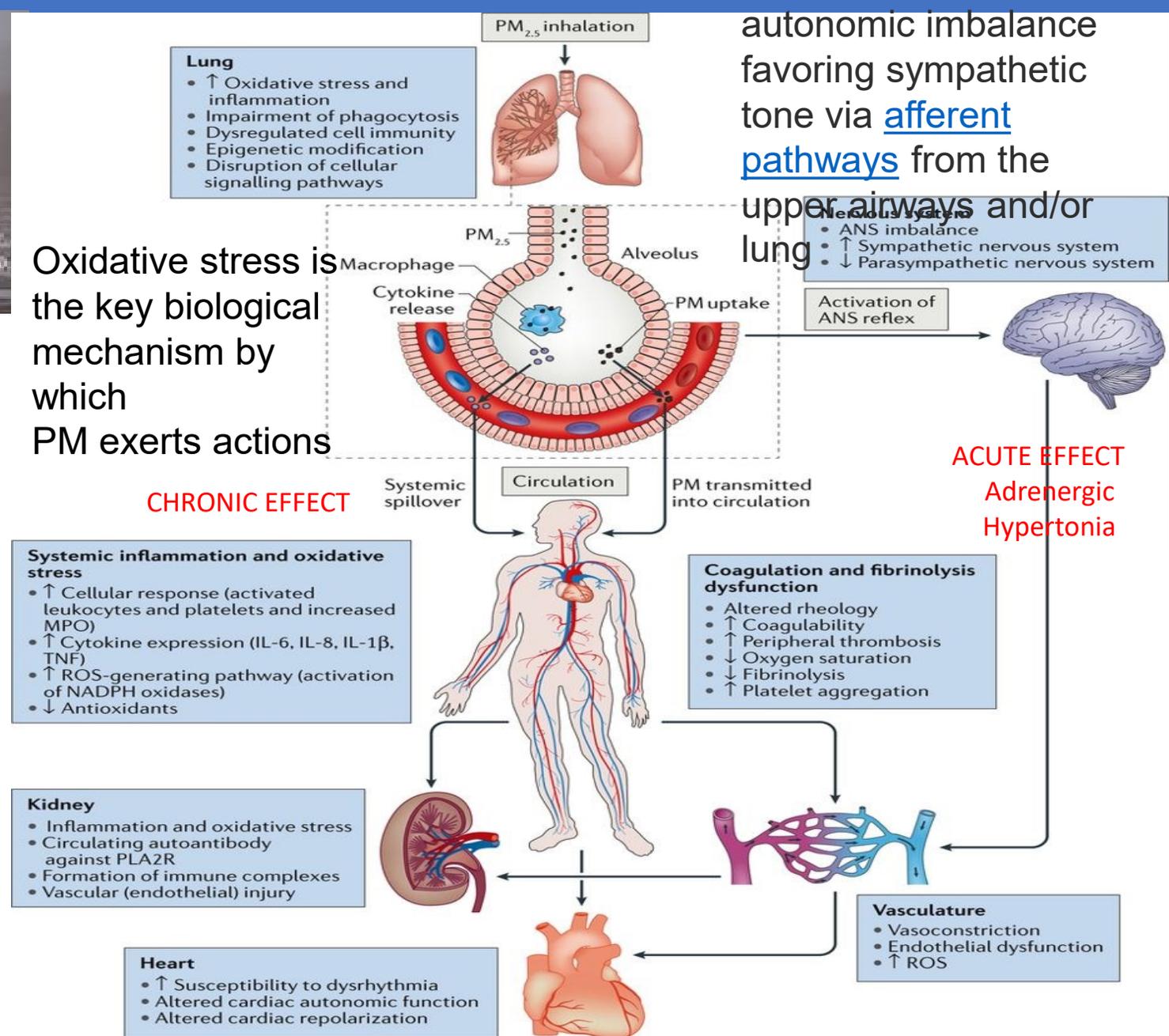


what happens when we walk along a busy street?

PM 10 penetrate conducting airways; PM<sub>2.5</sub> can penetrate into the gas-exchanging regions of the lung and the ultrafine ones potentially into the bloodstream

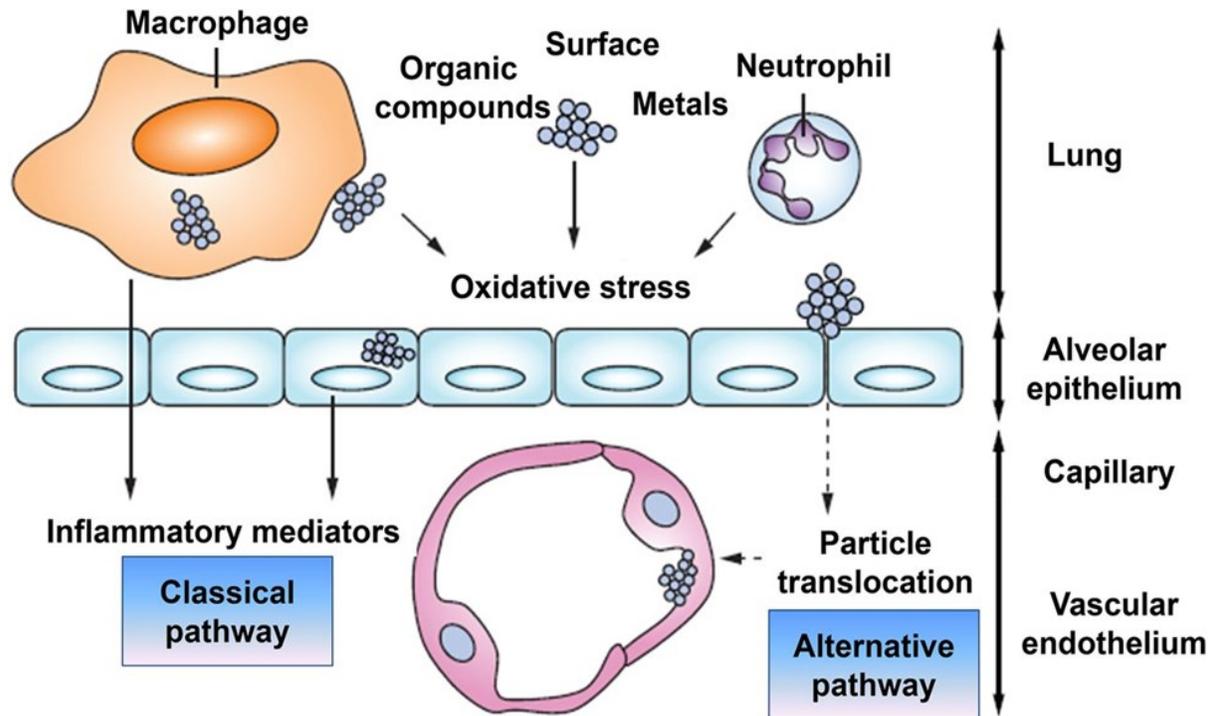


Oxidative stress is the key biological mechanism by which PM exerts actions



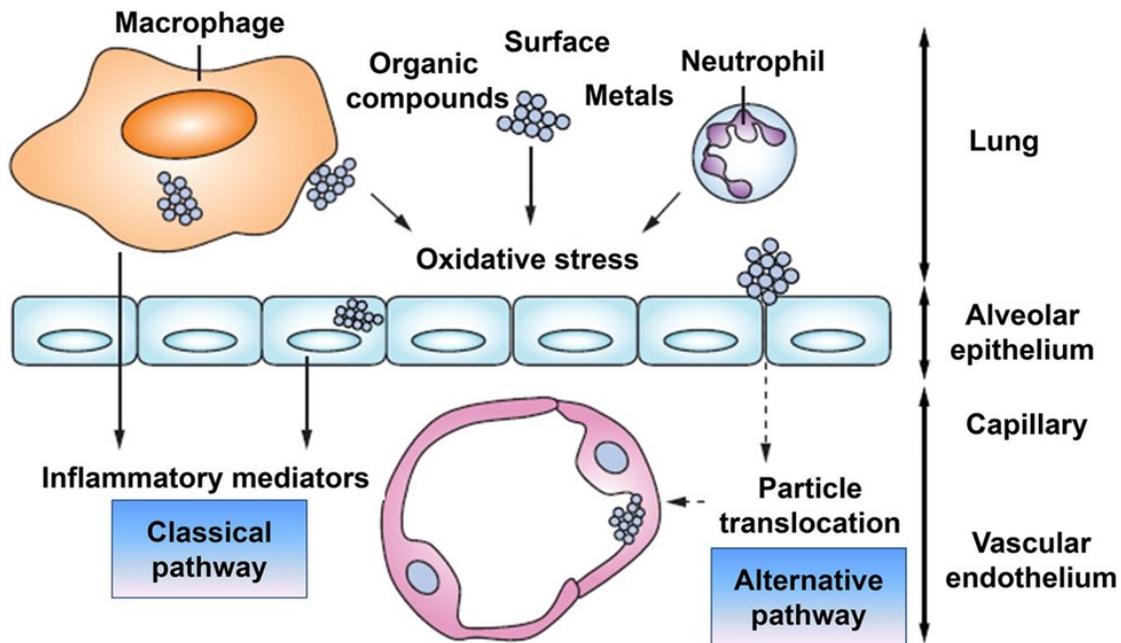


# Classical pathway: indirect pulmonary-derived effects



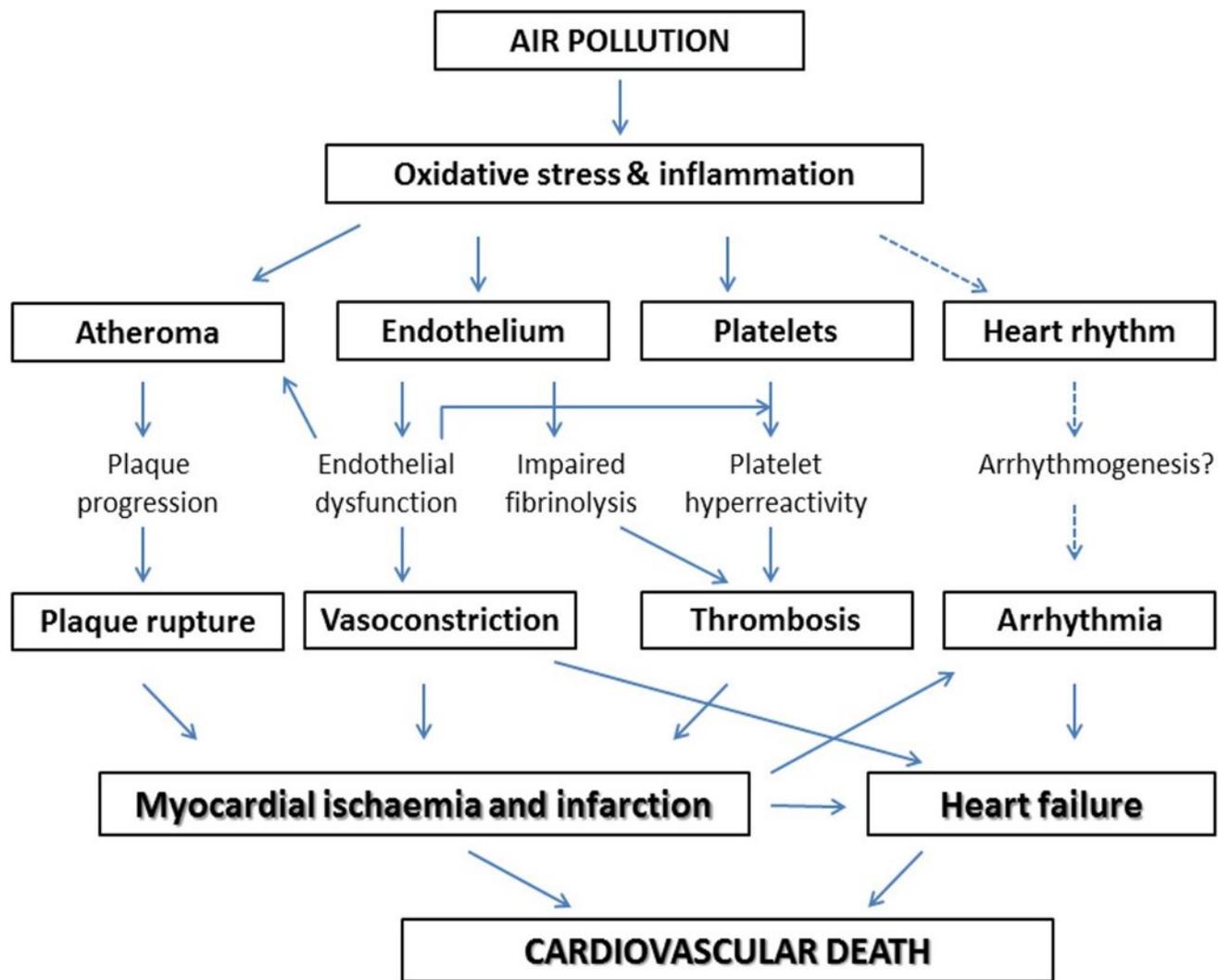
- The original hypothesis proposed that inhaled particles provoke an inflammatory response in the lungs, with consequent release of prothrombotic and inflammatory cytokines into the circulation
- exposures led to elevated plasma concentrations of cytokines such as interleukin (IL)-1 $\beta$ , IL-6, and granulocyte–macrophage colony-stimulating factor, all of which could be released as a consequence of interactions between particles, alveolar macrophages, and airway epithelial cells
- Increases in plasma or serum markers of systemic inflammation have been reported after exposure to PM
- exposure has been associated with evidence of an acute phase response, namely increased serum C-reactive protein and plasma fibrinogen concentrations, enhanced plasma viscosity, and altered leukocyte expression of adhesion molecules

# Alternative pathway: direct translocation into the circulation

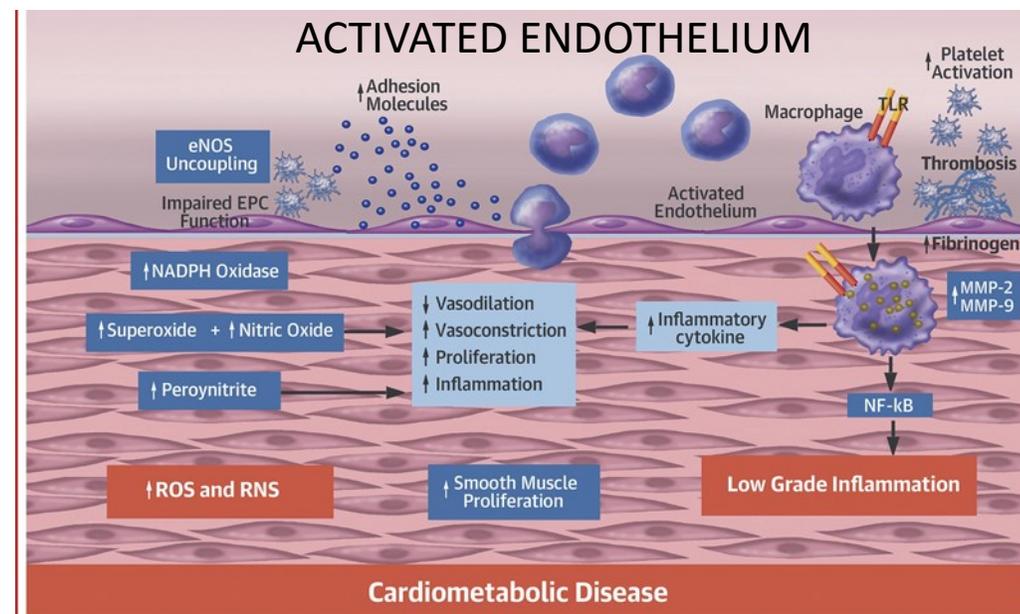


- This hypothesis proposes that inhaled, insoluble, fine PM or nanoparticles could rapidly translocate into the circulation, with the potential for direct effects on hemostasis and cardiovascular integrity. The ability of nanoparticles to cross the lung–blood barrier is likely to be influenced by a number of factors including particle size and charge, chemical composition, and propensity to form aggregates
- Translocation of inhaled nanoparticles across the alveolar–blood barrier has been demonstrated in animal studies for a range of nanoparticles delivered by inhalation or instillation
- Once in the circulation, nanoparticles could interact with the vascular endothelium or have direct effects on atherosclerotic plaques and cause local oxidative stress and proinflammatory effects similar to those seen in the lungs

# PHYSIOPATHOLOGICAL MECHANISMS



- Pro-inflammatory effect
- Autonomous system dysfunction
- Pro-coagulant effect
- Hypertensiv effect
- Aterogenic effect
- Increasing of Insulin Resistance → ↑Glicemia → Diabetes



Rajagopalan, S. et al. J Am Coll Cardiol. 2018;72(17):2054-70.

Brook R.D. et al. Air Pollution and Cardiometabolic Disease: An Update and Call for Clinical Trials American Journal of Hypertension, Volume 31, Issue 1, January 2018, Pages 1–10,  
Baccarelli A et al. Effects of exposure to air pollution on blood coagulation. J Thromb Haemost 2007;

Expert Position European Society of Cardiology European Heart Journal, Volume 36, Issue 2, 7 January 2015, Pages 83–93,

# TECHNIQUES AND STRATEGIES TO PREVENT THE HARMFUL EFFECTS OF AIR POLLUTANTS

Studying and understanding the pathophysiological mechanism has allowed us to find techniques and strategies to prevent the harmful effects of air pollutants.

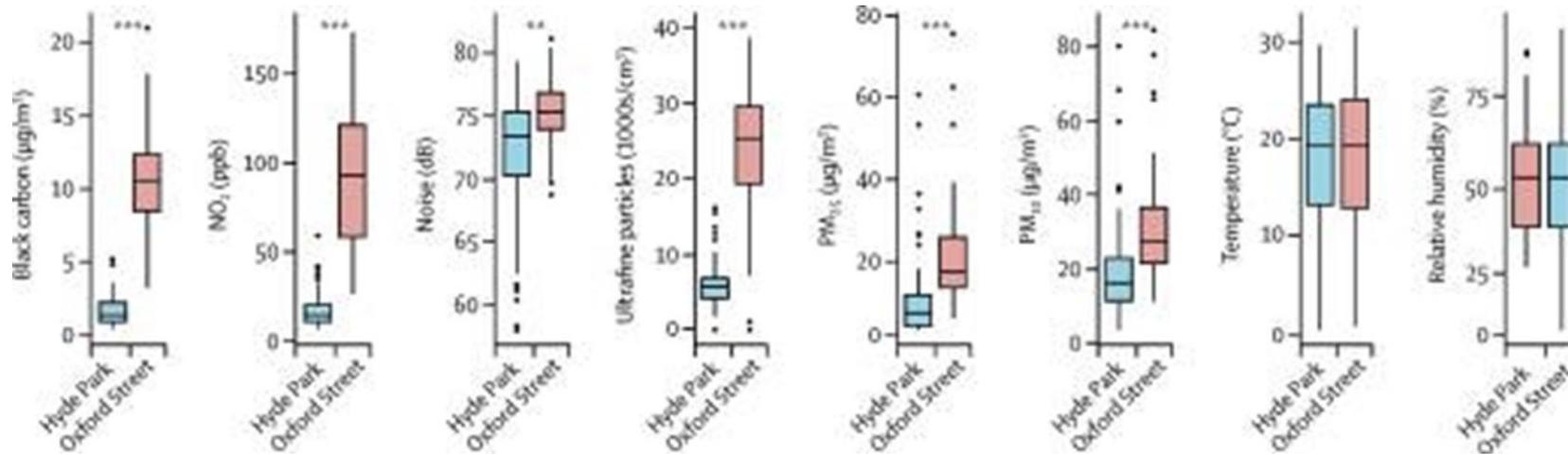
Although based on the current data available, there is no recognized level of air pollution that is considered 'safe'.

# Respiratory and cardiovascular responses to walking down a traffic-polluted road compared with walking in a traffic-free area in participants aged 60 years and older with chronic lung or heart disease and age-matched healthy controls: a randomised, crossover study

Rudy Sinharay\*, Jicheng Gong\*, Benjamin Barratt, Pamela Ohman-Strickland, Sabine Ernst, Frank J Kelly, Junfeng (Jim) Zhang, Peter Collins, Paul Cullinan, Kian Fan Chung *Lancet* 2018; 391: 339–49

## **In this randomised, crossover study, they recruited:**

- 1. 40 individuals with COPD (Chronic obstructive pulmonary disease) , and 39 with ischaemic heart disease**
- 2. Age-matched healthy volunteers**
- 3. Randomly half of the two groups walked in Oxford Street and half in Hyde Park**
- 4. During each walk session PM2.5 ,PM10, Ultrafine particles and black carbon concentrations were measured**



**Concentrations of black carbon, NO<sub>2</sub>, PM<sub>2.5</sub>, PM<sub>10</sub>, and ultrafine particles and noise level during the walk sessions were all significantly higher on Oxford Street than in Hyde Park**

- **In COPD participants there was an increase in small airways obstruction in association with pollutants. This greater effect of walking in a commercial roadside on lung function was associated with more respiratory symptoms of cough and sputum, shortness of breath, wheeze and reduction in lung function**
- **Participants with COPD or ischaemic heart disease also exhibited worst cardiovascular parameters after walking in Oxford Street**
- **We found that participants with COPD were especially sensitive to black carbon and ultrafine particles in terms of both pulmonary and cardiovascular effects**

The background of the slide is a scenic landscape. In the upper half, a mountain peak is visible, covered in dense forest with trees in various shades of green, yellow, and orange, indicating autumn. The sky above is a clear, bright blue. In the lower half, a body of water, possibly a lake or a wide river, reflects the colors of the trees and the blue sky. The water is calm, creating a clear reflection of the mountain and sky.

The current data are sufficiently compelling **to advise older adults and patients with chronic pulmonary and cardiovascular disease to avoid walking in highly polluted environments** such as city streets with high traffic density.

Exercise such as walking should be done in urban green space areas away from high density traffic or in indoor facilities with effective air filtration if located near polluted streets.

# POLLUTION FACE MASKS AND DOMESTIC AIR FILTRATION DEVICE

- Data from four studies (three single-blind studies and one double-blind, randomized controlled trial) demonstrate that use of domestic air-filtration devices, particle-filtration masks, and car air filtration/air conditioning leads to meaningful reduction in Cardiovascular parameters such as systolic blood pressure, improvements in microvascular function, autonomic tone, and lower levels of inflammatory biomarkers in adults exposed to  $PM_{2.5}$

# POLLUTION FACE MASKS AND DOMESTIC AIR FILTRATION DEVICE

• **N95 facemasks** **22 in 1 set**



**Respirator 3200 with  
Particulate Filter 3701CN**



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# ARE WE REALLY SURE THAT IS WHAT WE WANT???



# STOP TRAFFIC COULD HELP??

From a medical point of view

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# Association Between Changes in Air Pollution Levels During the Beijing Olympics and Biomarkers of Inflammation and Thrombosis in Healthy Young Adults

JAMA, May 16, 2012—Vol 307, No. 19



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Jian Tong, MS

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Duncan Thomas, PhD

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Tong Zhu, PhD

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Junfeng (Jim) Zhang, PhD

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- Using a quasi-experimental opportunity offered by greatly restricted air pollution emissions during the Beijing Olympics, they measured pollutants daily and the outcomes listed below in 125 healthy young adults before, during, and after the 2008 Olympics (June 2-October 30). They measured:
- Systemic Inflammation markers:
  - C-reactive protein (CRP)
  - White blood cell count (WBC)
  - fibrinogen
- Endothelial dysfunction markers:
  - platelet activation markers P-selectin [sCD62P]
  - soluble CD40 ligand [sCD40L]
  - the adhesive endothelial glycoprotein von Willebrand
- Heart rate and blood pressure.

From the pre-Olympic to the during-Olympic period they observed reductions in the mean concentration of:

- sulfur dioxide (−60%),
- carbon monoxide (−48%),
- nitrogen dioxide (−43%),
- Elemental carbon (−36%),
- PM2.5 (−27%),
- organic carbon (−22%)
- Sulfate (−13%)

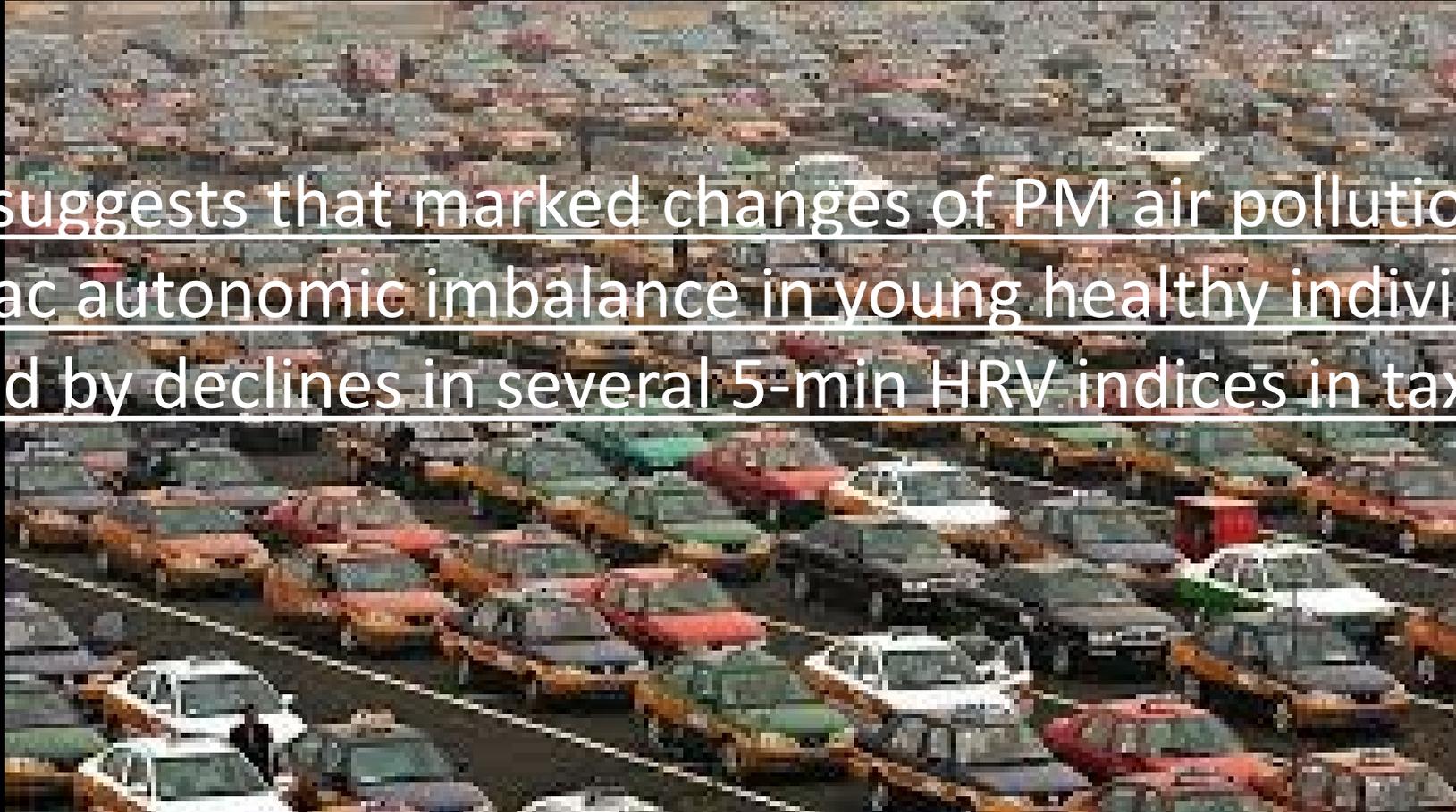
From the pre-Olympic to the during-Olympic period **they observed statistically significant:**

- Biomarkers reduction (Confirming importance of the thrombosis–endothelial dysfunction mechanism):
  - ↓ von Willebrand factor
  - ↓ sCD62P (Soluble P-selectin, cell adhesion molecule (CAM) on the surfaces of activated endothelial cells)
- ↓ systolic blood pressure

# Association of Heart Rate Variability in Taxi Drivers with Marked Changes in Particulate Air Pollution in Beijing in 2008

Wu S. et al. Environ Health Perspect 2010;118:87–91

This work suggests that marked changes of PM air pollution may lead to cardiac autonomic imbalance in young healthy individuals, as indicated by declines in several 5-min HRV indices in taxi drivers

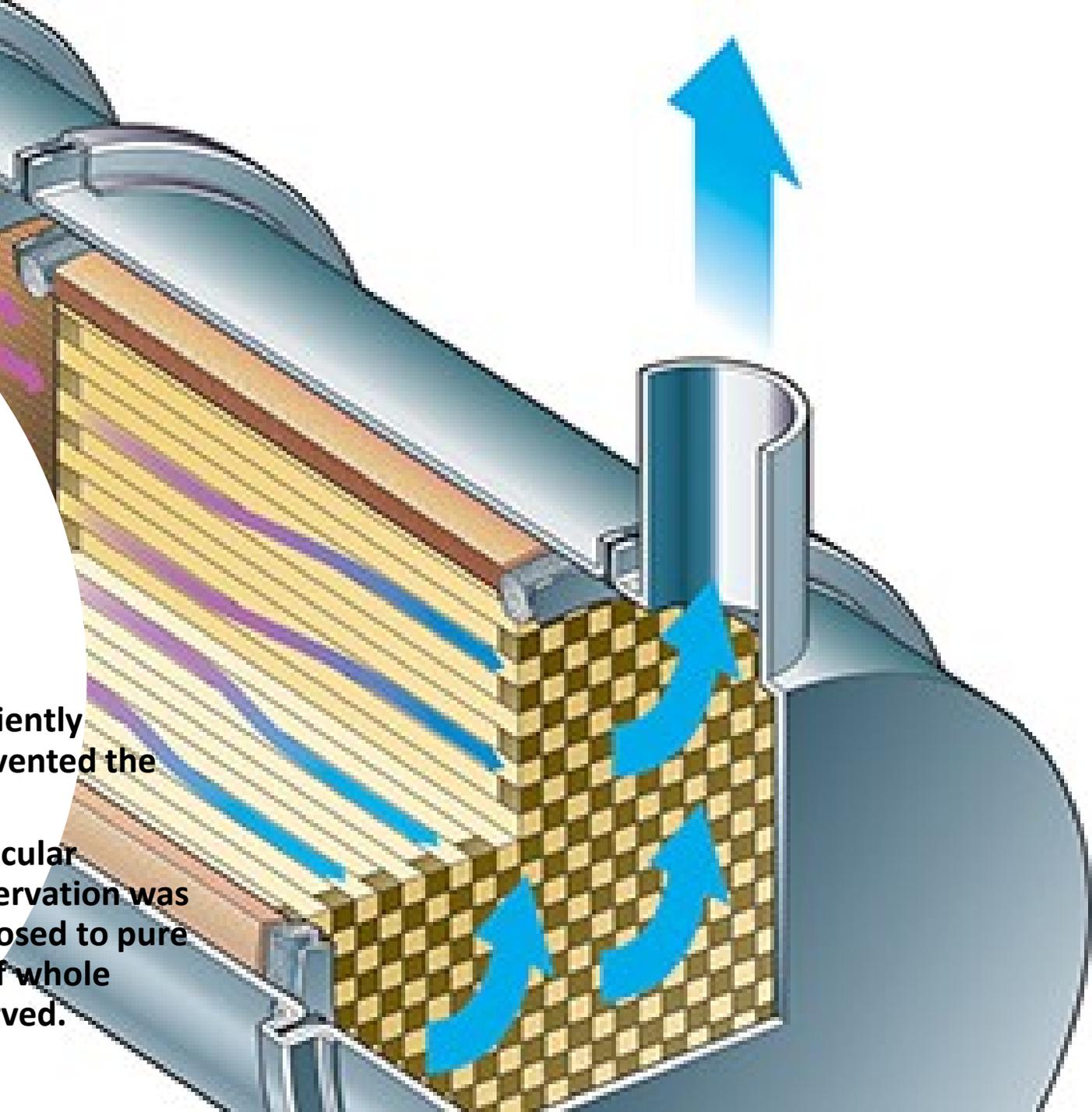


A photograph of a city street scene. In the foreground, a large truck is moving from left to right, emitting a thick, dark plume of dust or smoke that fills the lower half of the frame. The truck has a red trailer and a purple and yellow canopy. In the background, there are several multi-story apartment buildings under a clear sky. The text is overlaid in the center of the image.

**IF WE CAN NOT STOP THE TRAFFIC  
WE COULD STOP THE PM  
PRODUCED BY THE MOST  
POLLUTING VEHICLES**

## Particle trap

- Two studies indicate that particles drive the acute cardiovascular effects of Diesel Exhaust exposure.
- A retrofit 'particle trap' on the engine exhaust efficiently reduces particle mass in the DE and completely prevented the thrombotic actions of Diesel Exhaust
- Filtering of particles from DE also prevented the vascular impairment observed with whole exhaust. This observation was supported by a study whereby volunteers were exposed to pure nitrogen dioxide at concentrations representative of whole exhaust; no acute cardiovascular effects were observed.



*Andrew J. Lucking. Circulation. Particle Traps Prevent Adverse Vascular and Prothrombotic Effects of Diesel Engine Exhaust Inhalation in Men, Volume: 123, Issue: 16, Pages: 1721-1728, DOI: (2011 CIRCULATION AHA.110.987263)*

- **Although there are many potentially harmful components in ambient air pollution, traffic-derived fine and ultrafine particles are most closely and consistently linked to acute cardiovascular events. This has been the rationale for the development of, and legislation for, targeted interventions to reduce the particulate matter content of vehicle emissions**
- **Exhaust particle traps are a highly efficient method of reducing particle emissions from diesel engines.**
- **The use of a particle trap prevents several adverse cardiovascular effects of exhaust inhalation in men.**
- **Given these beneficial effects on biomarkers of cardiovascular health, the widespread use of particle traps on diesel-powered vehicles may have substantial public health benefits and reduce the burden of cardiovascular disease.**



A dense field of various flowers in full bloom, including tulips in shades of orange, yellow, and white, daffodils, and clusters of purple hyacinths. The flowers are set against a backdrop of lush green foliage. The text is centered over the image in a bold, white, sans-serif font.

**AS USUAL THE BEST ANSWER  
COMES FROM NATURE**



## Efficient Removal of Ultrafine Particles from Diesel Exhaust by Selected Tree Species: Implications for Roadside Planting for Improving the Quality of Urban Air

•Huixia Wang *Environ. Sci. Technol.* 2019, 53, 12, 6906-6916

- They quantify the size-resolved capture efficiency of UFPs from diesel vehicle exhaust by nine temperate-zone plant species, in wind tunnel experiments
- silver birch (79% UFP removal), yew (71%), and elder (70.5%) have very high capabilities for capture of airborne UFPs
- **roadside planting of selected species at PM “hotspots” can contribute substantially and quickly to improve in urban air quality and reductions in human exposure**

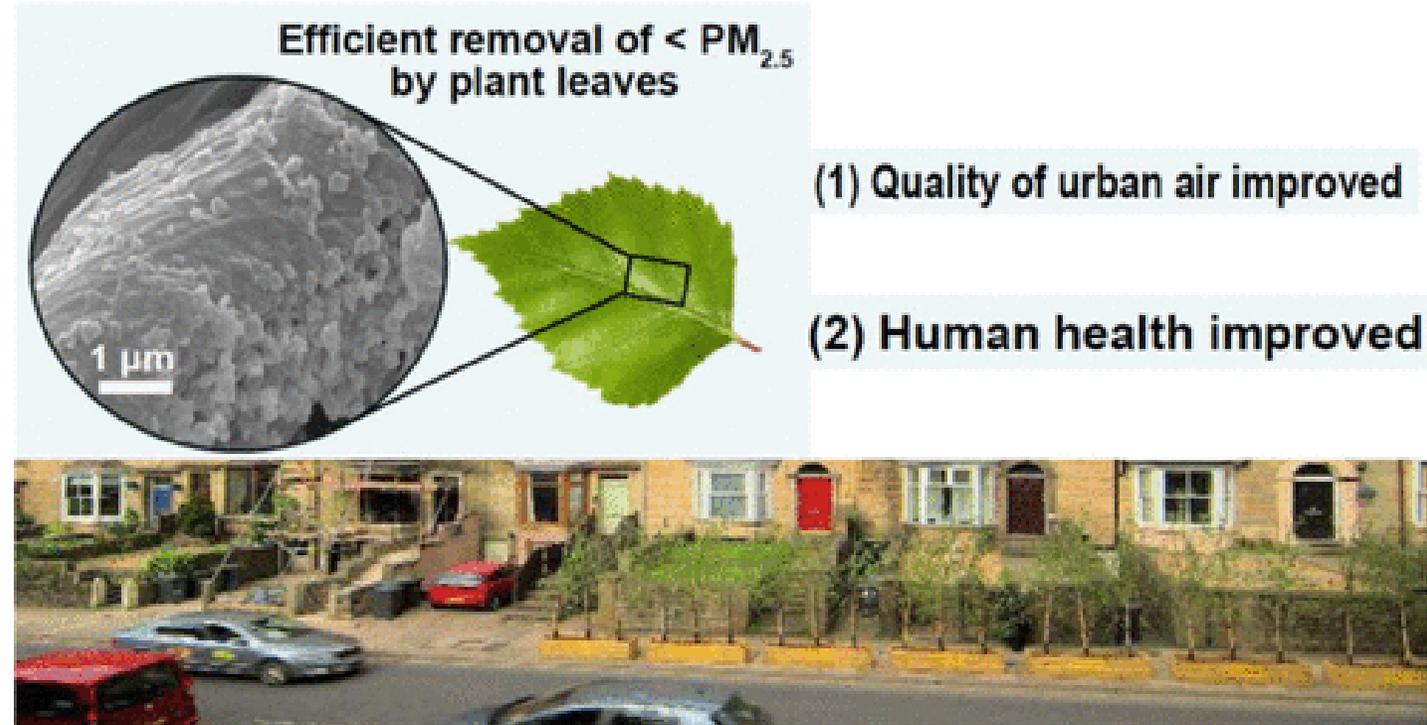
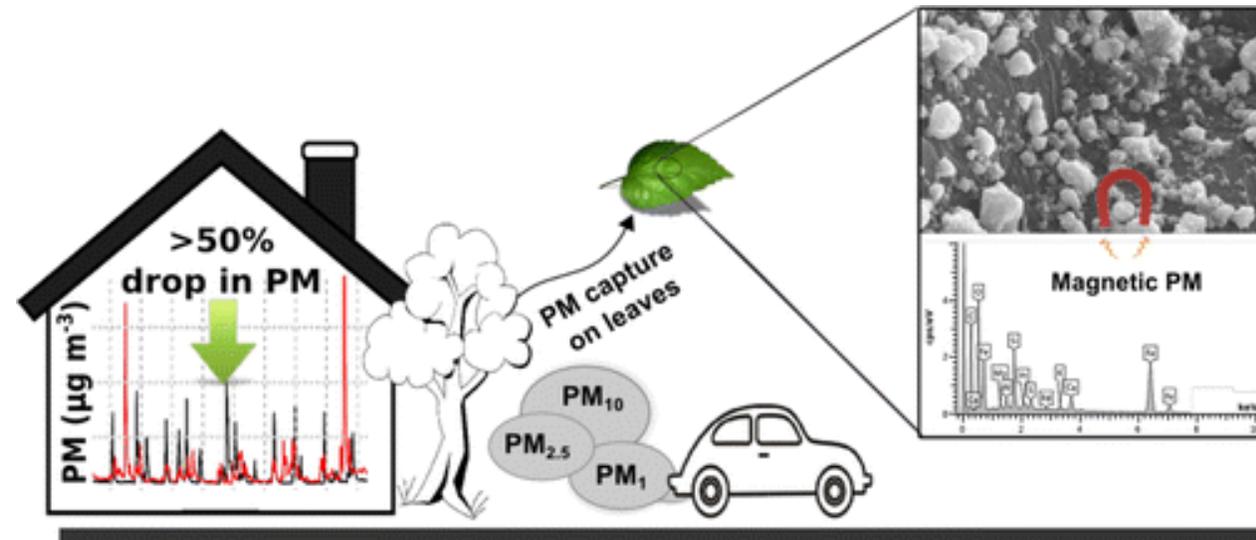


Figure: Scanning electron microscopy showed that UFPs were concentrated along the hairs of these leaves



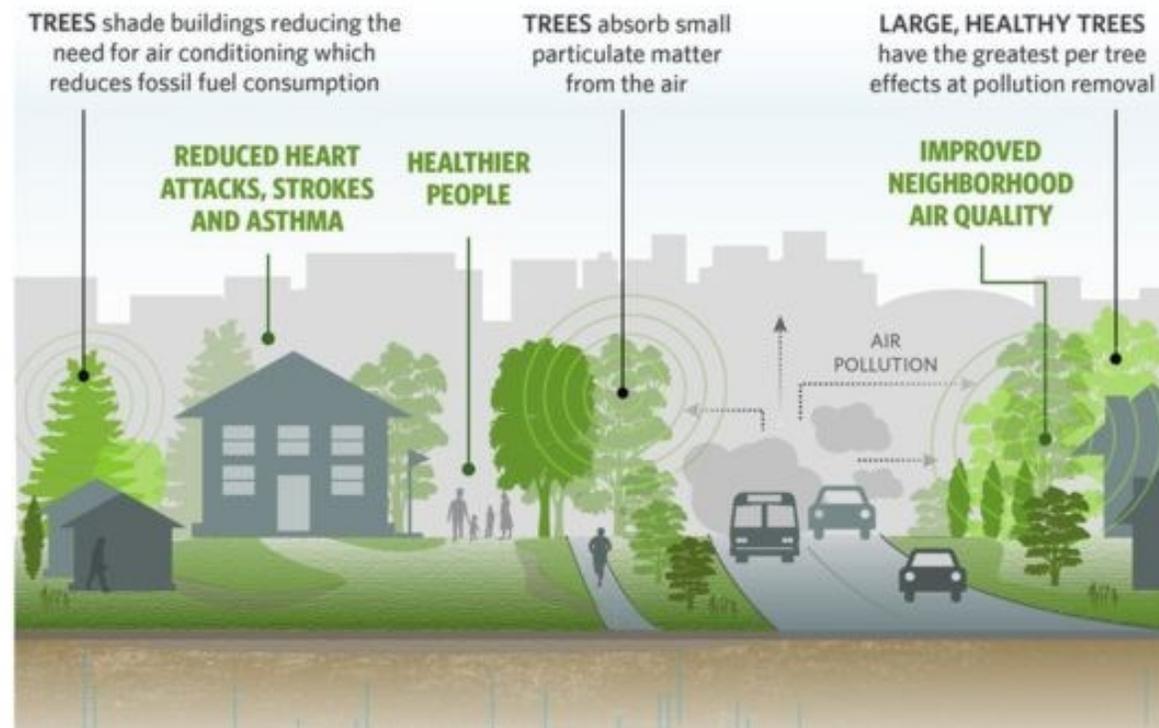
# Impact of Roadside Tree Lines on Indoor Concentrations of Traffic-Derived Particulate Matter Barbara A. Maher et al. *Environ. Sci. Technol.* 2013, 47, 23, 13737-13744

- >50% reductions in measured PM levels inside those houses screened by the temporary tree line





- **Planting trees is a cost-effective way to tackle urban air pollution, which is a growing problem for many cities.** Studies reported that the average reduction of particulate matter near a tree was between 7% and 24%.
- A study has looked at 245 cities in US, it found that if all the people in them spent an extra US \$4 a year on planting trees, you could save between 11,000 and 36,000 lives each year. This is mostly as a result of having cleaner air.





# **Air pollution removal by urban trees and shrubs in the United States**

David J. Nowak\*, Daniel E. Crane, Jack C. Stevens

*USDA Forest Service, Northeastern Research Station, 5 Moon Library, SUNY-ESF, Syracuse, NY 13210 USA*

- **A modeling study using hourly meteorological and pollution concentration data from across the coterminous United States demonstrates that:**
- **urban trees remove large amounts of air pollution that consequently improve urban air quality.**
- **Pollution removal (O<sub>3</sub>, PM<sub>10</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO) varied among cities with total annual air pollution removal by US urban trees estimated at 711,000 metric tons (\$3.8 billion value).**
- **Pollution removal is only one of various ways that urban trees affect air quality.**
- **Integrated studies of tree effects on air pollution reveal that management of urban tree canopy cover could be a viable strategy to improve air quality and help meet clean air standards**



# CONCLUSIONS





## IMMEDIATE MEASURES



### Identify vulnerable individuals :

- Elderly
- Patients with cardiovascular disease or high cardiovascular risk
- Patients with respiratory diseases (asthma, COPD, cancer, etc.)
- Patients with diabetes
- Children
- Pregnant women

### Inform our patients of the risk and advise the following precautions:

- avoid exercising and walking along high-traffic roads
- on days of maximum concentration of pollutants, avoid leaving the house and opening the windows
- wear protective masks during peak concentrations of PM 2.5 and use air purifiers with a HEPA filter for homes (removal from the inside of 99% of the PM of 0.3  $\mu\text{m}$  size)
- cultivate some types of houseplants with anti-smog action (Ficus Benjamin, Potus, Filodendro, Dracena)



# MEDIUM LONG-TERM MEASURES



Energy reform	Change coal and methane power plants with renewable energy plants such as solar, wind, geothermal. Use state-of-the-art condensing boilers. Maintain house and office temperatures below 20 ° C
Transport reform	Promote the use of zero-emission vehicles and increase the efficiency of engines powered by fossil fuels, reduce sulfur and nitrogen content in fuels. Restrict access to trucks in cities, switch to small electric trucks and encourage eco-sustainable and healthy mobility such as pedestrian and bicycle mobility
Technology improvement	Establish monitoring systems in schools and hospitals, <b>Ultra-fine particulate measurement</b> . Diesel particulate filters, catalytic converters, alternative fuels (methane, LPG) or better the hydrogen
Reform of urban projects	Increase the extension of pedestrian areas, the km of cycle paths. Increase the safety of pedestrians and cyclists. Increase the number of trees in public green areas especially near high-traffic roads and encourage the planting of private airplanes too
Tax the pollutants and de-tax those who pollute less	Increase taxes on polluting vehicles and encourage the purchase of environmentally friendly vehicles
Invest in research	Increase the funds available for research into the pathological effects of pollutants and research for alternative energy sources
<b>Raise the collective consciousness</b>	Role of the doctor as an educator to the health of patients and the environment in which they live, advertising campaigns, conferences, school projects
Advertising control, sports and movies	Prohibit advertising of the tobacco, oil and light multinational corporations encouraging cigarette smoke, polluting vehicles, polluting fuels





James Allison

Tasuku Honjo

Youyou Tu

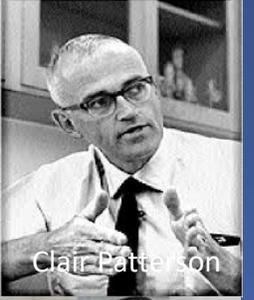
Michael J. Sofia

Robert Brook

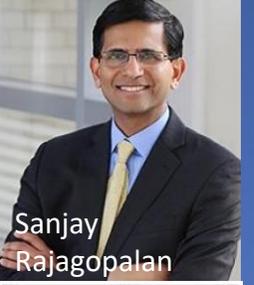
May-Britt Moser

Eric Kandel

Ugo Montanari



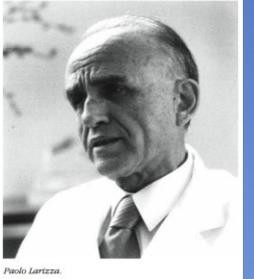
Clair Patterson



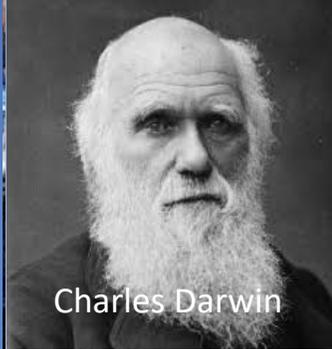
Sanjay Rajagopalan



Luigi Migone



Paolo Luriza



Charles Darwin



Ibn Sina Avicenna

THE FUTURE OF OUR PLANET IS IN OUR HANDS!

THANK YOU FOR YOUR ATTENTION!