Effects of atmospheric pollution

Jesús Miguel Santamaría

Universidad de Navarra

Universidad de Navarra

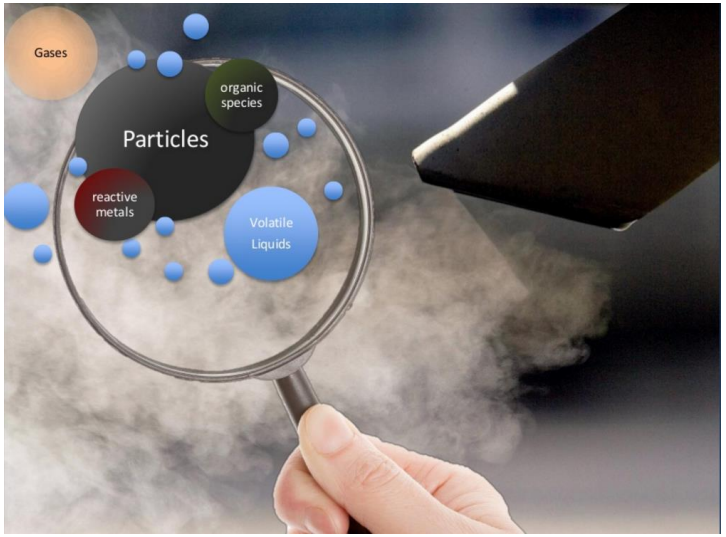
Air quality and public health

- Persons affected due to exposure:
  - ✓ Professional drivers (trucks , taxis)
  - ✓ Parking lot attendants
  - ✓ Construction workers
  - ✓ People living/working near pollution sources
- Persons affected due to sensitivity:
  - ✓ Have existing health conditions:
    - Asthma
    - Chronic obstructive pulmonary disease (COPD)
    - Heart disease
    - Allergies
  - ✓ Young children
  - ✓ Elderly

Universidad de Navarra

Respiratory system

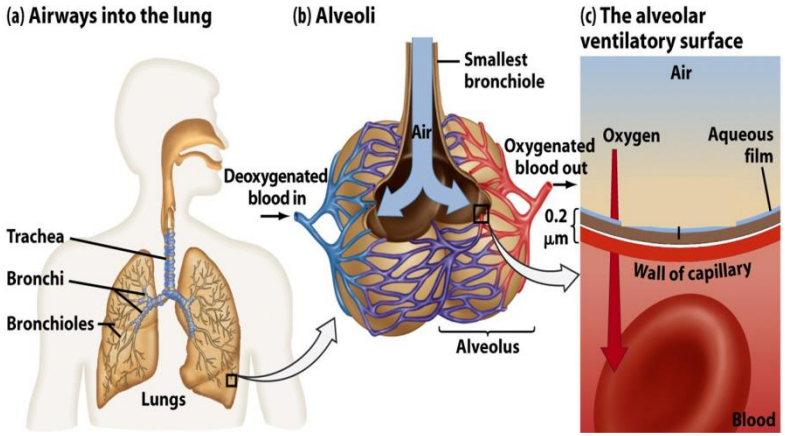
- The behavior of pollutants in the respiratory process depends on how they appear:
  - ✓ Gases: most soluble stay in the upper airways and least reach the alveoli
  - ✓ Particles: the behavior of PM depends on:
    - The shape (more or less aerodynamic)
    - Mass
    - The size
    - The number
    - The composition
    - Orientation (in the case of fibers)



Universidad de Navarra

Respiratory system

- A person at rest breathes 12 to 15 times a minute (10 L/min)
- The respiratory system has natural protection mechanisms for air pollutants:
  - ✓ Nose hairs (filter particles)
  - ✓ Cough, sneeze
  - ✓ Mouth breathing *vs* nasal breathing
  - ✓ Bronchial constriction
  - ✓ Macrophages (phagocytosis)
- Once inside the body pollutants are deposited in:
  - ✓ Blood
  - ✓ Urine
  - ✓ Soft tissues, hair and nails
  - ✓ Bones, etc.



Universidad de Navarra

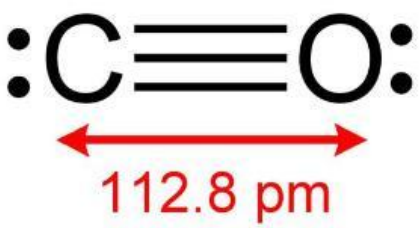
Tropospheric ozone (O_3)

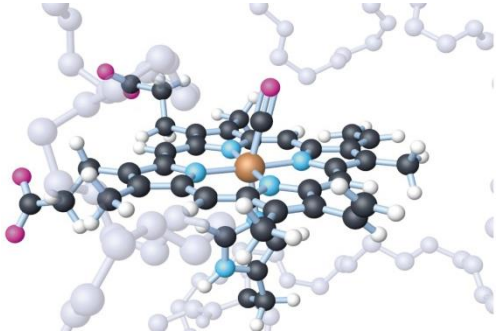
- Low solubility and high oxidizing power
- Respiratory diseases
  - ✓ Respiratory tract irritation
  - ✓ Reduced lung function
  - ✓ Exacerbation of asthma
  - ✓ Inflammation of lung tissue
- Eye irritation
- Headaches and fatigue
- Risk groups
  - ✓ Active children and adults
  - ✓ People with asthma or other respiratory diseases
  - ✓ Especially sensitive people

Universidad de Navarra

Carbon monoxide (CO)

- It's a toxic, colorless, odorless, tasteless and partially water soluble gas
- Greater affinity for hemoglobin than O_2 (240 times the O_2)
  - ✓ Decreased blood O_2 transport
  - ✓ Increased heart rate (<50 ppmv)
  - ✓ Neurological disorders
- CO removal is slow with a half-life of 2 to 6.5 hours, so that the CO could accumulate in a continuous exposure, being the vascular system its main store





Carbon monoxide (CO)

Decreasing the amount of oxygen in blood as a result of the presence of COHb causes a decrease of oxygen in the brain with consequent neurological effects:

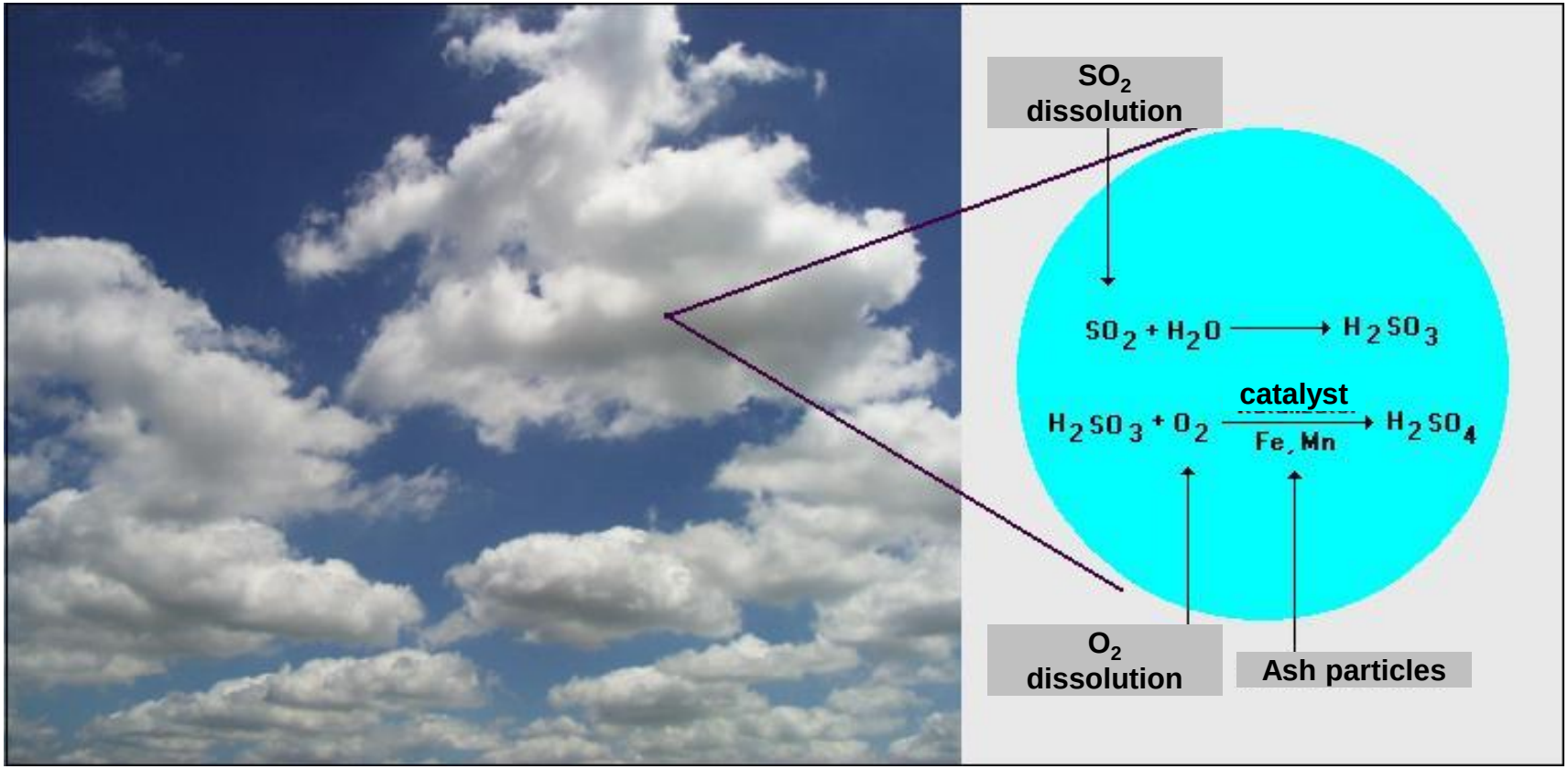
[COHb]	Effects
0-1%	None
2.5%	Loss of time interval discrimination (confusion)
3%	Changes in brightness thresholds
4.5%	Increased reaction time to visual stimuli
10%	Changes in driving skill
10-20%	Headaches, fatigue, loss of coordination

Universidad de Navarra

Sulfur dioxide (SO_2)

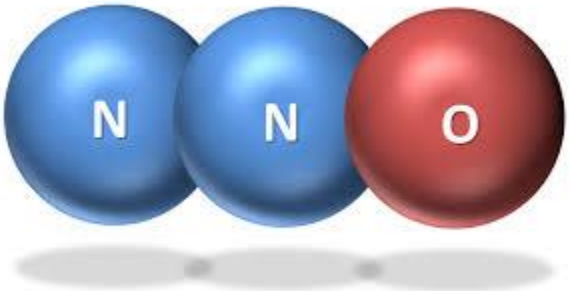
- Sulfur dioxide is a colorless gas with an irritating pungent odour
- Soluble in water
- Toxic by inhalation, dermal and eye exposure
- Chemical classification: toxic and corrosive
- Inhalation causes irritation to the nose and throat
- Exposure to high concentrations causes nausea, vomiting, stomach pain and corrosive damage to the airways and lungs
- Skin contact causes stinging pain, redness of the skin and blisters
- Eye contact causes watering and in severe cases can cause blindness

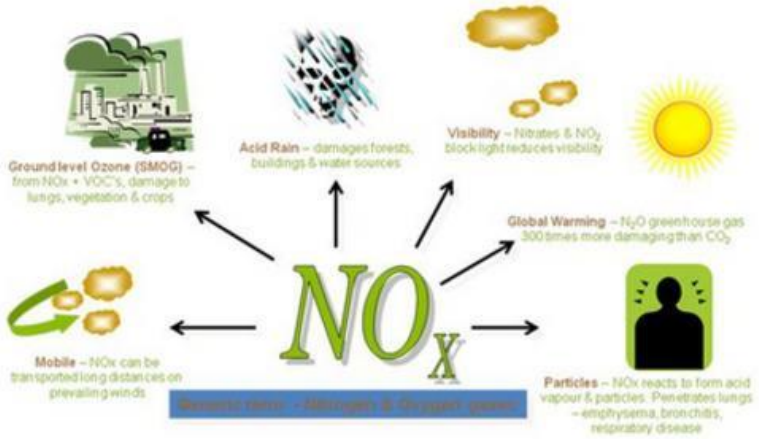
Acid rain


SO_2 dissolution
$SO_2 + H_2O \rightarrow H_2SO_3$
catalyst
Fe, Mn
$H_2SO_3 + O_2 \rightarrow H_2SO_4$
O_2 dissolution
Ash particles

Nitrogen dioxide (NO_2)

- Toxic and irritating gas, less soluble than SO_2, so it penetrates more easily into the lungs, damaging the tissue
- Toxicological studies reveal that the NO_2 causes:
  - ✓ Decreased lung function
  - ✓ Increase the effect of pathogenic diseases
  - ✓ Pulmonary edema (long exposure)
  - ✓ Increased allergic response to inhaled pollen



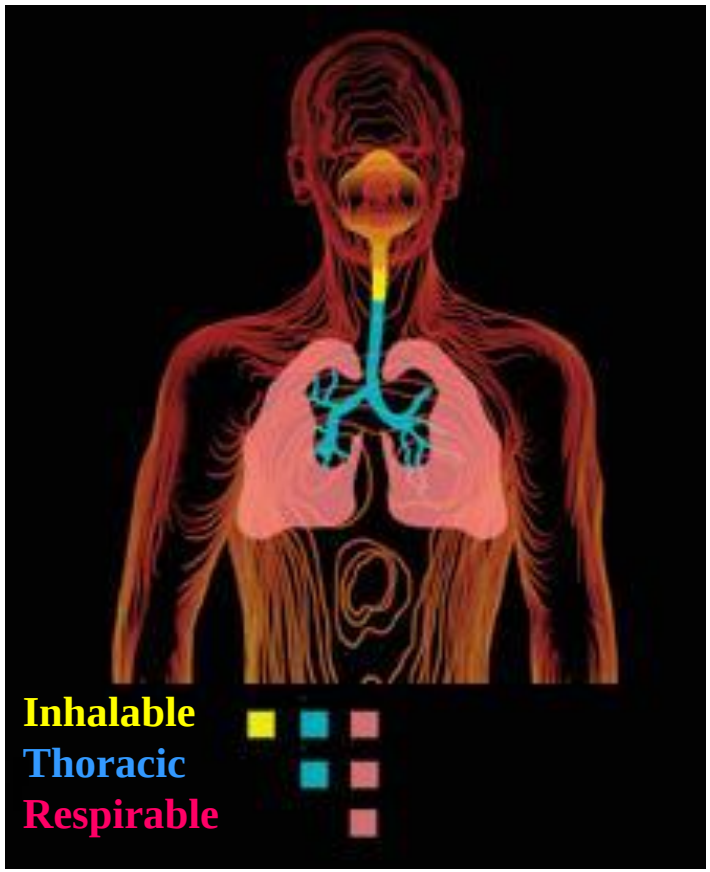


Universidad de Navarra

Particulate matter

- Depending on the particle size PM can access different areas of the respiratory system:
  - ✓ Inhalable: ≤ 100 μm
  - ✓ Thoracic: ≤ 10 μm
  - ✓ Respirable: ≤ 4 μm

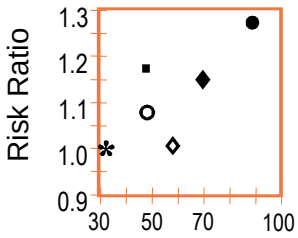
- The dangerousness of particles is inversely proportional to their size
- Many harmful compounds (Pb, Zn, Cr, Hg, $SO_4^=$ and NO_3^-) are concentrated in the smallest particles (fine fraction)



Particulate matter

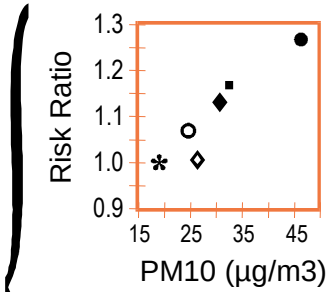
Mortality risk vs PM

Total particles

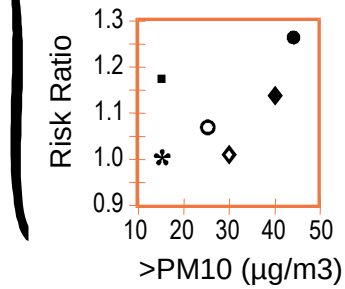


Total particles (µg/m3)

PM10 and >PM10

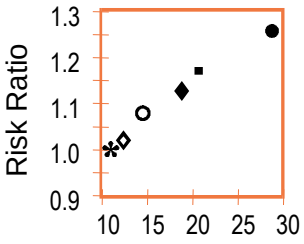


PM10 (µg/m3)

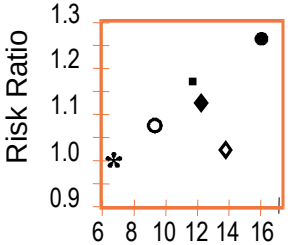


>PM10 (µg/m3)

PM1 and PM10-PM1

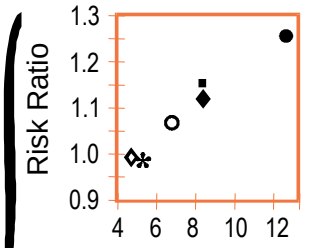


PM1 (µg/m3)

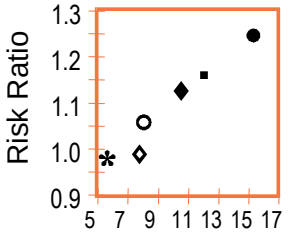


PM10-1 (µg/m3)

SO_4^{2-} in PM1



SO_4^{2-} in PM1 (µg/m3)



No SO_4^{2-} in PM1 (µg/m3)

Particulate matter

- The main effects associated with exposure to MPA are:
  - ✓ Increased frequency of lung cancer
  - ✓ Premature deaths
  - ✓ Severe respiratory symptoms
  - ✓ Eye and nose irritation
  - ✓ Worsening asthma
  - ✓ Worsening of cardiovascular diseases
- Its accumulation in the lungs causes diseases such as:
  - ✓ Silicosis
  - ✓ Asbestosis

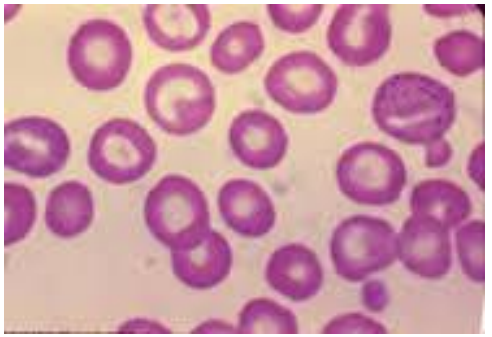
Universidad de Navarra

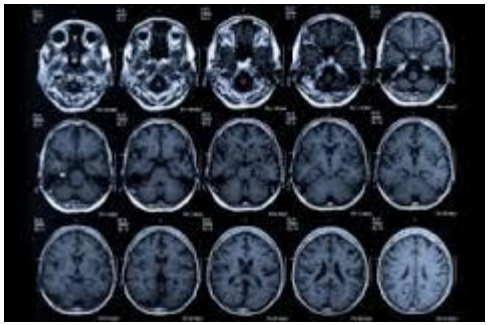
Lead (Pb)

- It is a heavy metal with low melting point, malleable and ductile and corrosion resistant which occurs naturally in soil, water and even in air
- It has been used in:
  - ✓ Pipes
  - ✓ Roofs
  - ✓ Car batteries
  - ✓ Paintings
- In modern times it has been used as an anti-knock in gasoline engines. Today has been banned its use in this type of fuel. Leaded gasoline has already been replaced throughout the EU

Lead (Pb)

- The route of entry of lead in the body is:
  - ✓ Ingestion of water and food
  - ✓ Particle inhalation
- Acute exposures to lead can cause:
  - ✓ Colic and shocks
  - ✓ Severe anemia (Hb inhibits synthesis)
  - ✓ Kidney and liver damage
  - ✓ Irreparable damage to the brain
  - ✓ Saturnism (lead poisoning)
  - ✓ Death
- Chronic exposure to lead causes:
  - ✓ Damage to the kidneys and liver
  - ✓ Damage to the nervous system

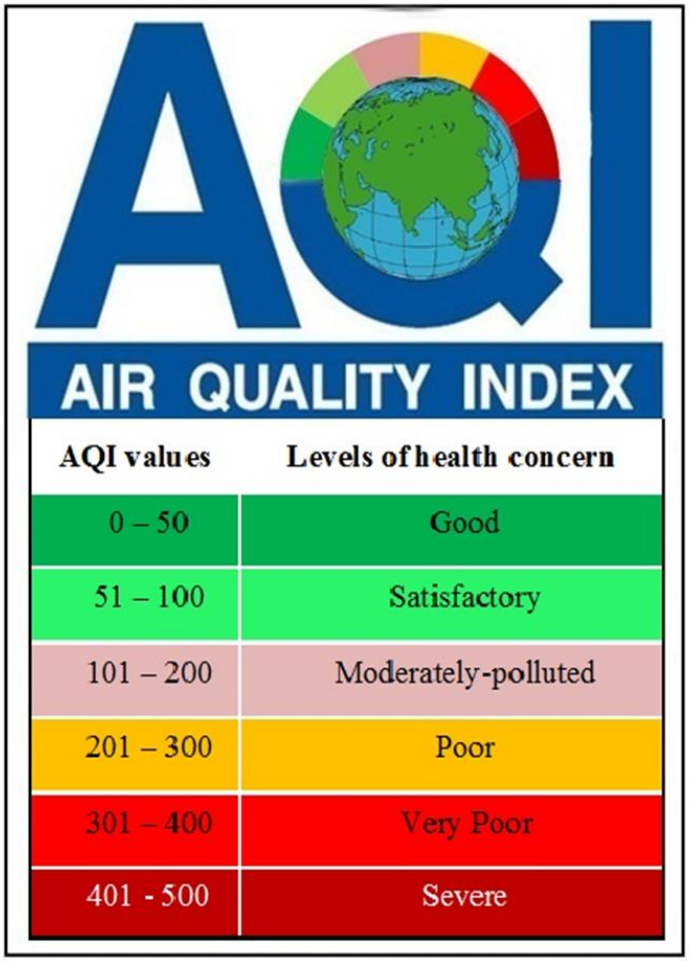




Universidad de Navarra

Air Quality Index (AQI)

- AQI is an overall scheme that transforms individual air pollutant levels into a single number, which is a simple description of air quality for the citizens
- AQI is very useful because it:
  - ✓ Relates to health impacts and citizens can avoid the unnecessary exposure to air pollutants
  - ✓ Indicates compliance with National Air Quality Standards
  - ✓ Prompts local authorities to take quick actions to improve air quality
  - ✓ Guides policy makers to take broad decisions
  - ✓ Encourages citizens to participate in air quality management



Universidad de Navarra

AQI: health impacts

https://waqi.info/

AQI	Possible Health Impacts
Good	minimal impact
Satisfactory	minor breathing discomfort to sensitive people
Moderate	breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor	breathing discomfort to people on prolonged exposure and discomfort to people with heart disease with short exposure
Very Poor	respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe	respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases

Universidad de Navarra

AQI calculation

Índice Global	O_3 1h	NO_2 1h	SO_2 1h	PM_{10} 24h	$PM_{2.5}$ 24h	CO 8h
Buena	0-100	0-35	0-70	0-25	0-15	0-3
Moderada	≥100-130	≥35-80	≥70-125	≥25-40	≥15-25	≥3-6
Deficiente	≥130-180	≥80-200	≥125-350	≥40-50	≥25-40	≥6-10
Mala	≥180-240	≥200-400	≥350-500	≥50-75	≥40-60	≥10-15
Muy mala	≥240	≥400	≥500	≥75	≥60	≥15

Units in $\mu g\ m^{-3}$, except CO in $mg\ m^{-3}$

Calculate the AQI for the city of Madrid if air pollutant concentrations are:

O_3: 55, NO_2: 33, SO_2: 7, PM_{10}: 74, $PM_{2,5}$: 21; CO: 1.5

Universidad de Navarra

Effects on buildings and monuments (stone decay)

- Air pollutants and particles profoundly affect building materials: iron, stone, paint, rubber, leather....
- The effects of air pollution on ancient monuments are becoming worrying in Europe, because their loss is often irretrievable
- The alteration of the materials may be:
  - ✓ Physical: particle abrasion or passive effect of the deposition of particulates (soot)
  - ✓ Chemical: a reaction between the material and any chemical compound occurs
- Limestone materials react with sulfuric acid to produce gypsum, that can break the stone after expanding:

$$CaCO_3\ (s) + H_2SO_4(ac) \Leftrightarrow CaSO_4\ (s) + H_2O\ (l) + CO_2(g)$$

$$2CaCO_3(s) + 2\ SO_2\ (g) + O_2(g) \Leftrightarrow 2CaSO_4(s) + 2CO_2\ (g)$$

Metal corrosion

- SO_2 and particles accelerate corrosion of ferrous metals, probably due to the associated presence of sulfuric acid
- Metals such as zinc are attacked by SO_2 in the presence of moisture
- Copper reacts with SOx (SO_2 + SO_3) to form a green patina of copper sulfate (bronze statues)

Effects of air pollutants on vegetation

- Damage caused by air pollutants on vegetation can be:
  - ✓ Acute: caused by a brief exposure of the plant at high concentrations. Affect the vegetation around the emission source (smelters, power stations, etc.)
  - ✓ Chronic: prolonged exposure to low concentrations of pollutants (ozone, acid rain, etc.). Occurs in areas far from emission sources
  - ✓ Visible: refer to deviations from the normal appearance of leaves
    - Necrosis: takes place when the parenchyma is damaged
    - Chlorosis: the epidermis is discolored (reduction or loss of chloroplasts)
  - ✓ Invisible: the plant does not exhibit external damage

Universidad de Navarra

Air pollution stress in plants

- Responses of plants to air pollutants may vary widely and these variations can be caused by many factors, such as:
  - ✓ Differences in pollutant concentrations
  - ✓ Distribution in time
  - ✓ The genetic origin
  - ✓ Physiological activity
  - ✓ Phenological stage
  - ✓ Nutritional status of plants as well as effects of various environmental factors

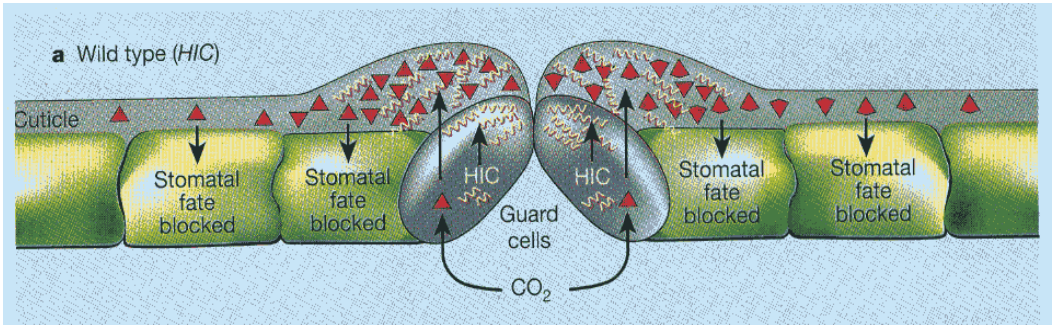
Universidad de Navarra

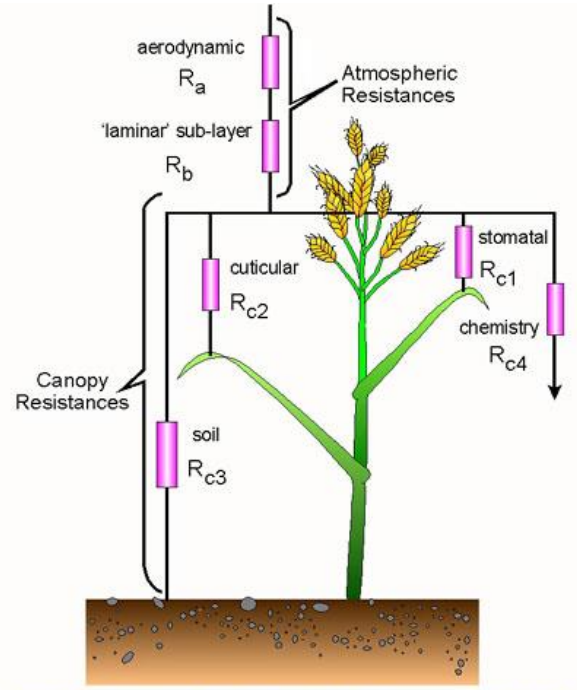
Sulfur dioxide (SO_2)

- After penetrating through the stomata causes damage to the mesophyll
- Produce, white, red, brown and even black spots (depending on the species and concentration)
- The damage extends from the base to the apex of the leave on both sides
- The younger leaves are more affected
- In dicotyledonous acute damages produce internervial necrosis

Tropospheric ozone (O_3)

- Ozone penetrates through the stomata
- The environmental factors that regulate stomatal control modulate the contaminant phytotoxicity
- Ozone mainly affects the palisade parenchyma
- It causes chlorotic mottle in the upperside of leaves





Resistance analogy for the deposition of atmospheric pollutants

Universidad de Navarra

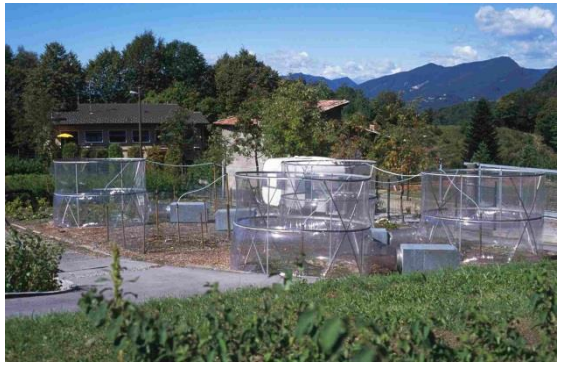
Tropospheric ozone (O_3)

Effects on vegetation

- Visible symptoms
- Leaf injury
- Biomass reduction (yield production)
- Change of fruit quality

Sensitive crops

- Artichoke
- Tomato
- Melon
- Zucchini
- Grape
- Wheat
- Potato
- Bean

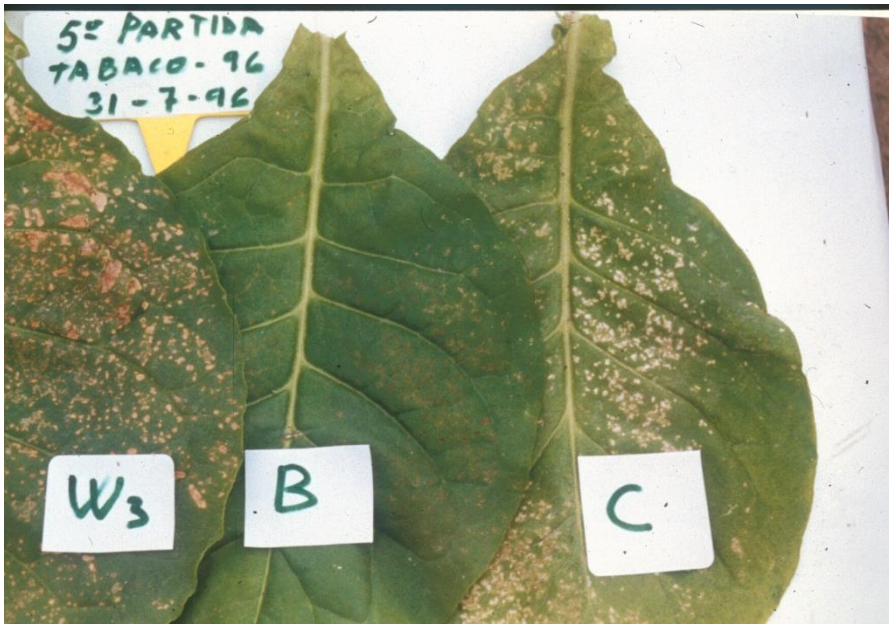


Universidad de Navarra

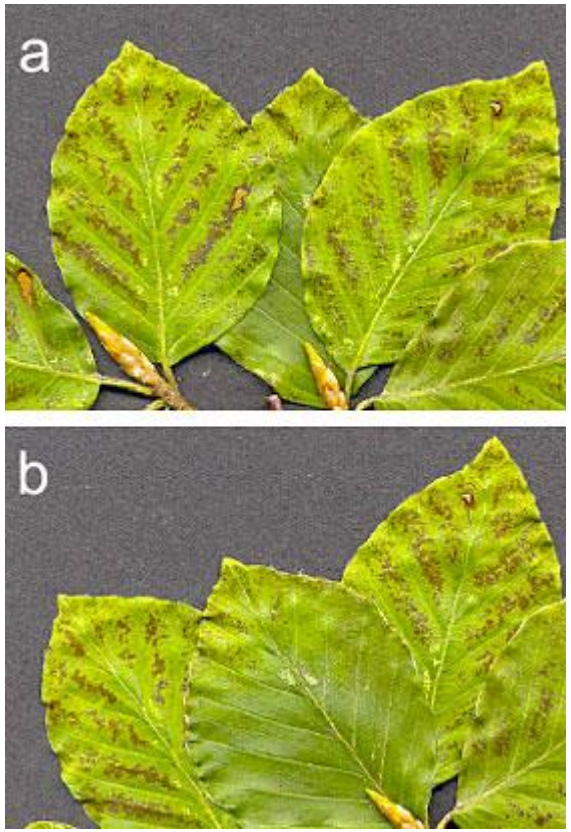
Ozone biomonitoring

Varieties of
Nicotiana tabacum

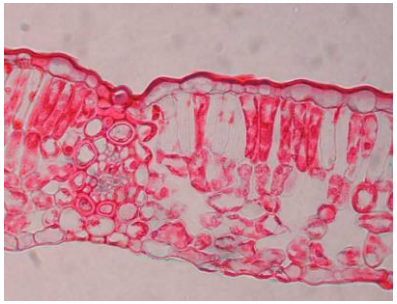
- Bel-W3 (sensitive)
- Bel-C (tolerant)
- Bel-B (resistant)



Foliar injury in *Fagus sylvatica*



- Ozone symptoms with overshading effect on the leaves of a young beech tree
- In the lower picture (b) the previously shaded leaf was placed on top

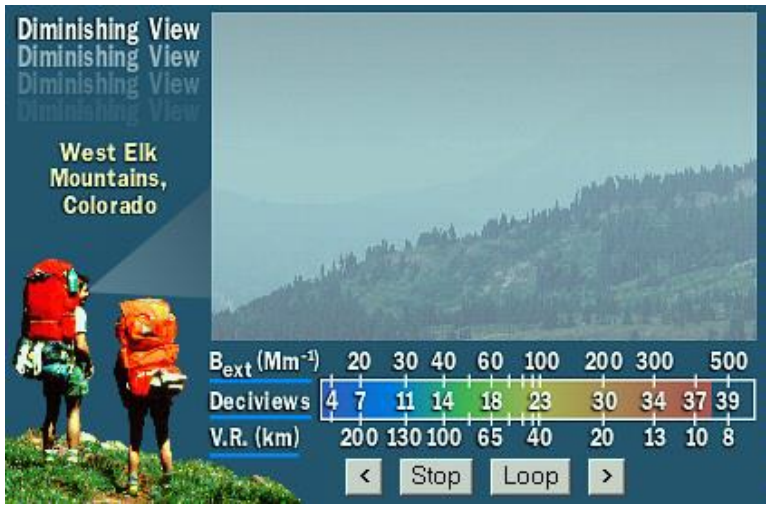


Fluorine

- Damage occurs due to the uptake of fluorine gas through stomata or through soluble particles deposited on leaves
- Once on the leave, fluorine is accumulated in the apex or edge thereof, causing a characteristic chlorosis
- Young leaves are more sensitive to fluorine

Effects of pollution on visibility

- Poor visibility is the most publicly accessible indicator of air pollution
- Haze is associated with adverse pollution levels that affect public health
- Tourists and homeowners pay much for highly prized views
- The same pollutants that affect haze also affect global radiation balance
- Haze is caused by particles and gases that remove light from a sight path and scatter light into a sight path, thereby obscuring the contrast of a target with background air



Effects of pollution on climate

- Radiative forcing: change of net radiant flux at the tropopause due to the variation of the concentration of a gas
- Greenhouse gases cause a positive radiative forcing, increasing the surface temperature of the Earth