# Health Effects of Atmospheric Aerosols

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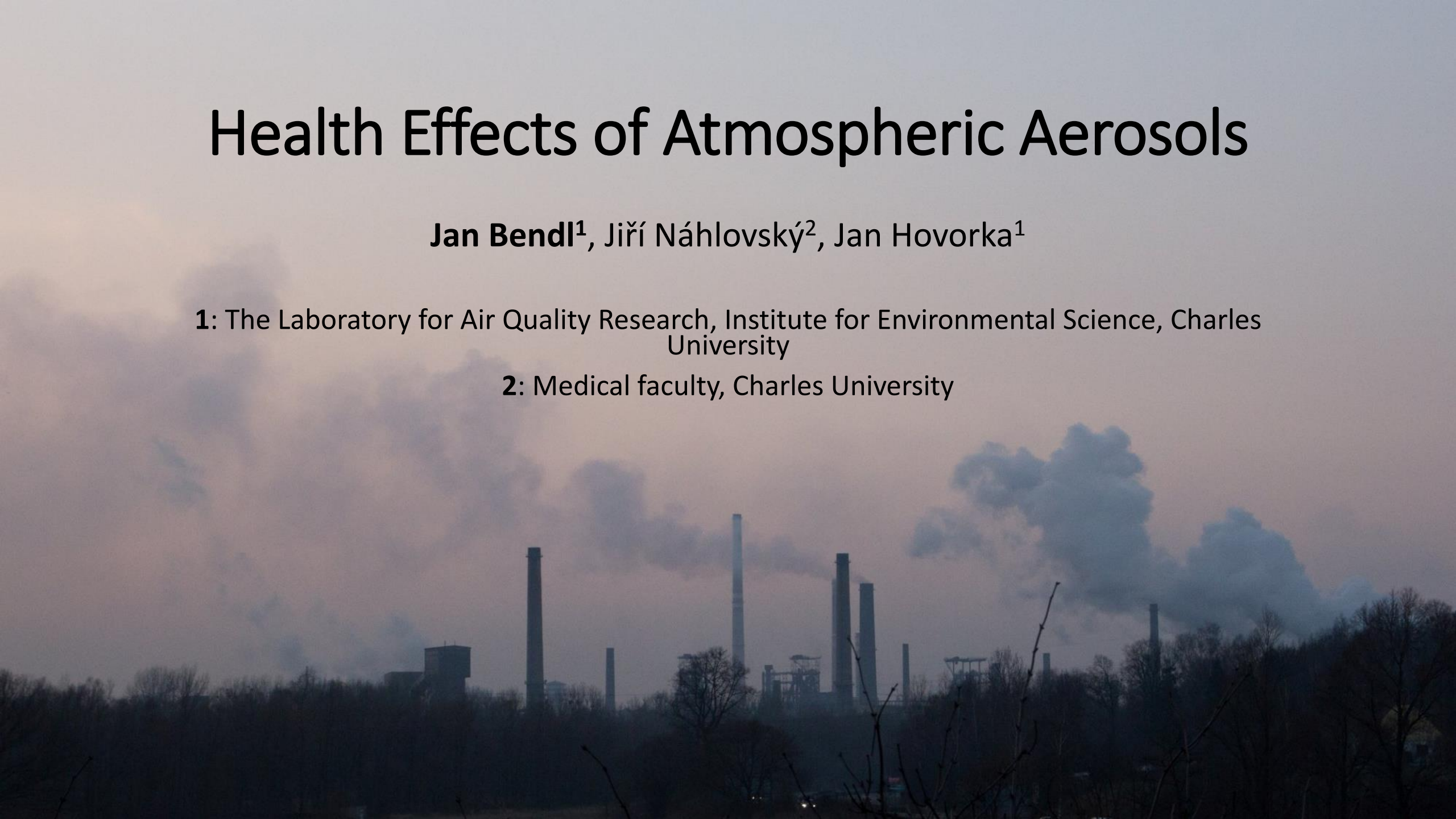
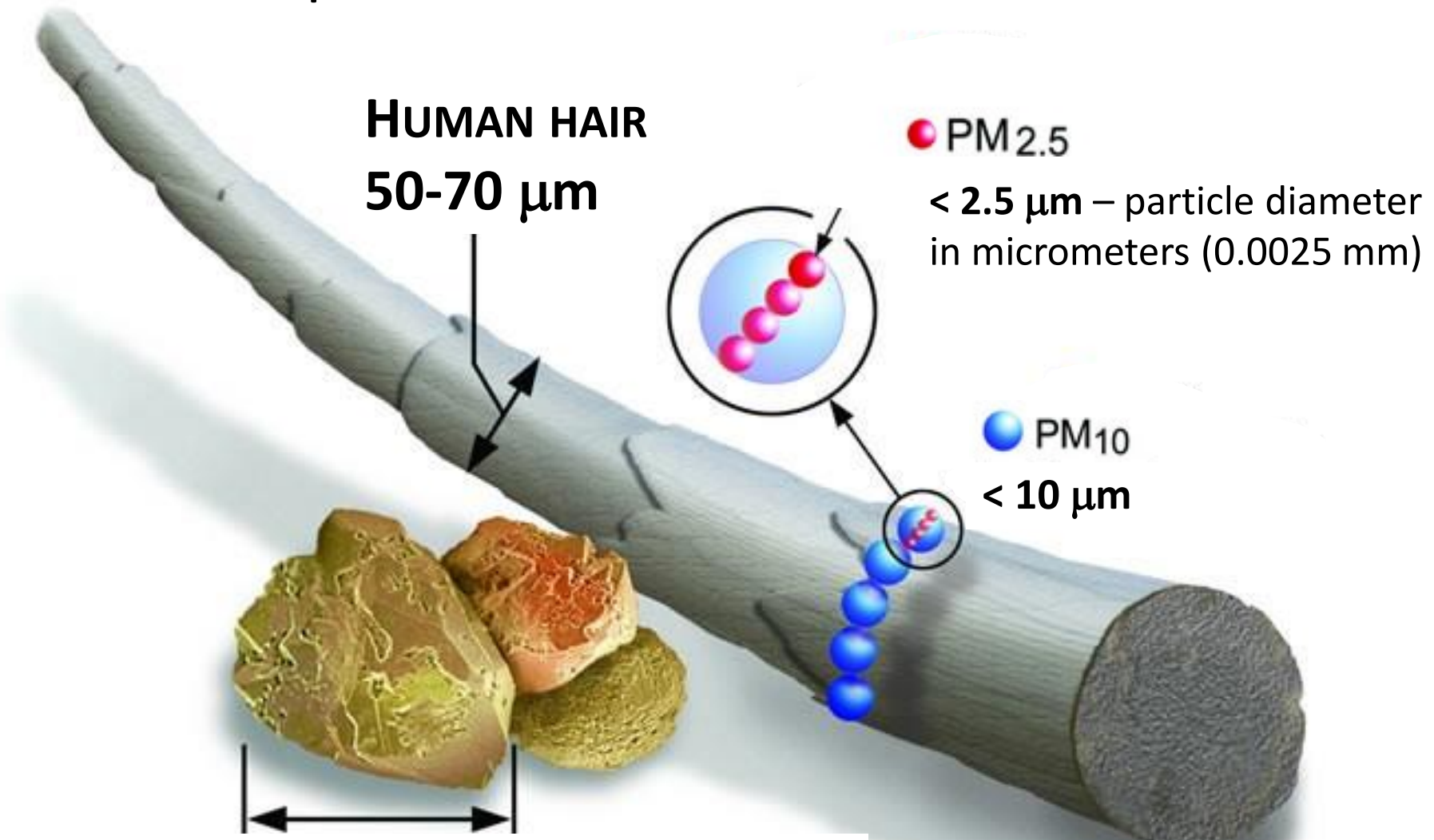


# Atmospheric Aerosol – Particle Sizes



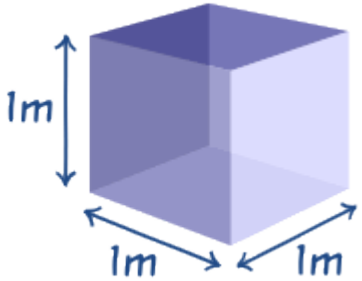
# What is Atmospheric Aerosol?

- The ubiquitous component of the atmosphere
- Solid, liquid, mixed particles

**1 nm – 100 µm**

**1 milionth of a milimeter – 1 tenth of a mm**

- Single particles are invisible, clusters as **cloud, fog, haze, smoke, mist, dust**




# How many Aerosols are in the Air?

**1 $m^3$** of air weights **1.3 kg:**

**The main components**

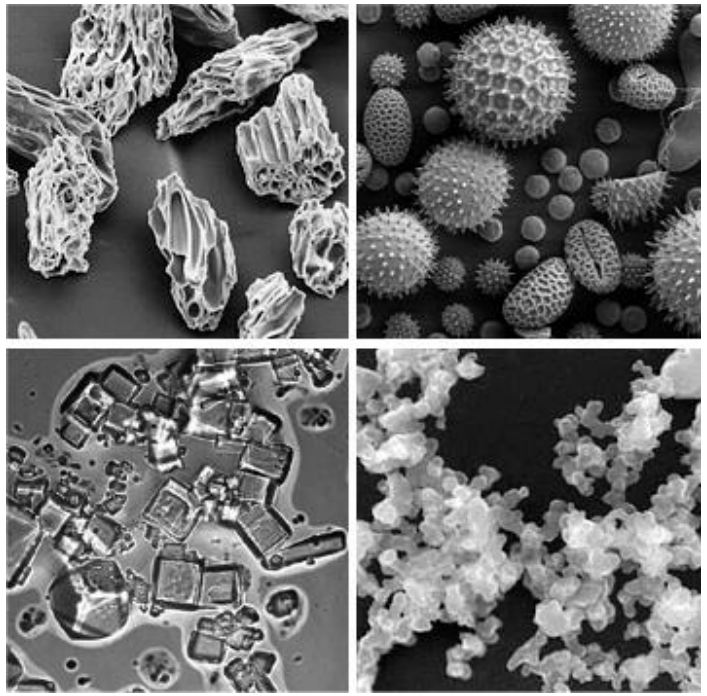
| | |
|---|---|
| • $N_2$ | 0,96 kg |
| • $O_2$ | 0,3 kg |
| • Ar | 16 g |
| • $H_2O$ | ~ 10 g |
| • $CO_2$ | ~ 0,6 g |

- **99,9998 % of mass**

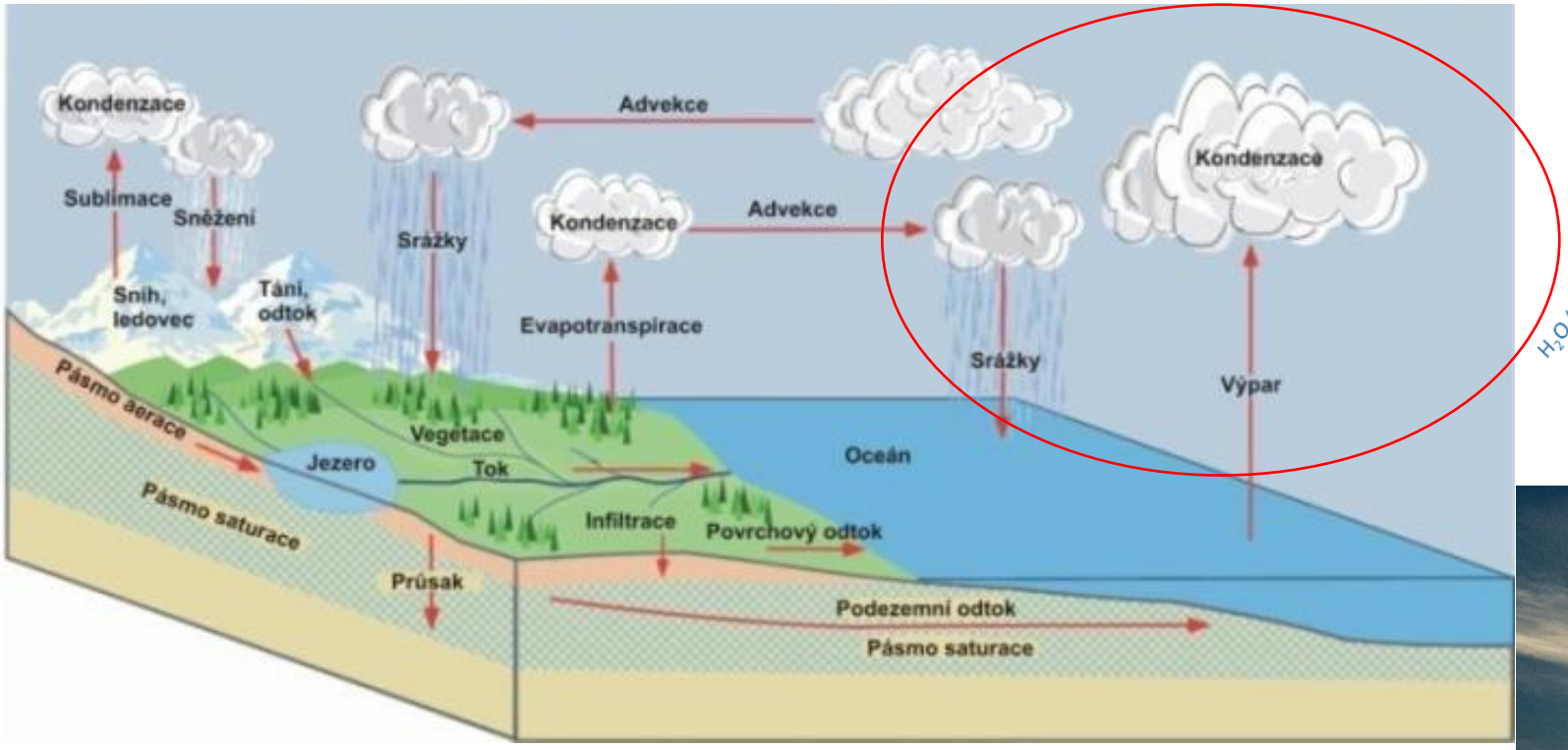
**In trace amounts**

| | |
|---|---|
| • $CH_4$ | 1 mg |
| • CO | 250 µg |
| • $H_2$ | 50 µg |
| • $O_3$ | 30-200 µg |
| • $NO_x$ | 10-200 µg |
| • **Aerosol particles** | **1-100 µg** |

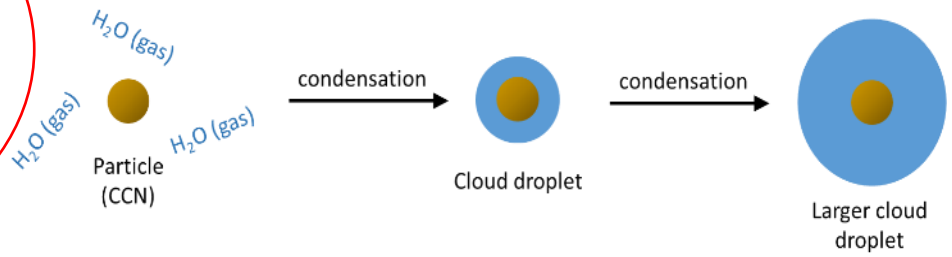
- **0,0002 % of mass**



# Is Atmospheric Aerosol Important?




## Condensation nuclei

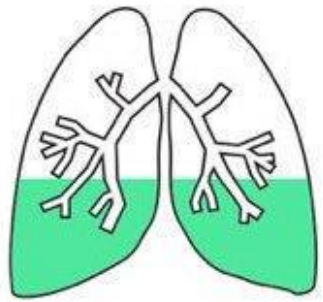



- The water cycle
- Earth thermal balance (atmospheric reflectivity)
- Optical phenomena (sunset, visibility,…)
- **Effects on human health and ecosystems**

# What causes the most deaths?

THE
**INVISIBLE KILLER**

Air pollution may not always be visible, but it can be deadly.



**35%**
OF DEATHS FROM
**COPD**
**(PULMONARY DISEASE)**

**BREATHELIFE.**
Clean Air. Healthy Future.

World Health Organization

CLIMATE & CLEAN AIR COALITION

| 2016 ranking | | % change 2005-2016 |
|---|---|---|
| 1 | Ischemic heart disease | 39.8% |
| 2 | COPD | 24.2% |
| 3 | Cerebrovascular disease | 20.4% |
| 4 | Lower respiratory infect | -33.6% |
| 5 | Diarrheal diseases | -41.9% |
| 6 | Diabetes | 58.8% |
| 7 | Neonatal encephalopathy | -26.5% |
| 8 | Road injuries | 6.7% |
| 9 | Chronic kidney disease | 36.9% |
| 10 | Tuberculosis | -29.9% |
| 11 | Asthma | -0.3% |
| 12 | Other neonatal | -31.6% |

Top 10 causes of death in 2016 and percent change, 2005-2016, all ages, number

**WHO:**

- Globally **3 milion deaths** every year (ambient air pollution)
- Globally **4.3 milion deaths** every year (indoor air pollution - cooking)
- **92%** of World population lives at places where air quality limits are exceeded

**EEA:**

- In Europe **>400 000** premature deaths

**IARC:**

- Air pollution classified as carcinogenic

# Effects on Public Health

## Air pollution, a preventable risk

**SLCPs, particularly $O_3$ and BC and co-pollutants, which are important parts of PM2.5 air pollution, are harmful to human health. Globally, PM2.5 is the leading environmental cause of poor health and premature death.**

**PREMATURE DEATHS** YEAR 2010

GLOBALLY, **AIR POLLUTION** IS RESPONSIBLE FOR:

**3,500,000** From **indoor** PM2.5 pollution

**3,200,000** From **outdoor** PM2.5 polution

**150,000** From **ozone** pollution

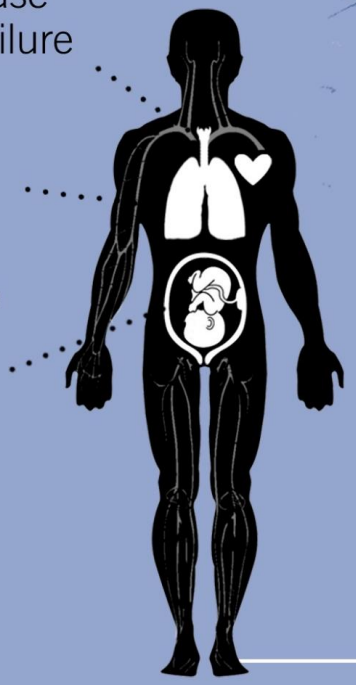
**DISEASES DUE TO:**

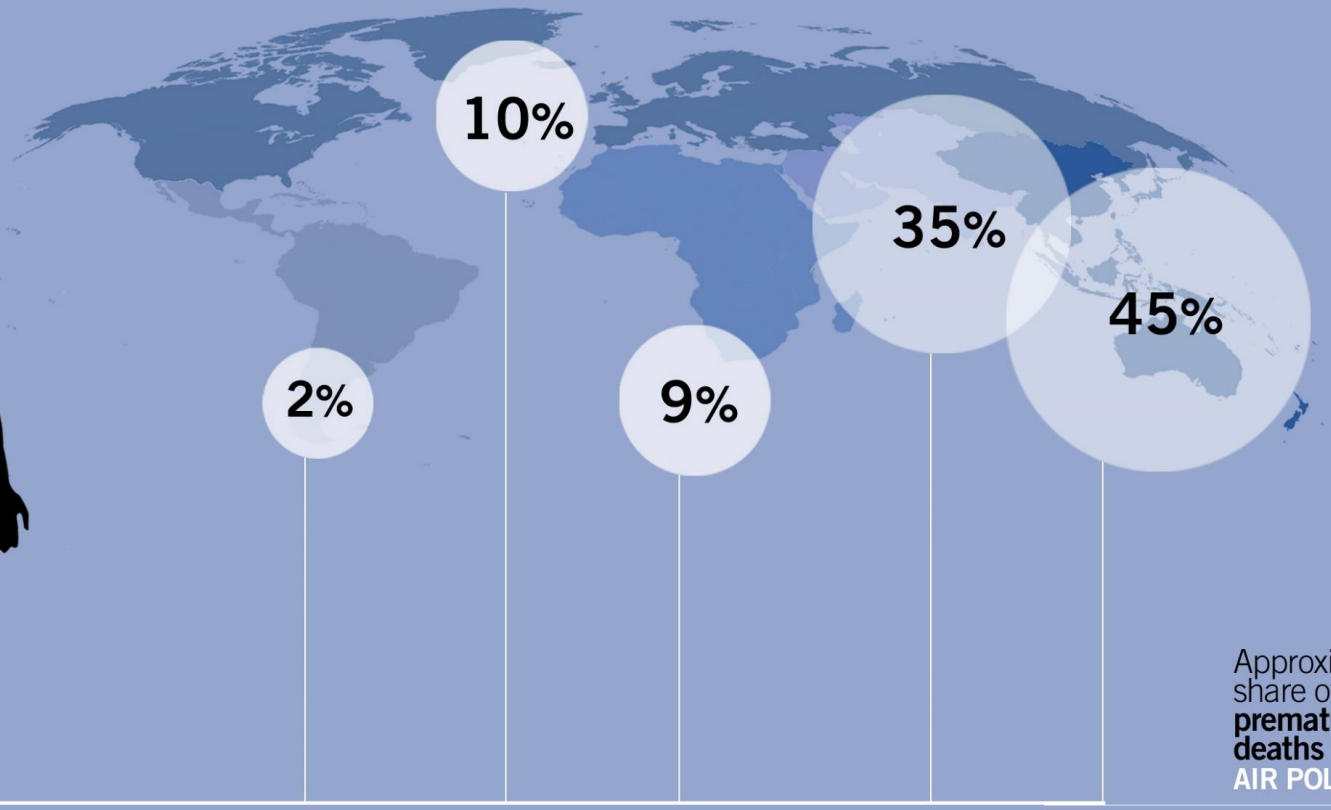
- PM2.5 AIR POLLUTION
- $O_3$

Heart attacks
Strokes, heart disease
Congestive heart failure

Lung cancer
Chronic bronchitis
Asthma
Emphysema
Scarred lung tissue

Low birth weight



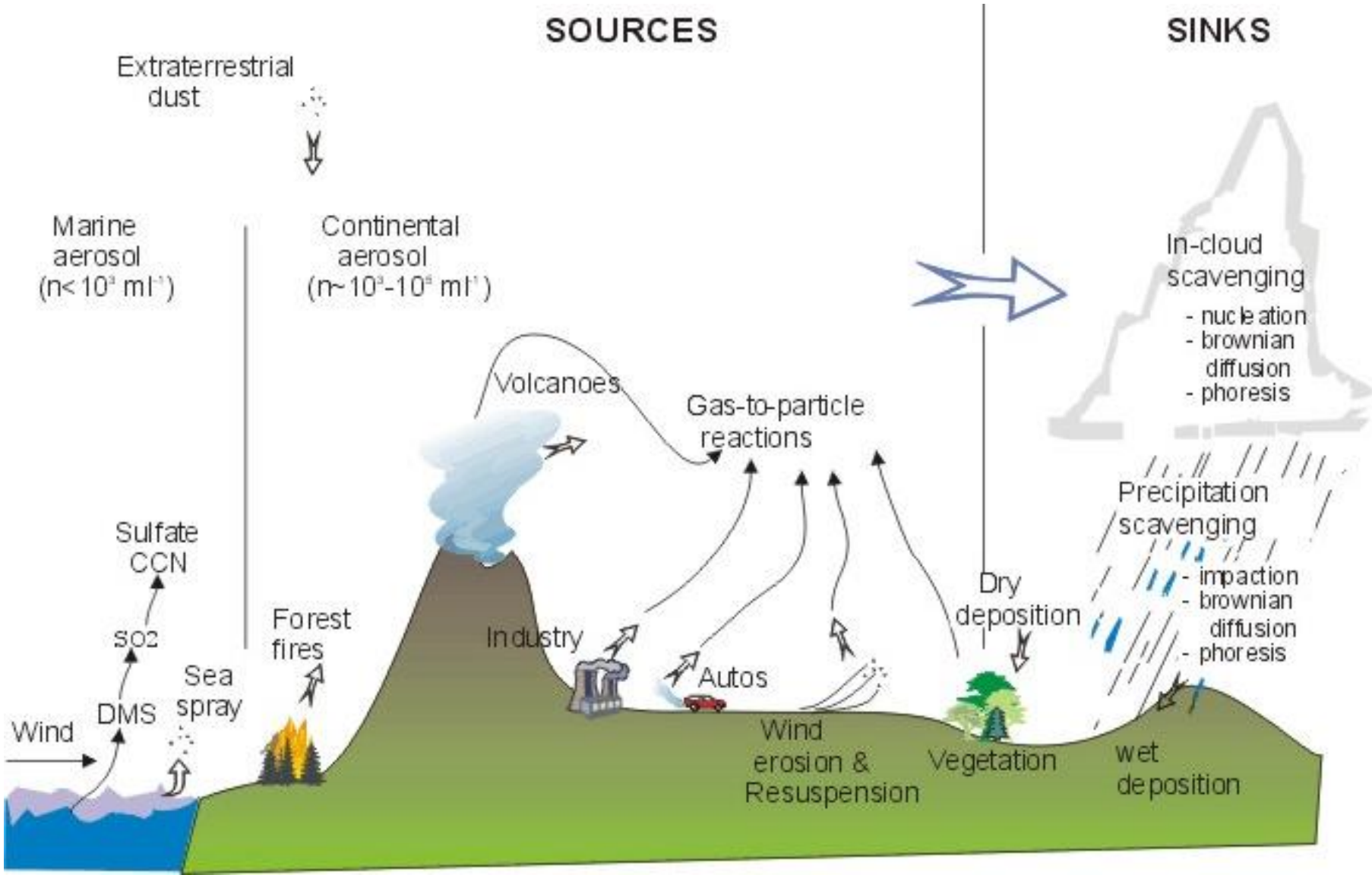


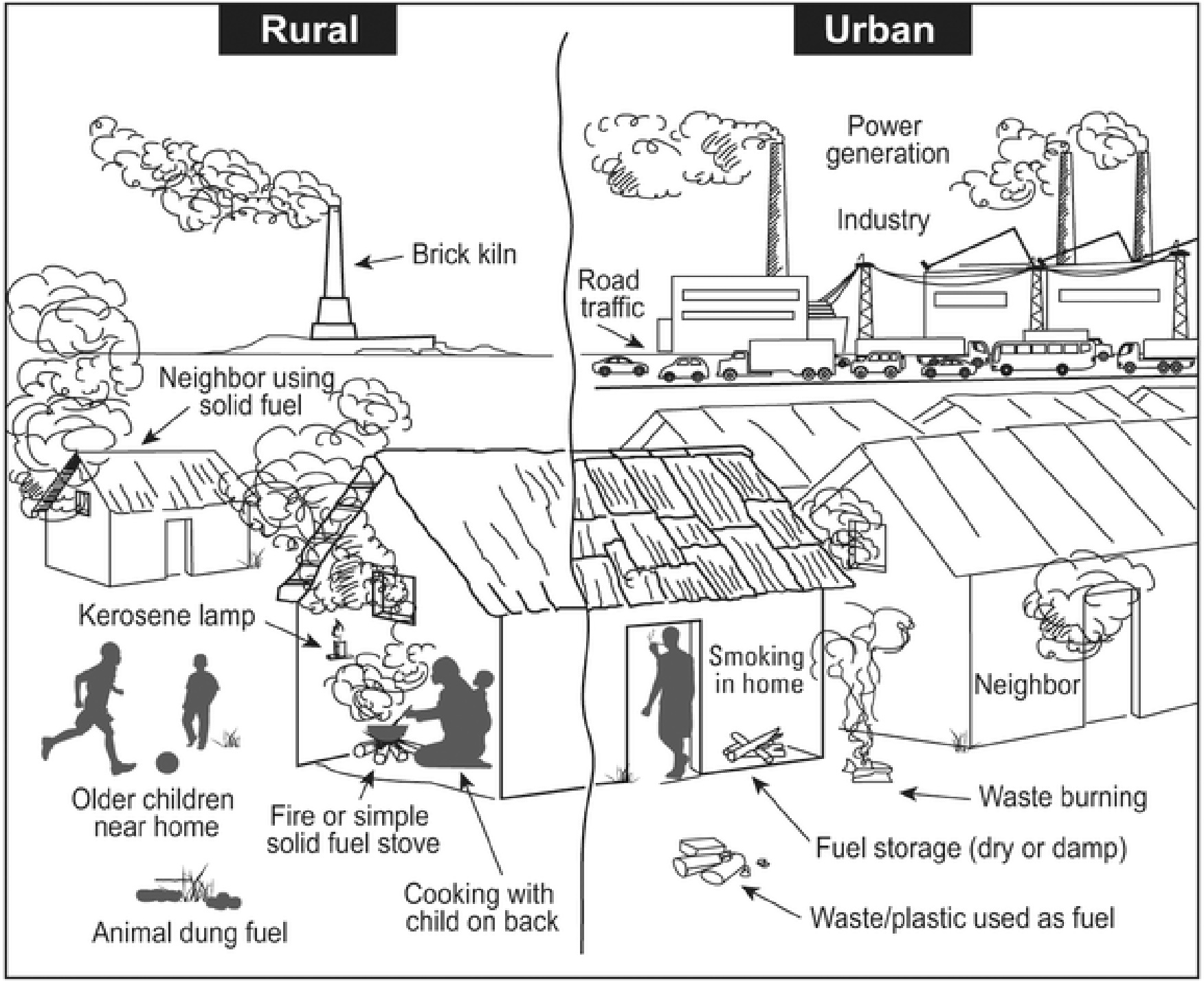

Approximate share of **premature deaths from AIR POLLUTION**

**year 2010**

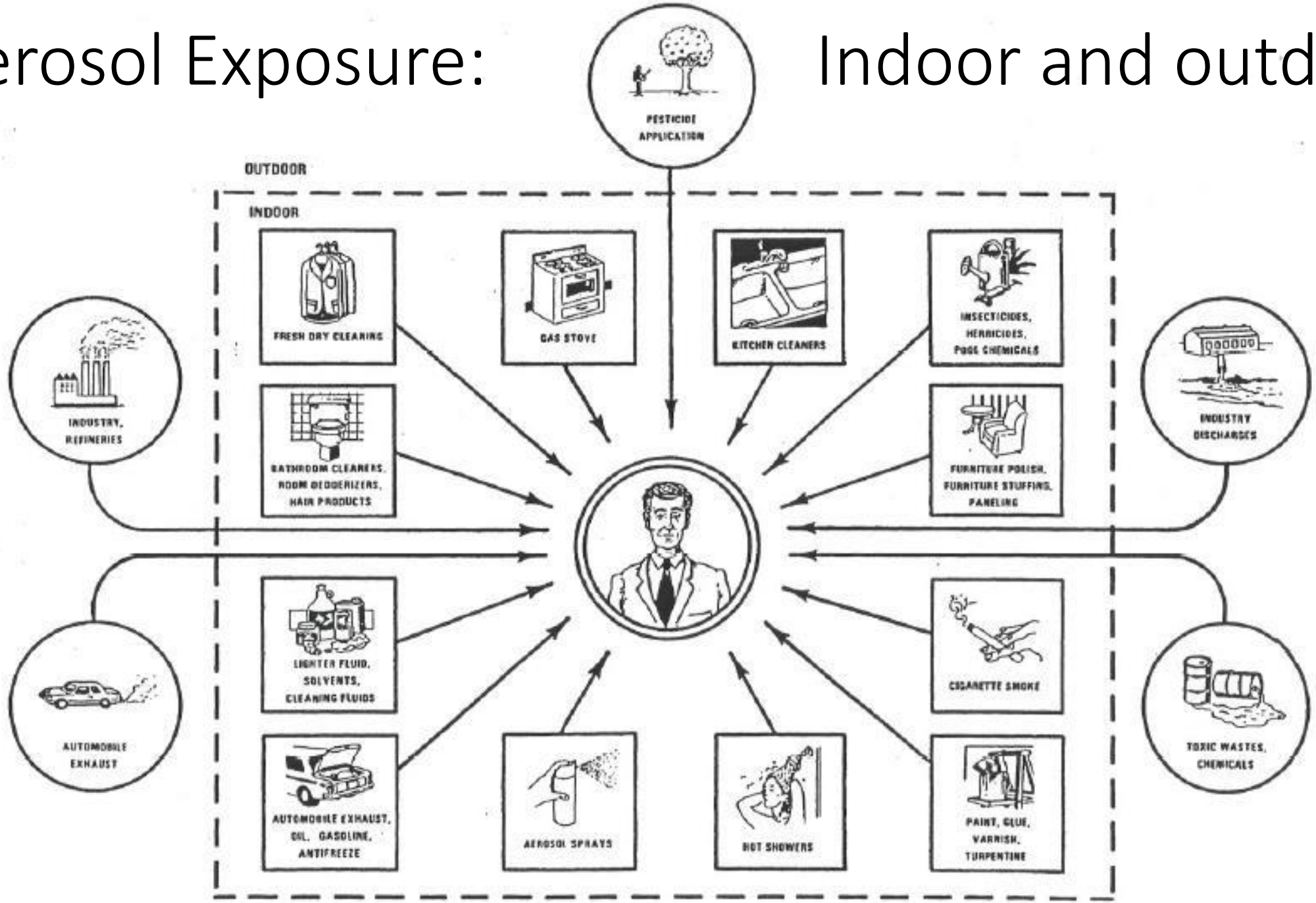
Globally, **air pollution** is the **2nd leading risk factor** for the global burden of disease in 2010, behind high blood pressure, and together with **tobacco smoking,** including second hand smoke.

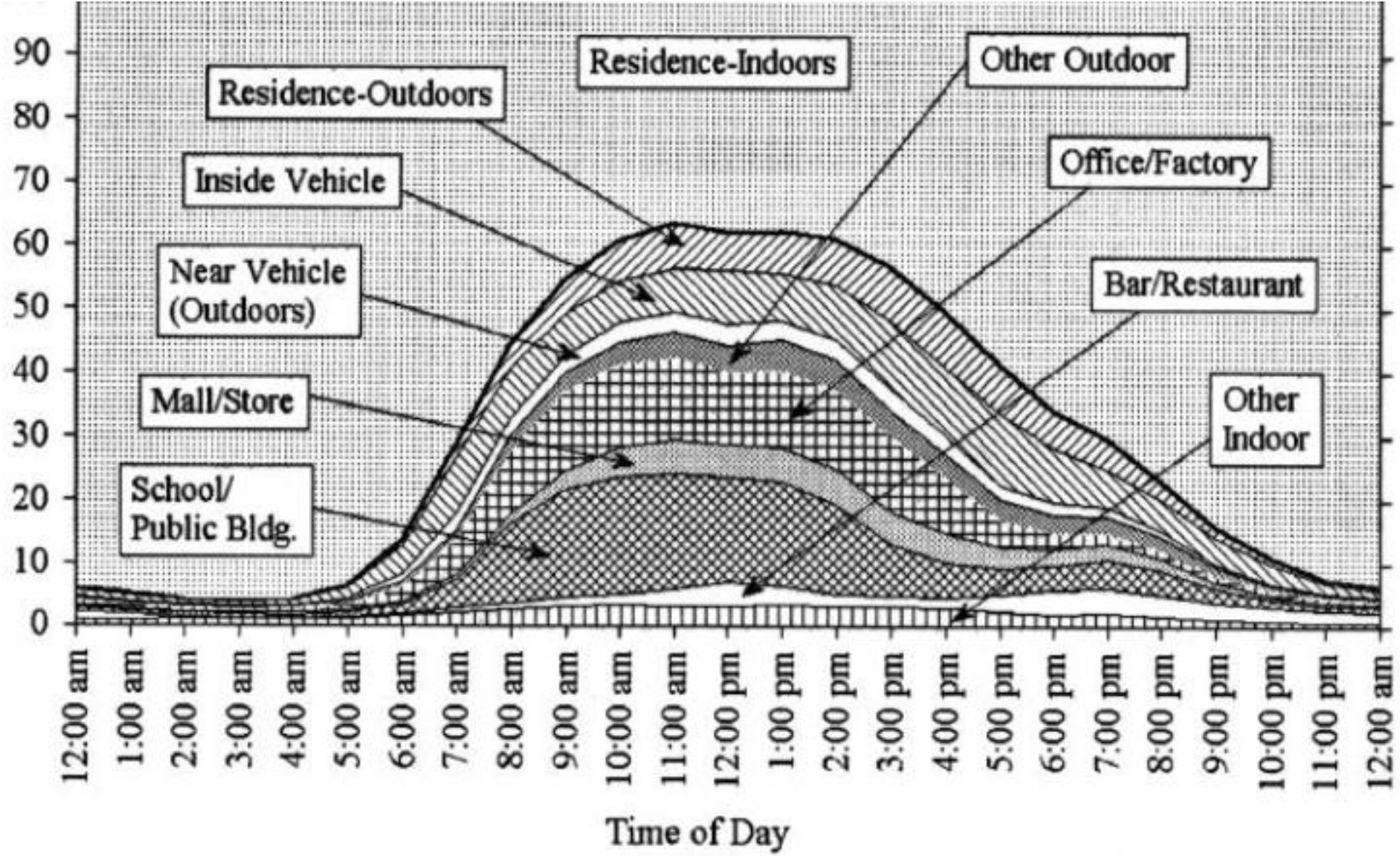
# Atmospheric Aerosol – Sources and Sinks




Rural
Urban
Brick kiln
Power generation
Industry
Road traffic
Neighbor using solid fuel
Kerosene lamp
Smoking in home
Neighbor
Older children near home
Fire or simple solid fuel stove
Waste burning
Fuel storage (dry or damp)
Cooking with child on back
Animal dung fuel
Waste/plastic used as fuel

# Aerosol Exposure: Indoor and outdoor






**4.** Stacked plot showing the weighted percentage of NHAPS respondents in each of 10 different locations according to the time of day. The 1 minute-by-minute diary data have been smoothed for clarification.

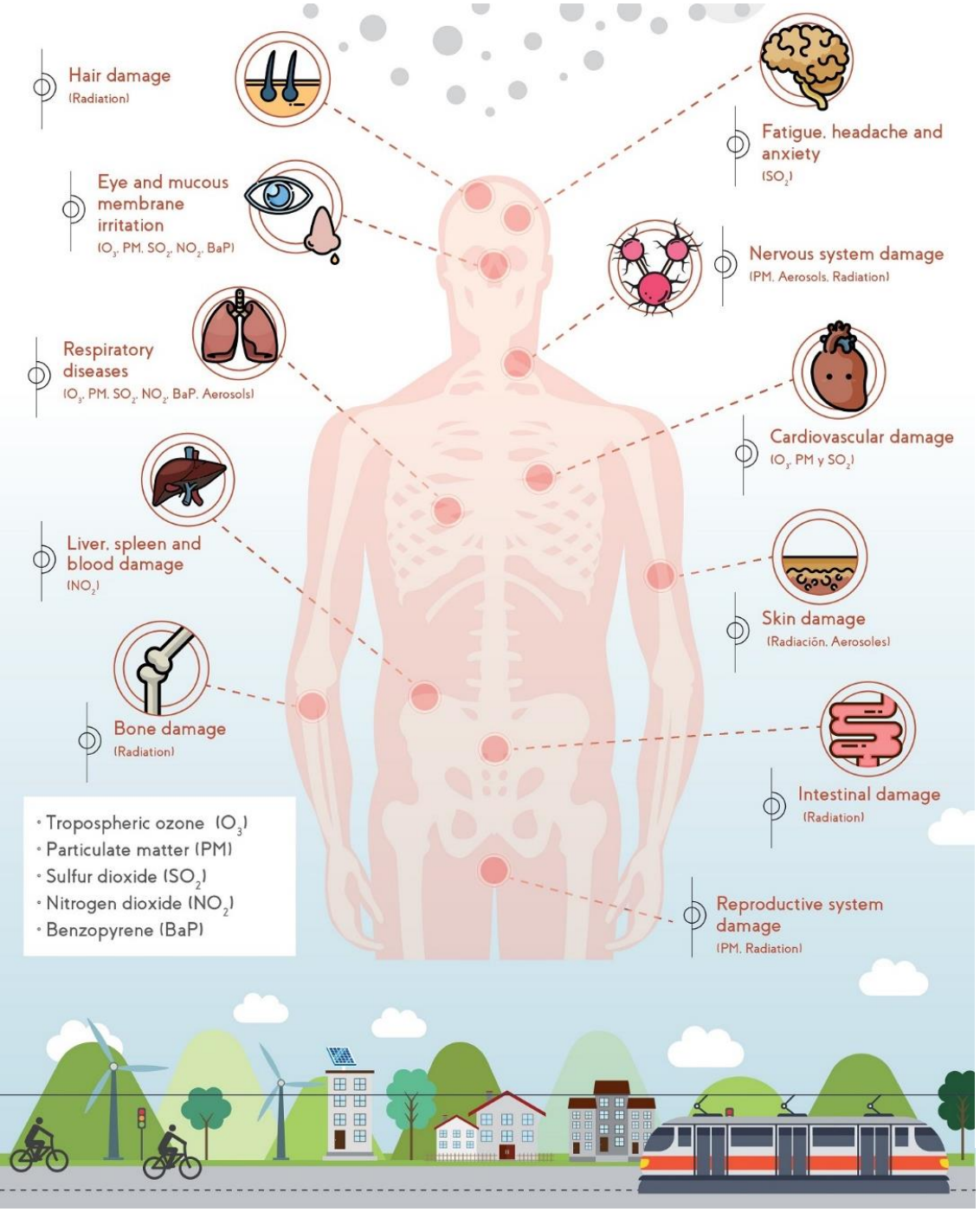
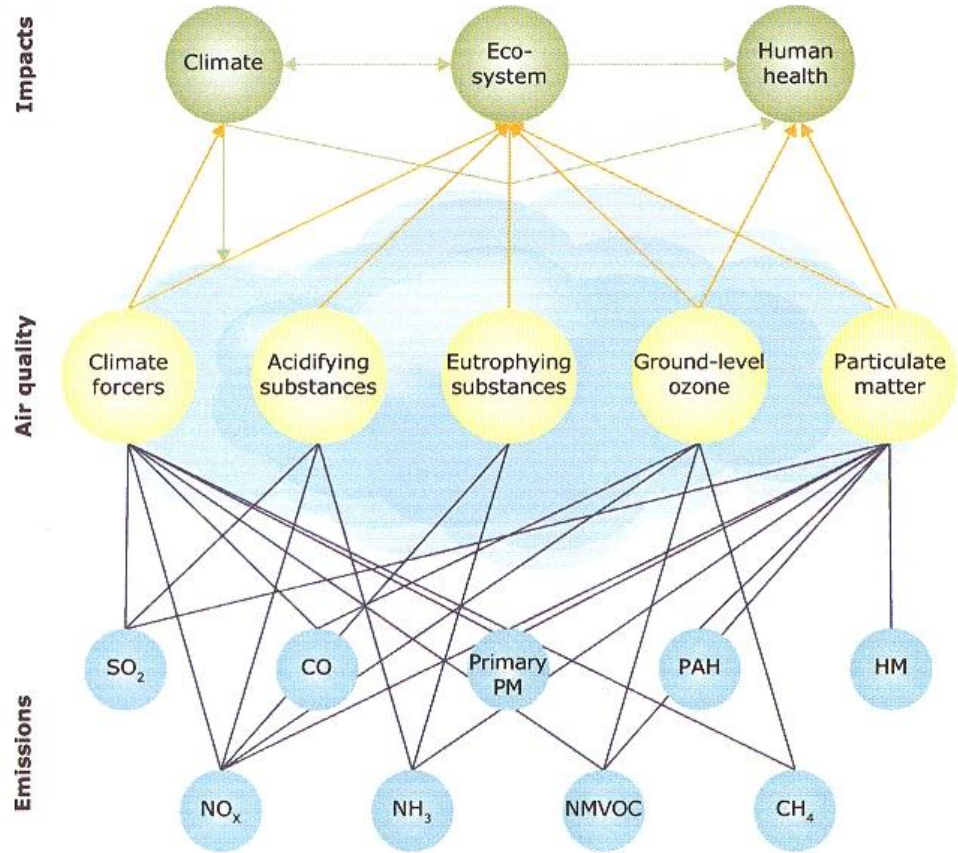



**Figure ES.1 Major air pollutants in Europe, clustered according to impacts on human health, ecosystems and the climate**




**Note:** From left to right the pollutants shown are as follows: sulphur dioxide ($SO_2$), nitrogen oxides ($NO_x$), carbon monoxide (CO), ammonia ($NH_3$), particulate matter (PM), non-methane volatile organic compounds (NMVOC), polycyclic aromatic hydrocarbons (PAH), methane ($CH_4$), heavy metals (HM).

Nanoparticles (invisible)

$PM_{10}$

$PM_{2.5}$

$PM_1$

Lungs

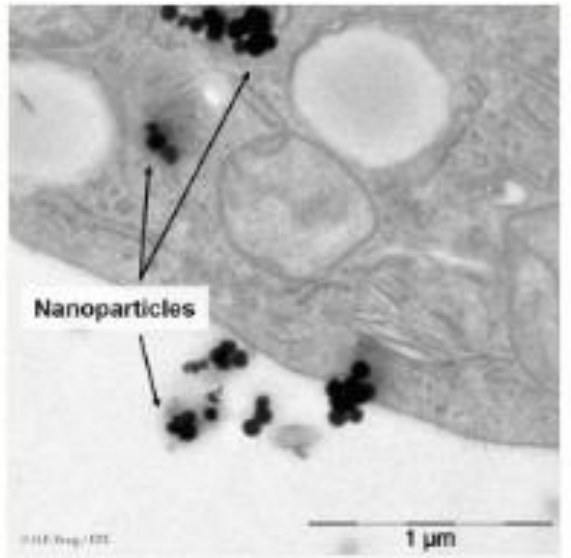
Blood Vessel with red Blood Cells

Lung Epithelial Cells

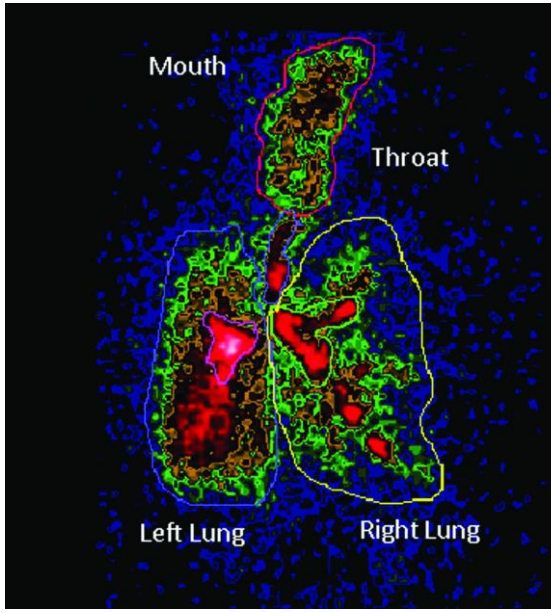
Alveolus

Macrophages

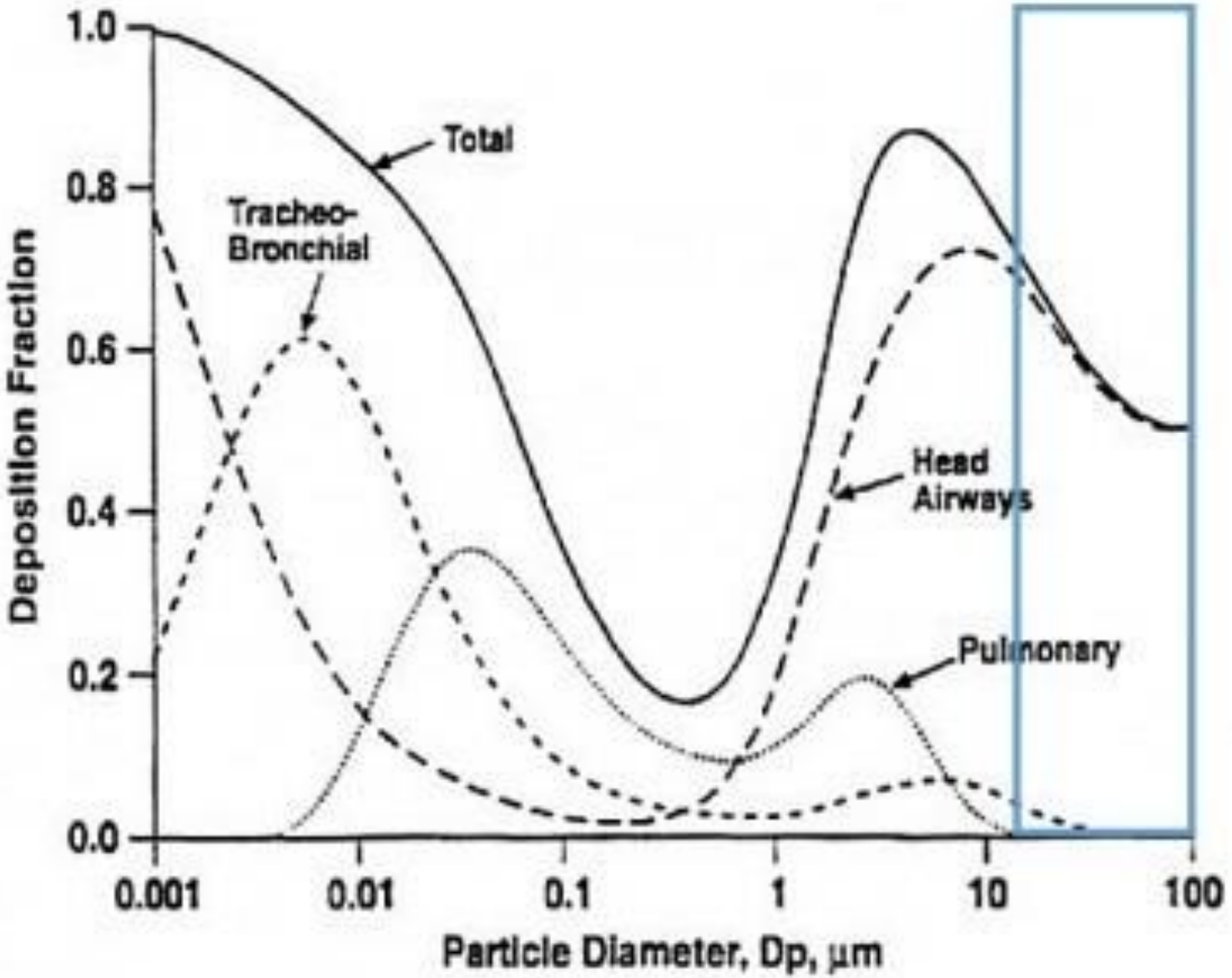
Dentritic Cell

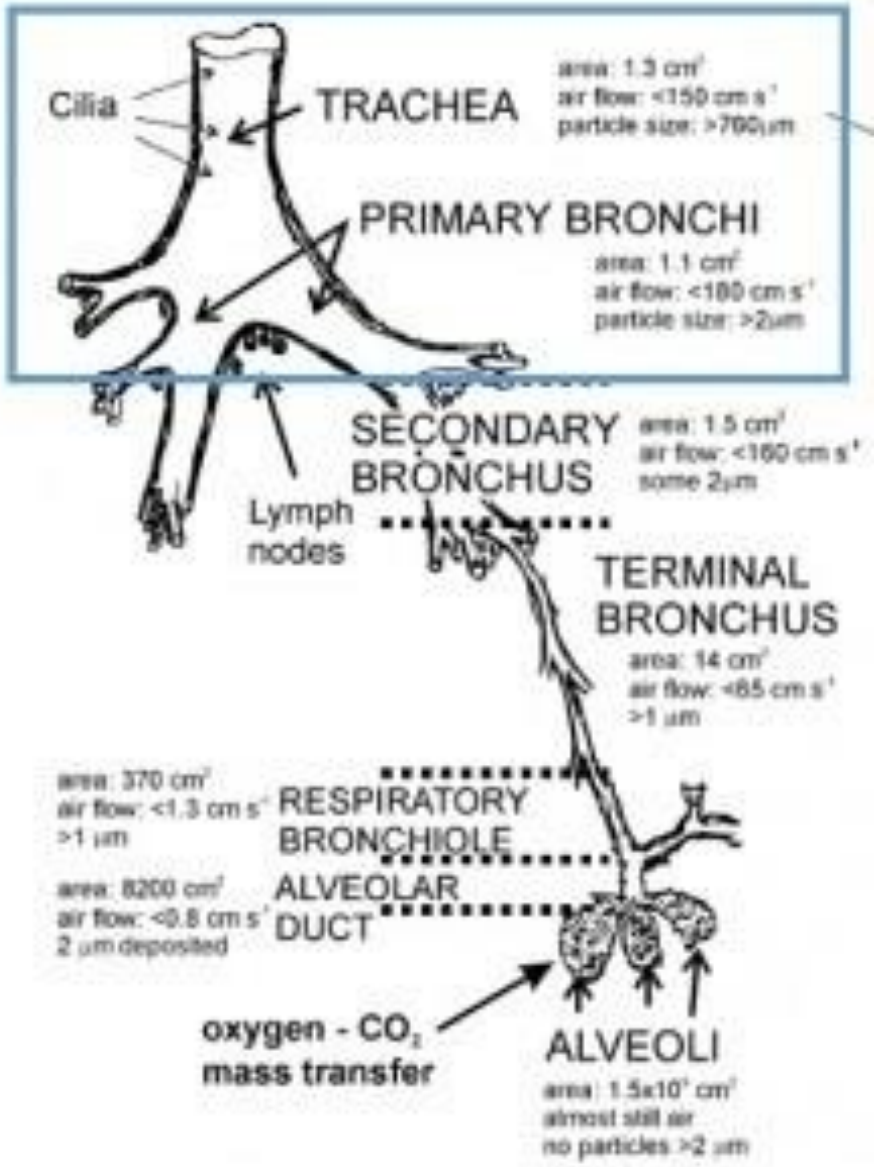



*TEM image of A549 cells with hematite nanoparticles (50 nm)*

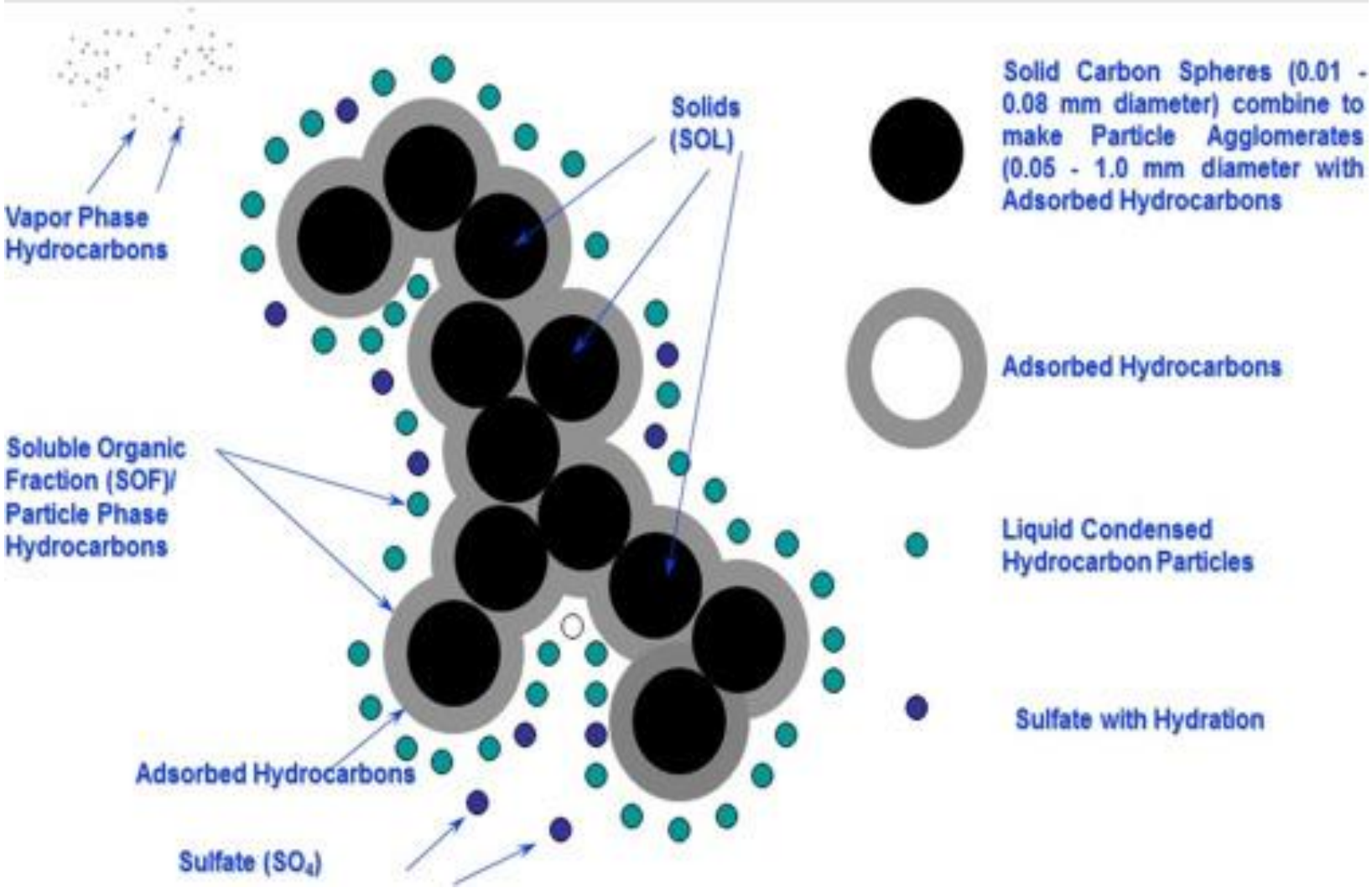


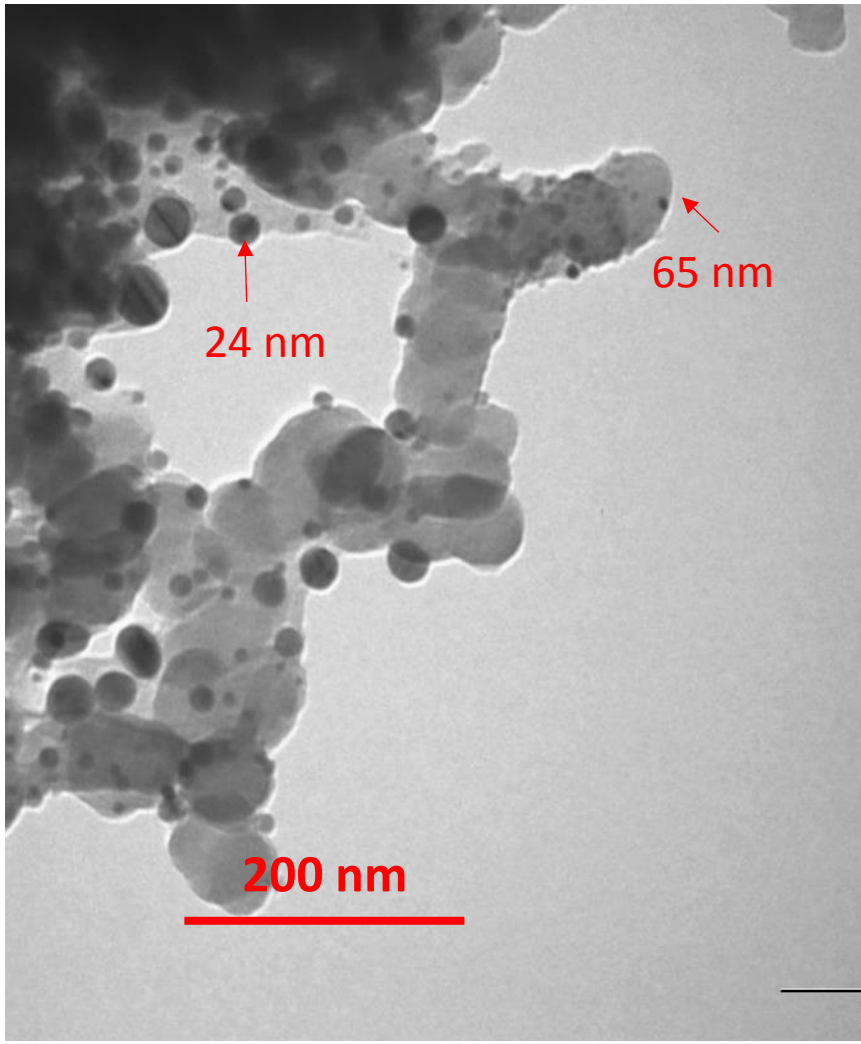
# Deposition of Aerosol Particles in Breathing System



# Why can be Aerosol Particles so Dangerous?



# Polycyclic Aromatic Hydrocarbons

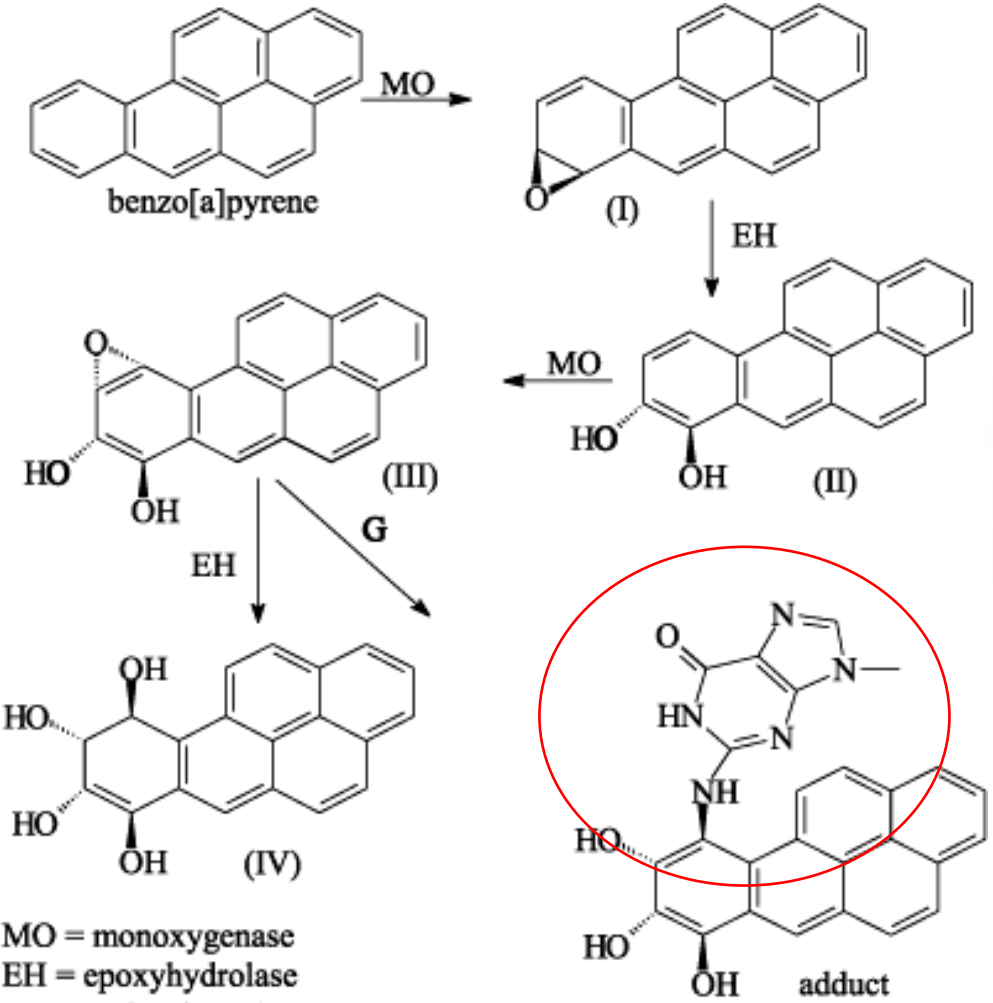
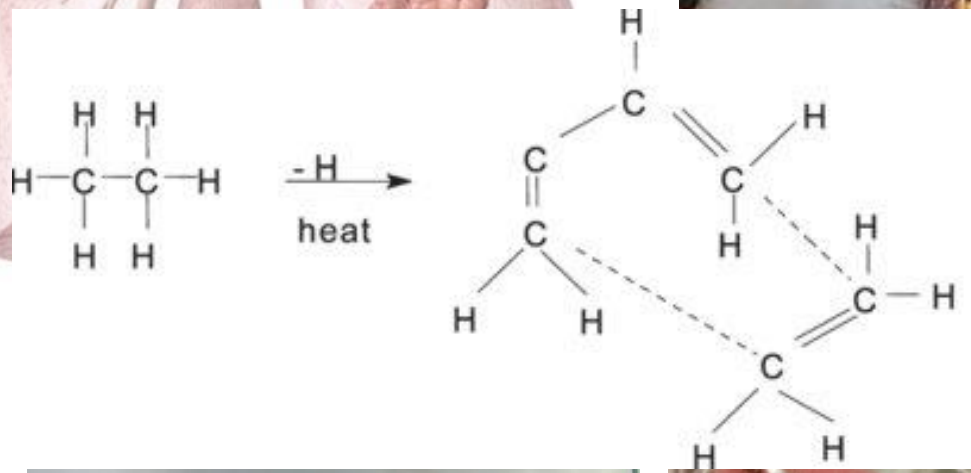
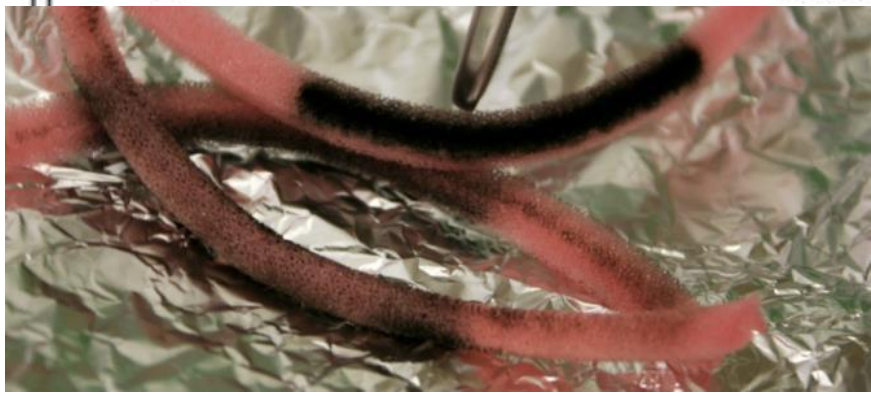


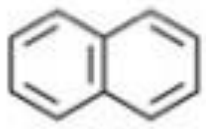

**Figure 1.** *In vivo* oxidative metabolic pathway of benzo[a]pyrene *via* hydrophilic intermediates (I-IV) and formation of DNA adducts with guanine base.



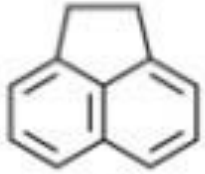



# US EPA 16 Priority Pollutants
# PAH Compounds

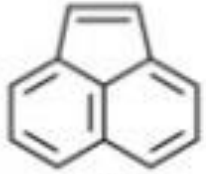
*Established in 1976



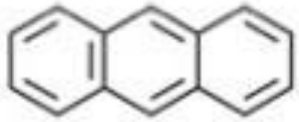
**naphthalene**



**acenaphthene**
1,2-dihydroacenaphthylene
1,8-ethylnaphthalene
Naphthyleneethylene
peri-ethylenenaphthalene

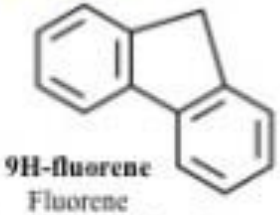


**acenaphthylene**

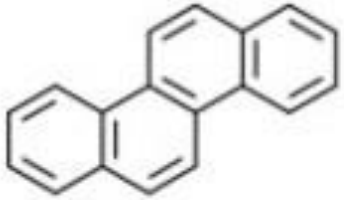


**anthracene**
paranaphthalene

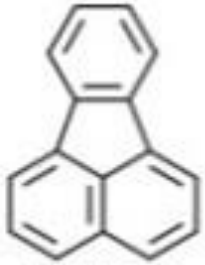
**phenanthrene**
3-Helicene
ravatite



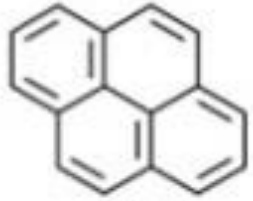
**9H-fluorene**
Fluorene
2,2'-methylenebiphenyl
o-biphenylenemethane
diphenylenemethane



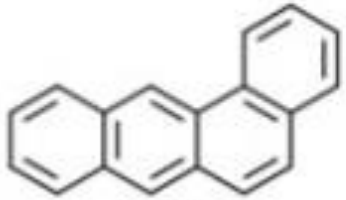
**chrysene**
1,2-benzophenanthrene
benzo(a)phenanthrene



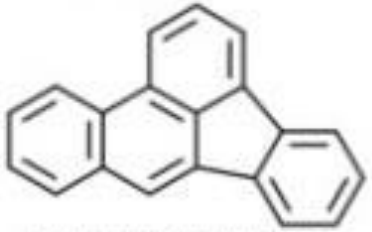
**fluoranthene**



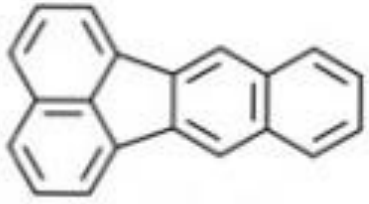
**Pyrene**
benzo(def)phenanthrene



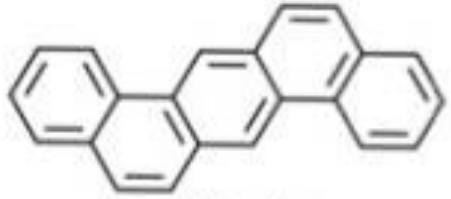
tetraphene
benz(a)anthracene
**benzo(a)anthracene**
1,2-benzanthracene
2,3-benzophenanthrene
benzo(b)phenanthrene



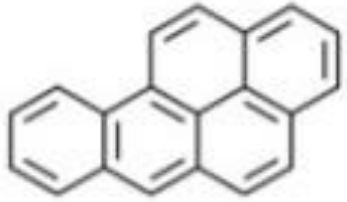
benzo(e)acephenanthrylene
**benzo(b)fluoranthene**
2,3-benzfluoranthene
3,4-benz(e)acephenanthrylene



**benzo[k]fluoranthene**
11,12-benzofluoranthene
2,3,1',8'binaphthylene
dibenzo(b,jk)fluorene
8,9-benzofluoranthene

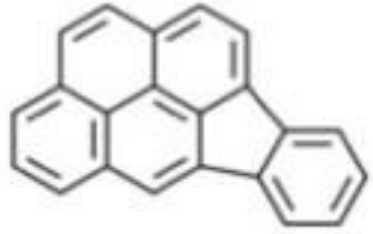


benzo(k)tetraphene
1,2:5,6-dibenzanthracene
**dibenzo(a,h)anthracene**

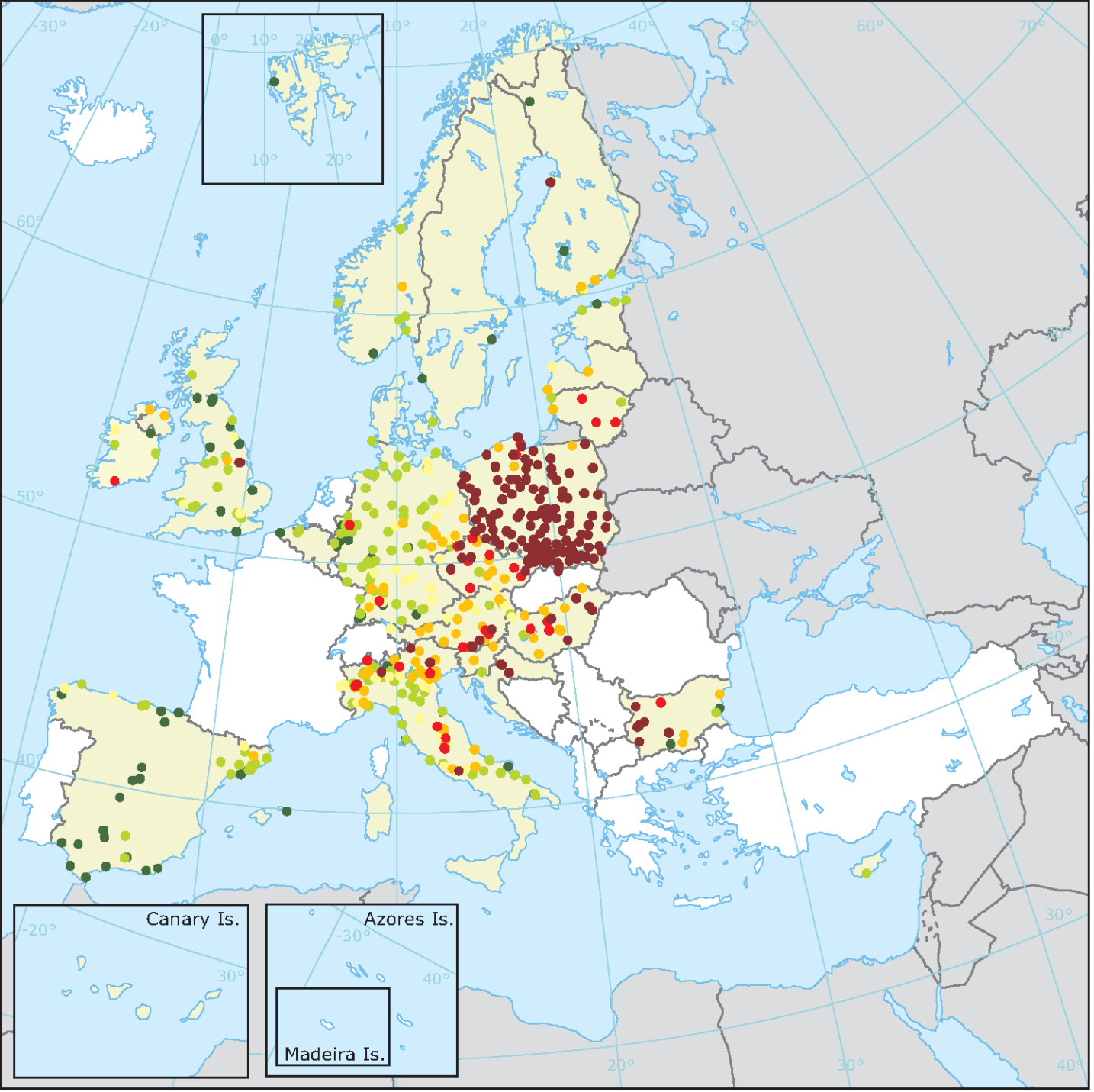


benzo(pqr)tetraphene
**benzo(a)pyrene**
3,4-benzpyrene
1,2-benzpyrene
benzo(def)chrysene

**benzo(ghi)perylene**
1,12-benzoperylene



**indeno[1,2,3-cd]pyrene**
1,1-(1,2-phenylene)pyrene
1,10-(o-phenylene)pyrene
2,3-o-phenylenepyrene



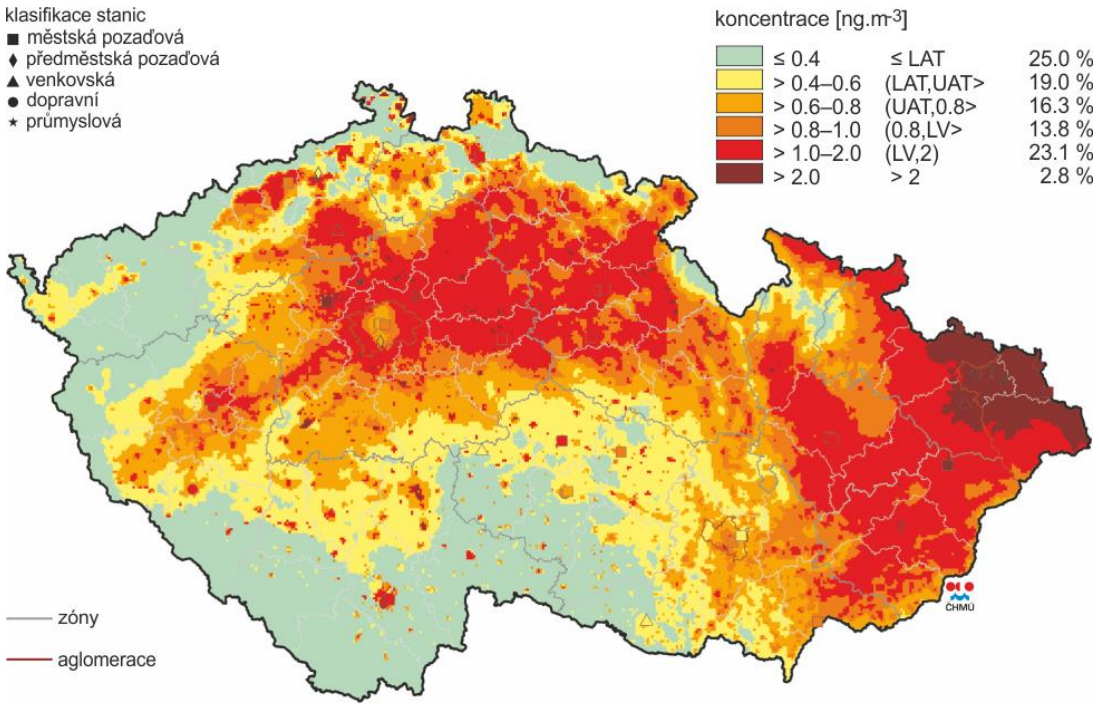

**Annual mean BaP concentrations in 2014**

ng/m³

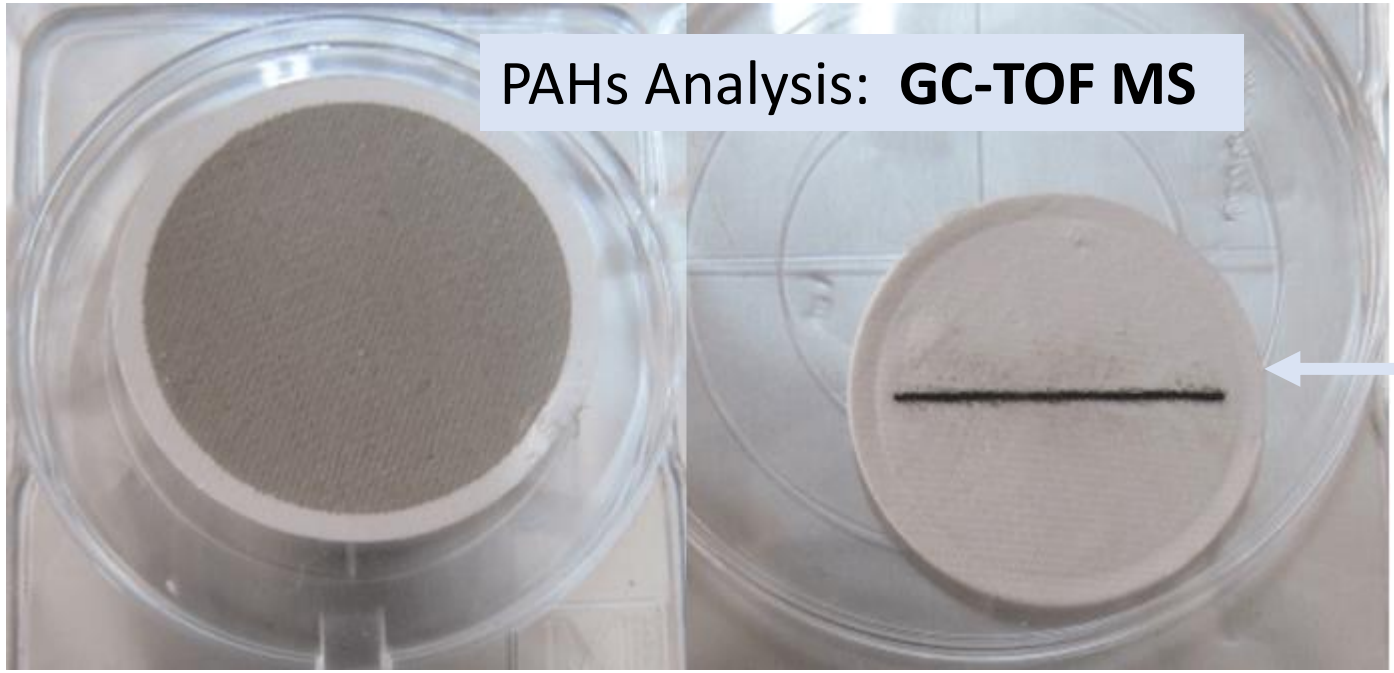
- ≤ 0.12
- 0.12–0.4
- 0.4–0.6
- 0.6–1
- 1–1.5
- > 1.5

No data

Countries/regions not included in the data exchange process




**Obr. IV.2.1 Pole roční průměrné koncentrace benzo[*a*]pyrenu, 2016**



PAHs Analysis: **GC-TOF MS**

**2.5 - 10 µm**

**1 – 2.5 µm**

**0,5 – 1 µm**

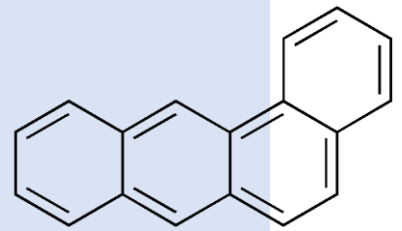
**0,25 – 0,5 µm**

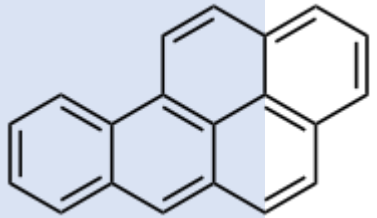
**< 0,25 µm**

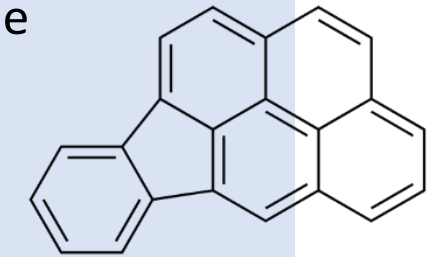
**Pump**
**9 l.min$^{-1}$**
**1h**

# Carcinogenic PAHs (c-PAHs):

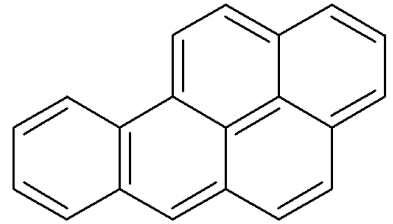
| | |
|---|---|
| **B[a]A** | Benzo[a]anthracene |
| **CHRY** | Chrysene |
| **B[b]F** | Benzo[b]fluorantane |
| **B[k]F** | Benzo[k]fluorantane |
| **B[a]P** | Benzo[a]pyren |
| **Db[a.h]A** | Dibenzo[a.h]anthracene |
| **B[g.h.i]P** | Benzo[g.h.i]perylene |
| **I[1.2.3-cd]P** | Ideno(1.2.3-cd)pyrene |







# Polycyclic Aromatic Hydrocarbons



- Result of **incomplete combustion** of organic matter at temperatures between 300-600°C
- **Benzo(a)Pyrene (BaP)** Forms DNA adducts – compounds that chemically bind to DNA and interfere with transcription and repair mechanisms
- PAHs became toxic through their degradation products formed mainly by liver

- BaP has very potent **teratogenic and cancerogenic** effect, is associated with birth defects and carcinomas.

- PAHs interfere with metabolic routes and cause mainly

  **long-term medical problems** (lung, kidney, liver, reproduction) and increases risk of **cancer** (skin, lung, bladder, gastrointestinal).

# Particulate Matter (PM)

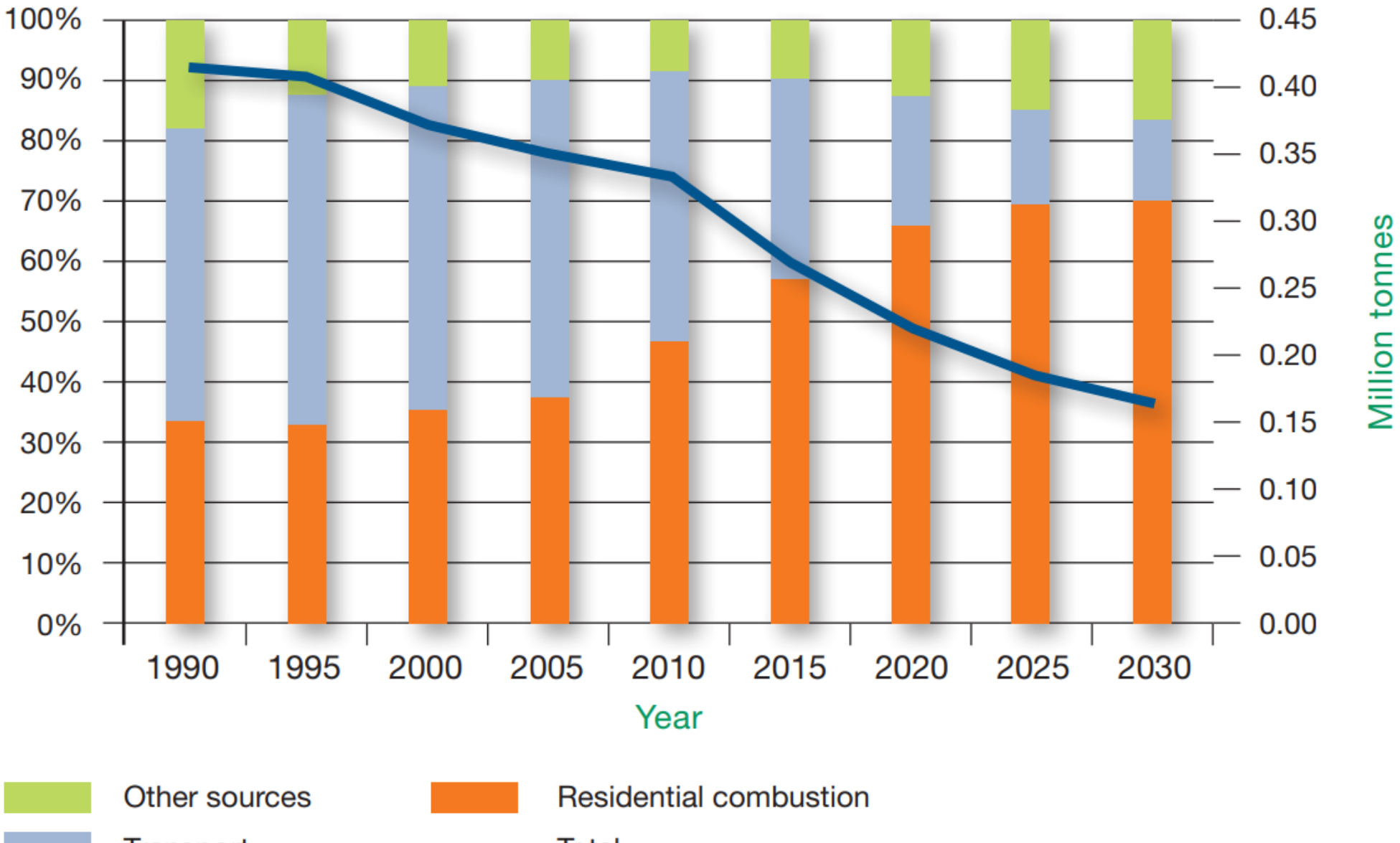
- Enters airways, depth of invasion depends on size – less than **10 – 2,5 – 1 µm**
- $PM_{2.5}$ and below are detectable in blood and other tissues
- Constitute form **black carbon (BC)** and **organic carbon (OC)**
- OC content increases with decrease in combustion efficiency
- Serve as **carriers for other compounds** (notably polyaromatic hydrocarbons – **PAHs, heavy metals**)

- Are associated with most of the previously mentioned major health effects

- Have increased **mutagenic** (teratogenic and cancerogenic) properties

- Are probably the single strongest associated factor for air pollution health problems

## Fig. 3. Baseline BC emissions from the common major sources in the EU-28, 1990–2030



# Nitrogen oxides (NOx), carbon monoxide (CO), sulphur dioxide ($SO_2$)

- **NOx** cause acute toxicity, mainly in the setting of bad ventilation and fugitive emissions, causes pulmonary oedema and tissue hypoxia by binding to hemoglobin instead of oxygen.

- **CO** causes some **acute toxicity**, but contributes to exacerbations of chronic diseases, long-term effects impair tissue **oxygen delivery** and metabolic health.

- **$SO_2$** is a significant predictor of life expectancy reduction and also major contributor to exacerbation of **chronic respiratory diseases**.

# Tropospheric Ozone ($O_3$)

**Tropospheric Ozone ($O_3$) is a major air and climate pollutant. It causes warming and is a highly reactive oxidant, harmful to crop production and human health. $O_3$ is known as a 'secondary' pollutant because it is not emitted directly, but instead forms when precursor gases react in the presence of sunlight.**

**LIFETIME IN ATMOSPHERE**

**Weeks**




## IMPACTS

$O_3$ precursors can be carried round the globe, making it a **transboundary pollution problem**

Tropospheric $O_3$ **warms the atmosphere**

$O_3$ damages plants and affects **agricultural production**:

- Reducing photosynthesis
- Reducing the plants ability to sequester carbon
- Reducing health and productivity of crops


$O_3$ air pollution causes over **150 thousand premature deaths** every year, and **millions more chronic diseases**, particularly in children and the elderly

# Effects on Human Health: **Reproductive / Neonatal**

- Higher probability of birth weight under 2.5 kg
- Fetal intrauterine growth restriction, higher rate of placental pathology

- Lower sperm mobility, higher probabilty of abnormal sperm morphology

- Decresed fertility, increased intrauterine mortality

- Higher neonatal respiratory mortality
- Increased sudden infant death syndrome (SIDS) probability

# Effects on Human Health: **Children**

- Higher respiratory **mortality**
- Higher respiratory morbidity – **asthma, chronic bronchitis, infections** susceptibility
- Higher incidence of **allergy and dermatitis**
- Decreased **lung vital capacity**
- Functional changes in **brain development:**
  **learning disabilities,**
  **attention disorders,**
  **reactivity impairment**

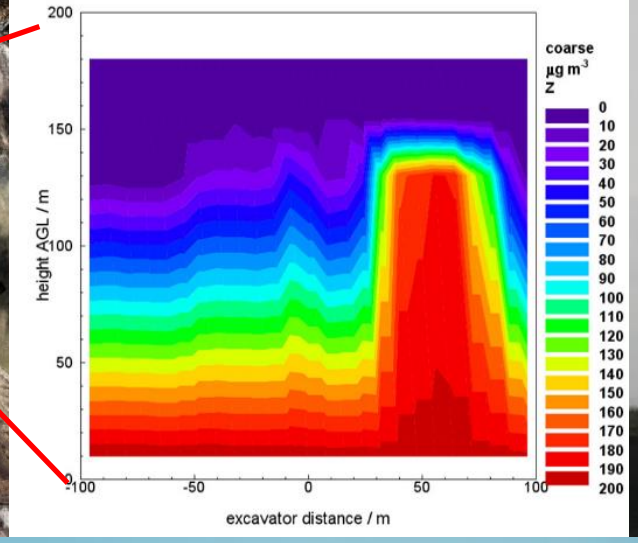
# Effects on Human Health: **Adults**

- Decreased **life expectancy** (up to 4 years)

- Higher long-term **respiratory morbidity** – chronic obstructive pulmonary disease (**COPD**)
- Higher incidence of **hypertension, obesity, cardiovascular diseases** (stroke, ischaemic heart disease), non-insulin dependent diabetes (**type II diabetes**)
- Higher probability of aggravation of **asthma**, increase in number of hospitalizations overall
- Higher incidence of **oncological diseases** (lung cancer, but other types as well – urinary tract)

- **Endocrine disruption** – mainly caused by volatile organic compunds (VOCs) that are very hard to detect and analyze


BGI900
High Volume
Cascade Impactor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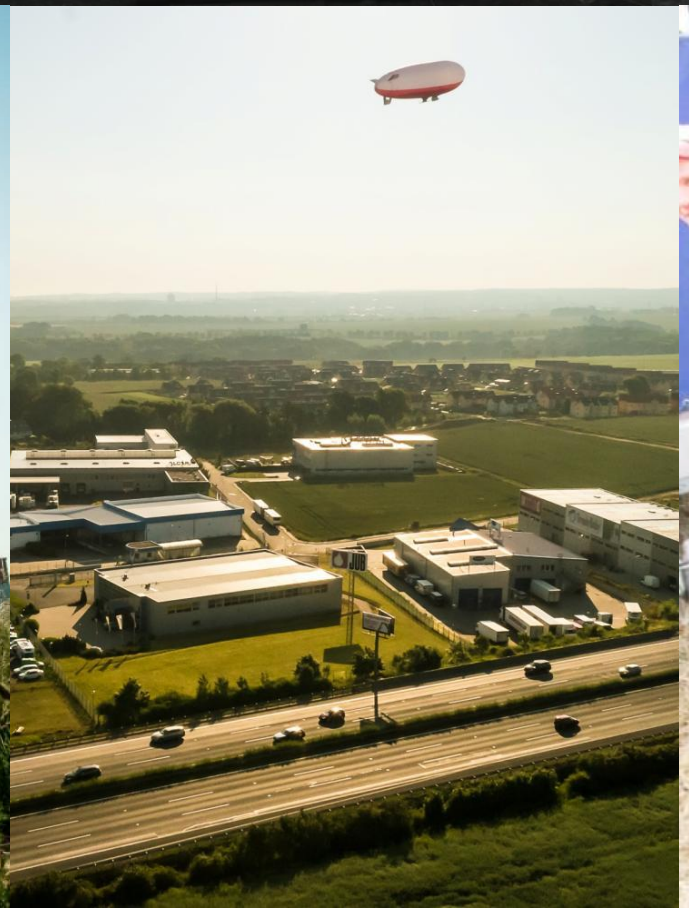

# Thank you for your attention!