Physico-chemical pollutants

Properties

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Aerosol definitions

Aerosol:

liquid and/or solid particles in suspension in a gas with a falling speed lower than 25 cm/s

Dust:

solid particles generated by erosion or abrasion processes

Fumes:

solid aerosols obtained by condensation of vapors or by chemical reaction

Mist:

liquid aerosols obtained from the condensation of vapors or by dispersion of liquids

Fibers definition

Fibers (WHO defintion)

- By convention (analogy with asbestos)
- Are to be considered as biologically significant the particles whose:
  - length/diameter ratio exceeds 3:1
  - length exceeds 5 um
  - diameter is less than 3 um

Exemple of asbestos

- Analysis: phase contrast microscopy
- Particles that do not meet these criteria are not considered fibers:
  - short asbestos fibers (<5 um),
  - fine fibers (0.2 um)

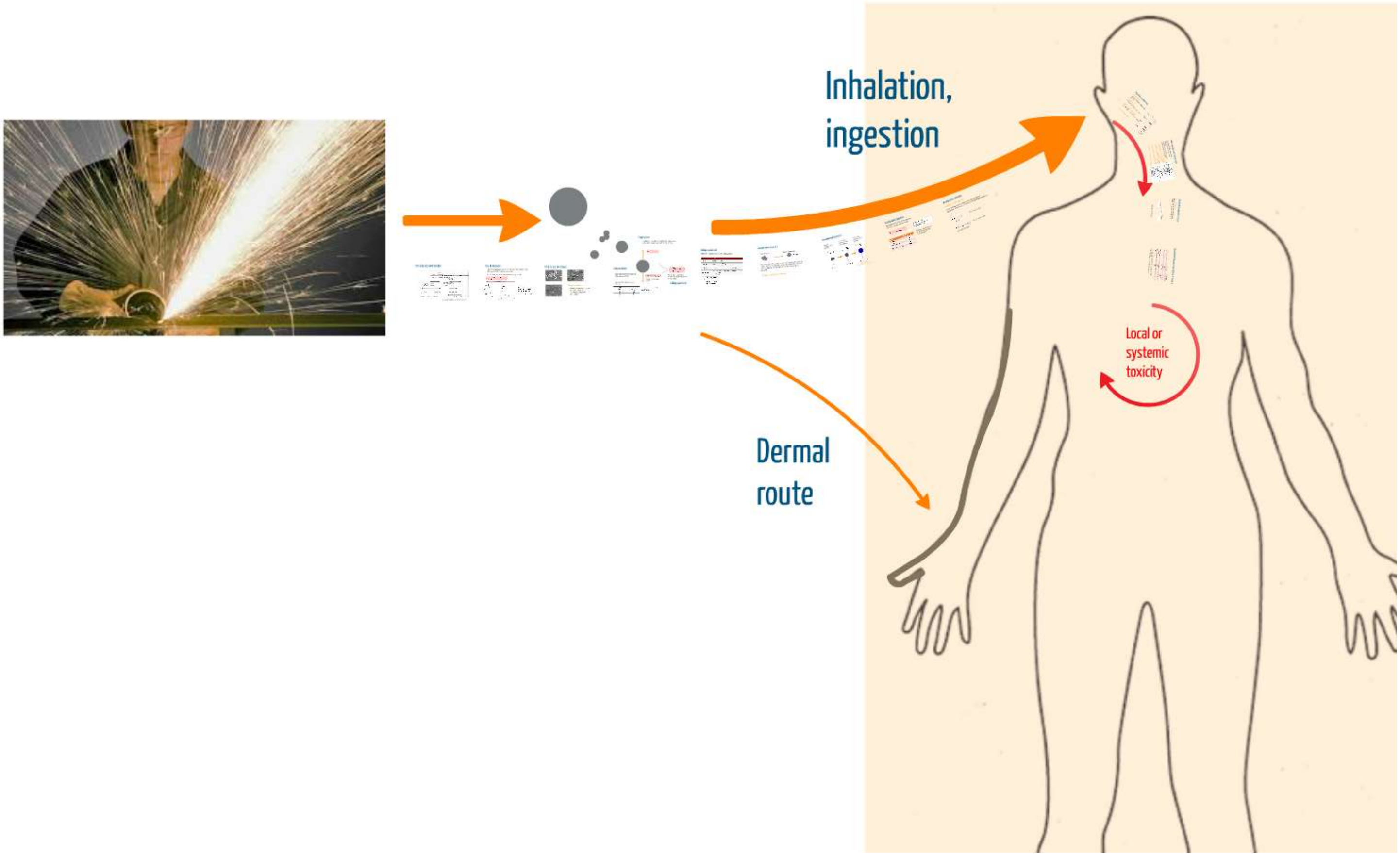
Sources of emission

Industrial sectors...

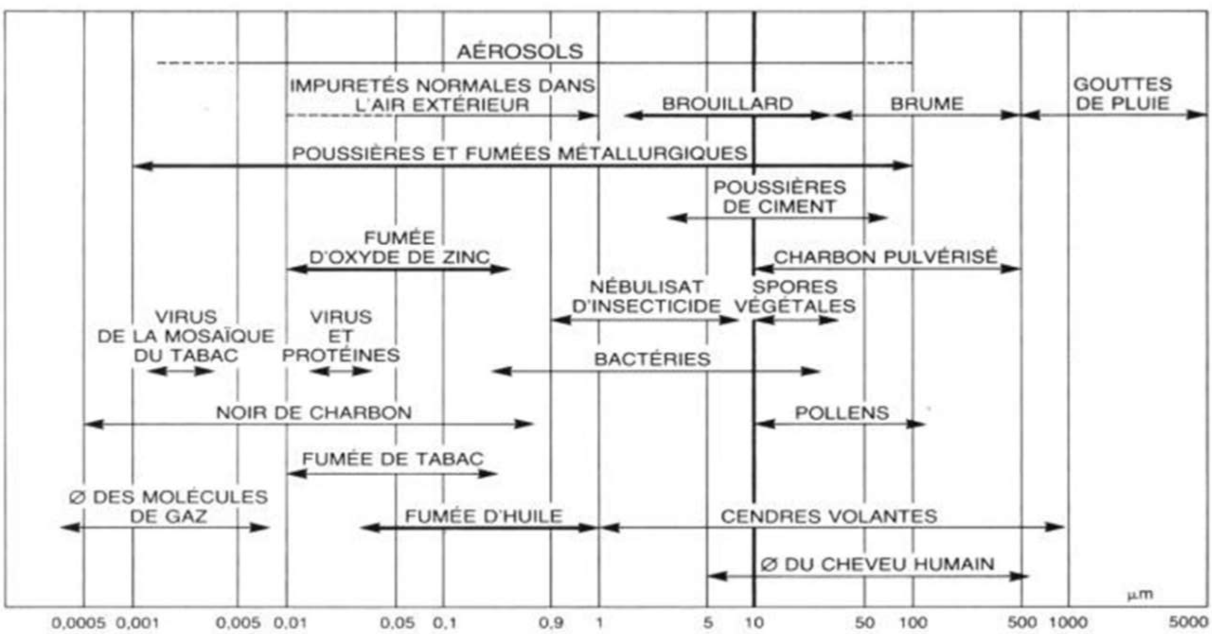
- Construction
- Food industry
- Agriculture
- Metallurgical industry
- Waste valorization
- Textile industry
- Office work ...

Production process:

- abrasion, combustion, boiling, suspension, nebulization,...



Particles size and variety



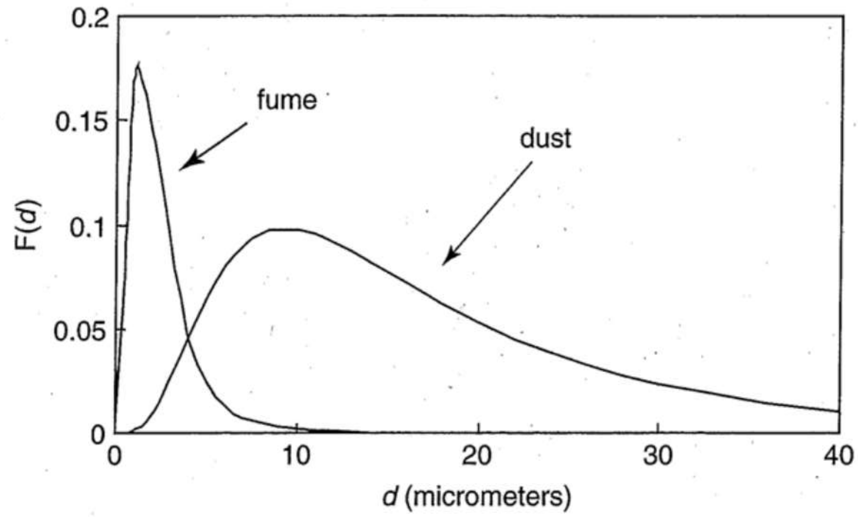
Aerodynamic diameter of common aerosols

Size distribution

Generally polydisperse aerosols, continuous statistical distribution.
More occasionally, monodisperse aerosols.

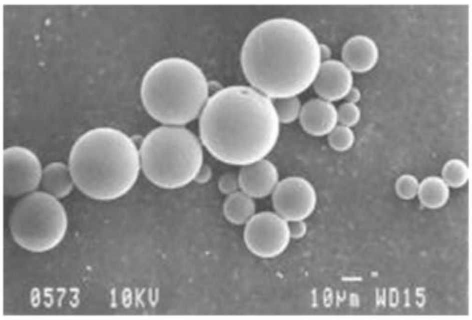
The mass fraction of diameter distribution (log-normal):

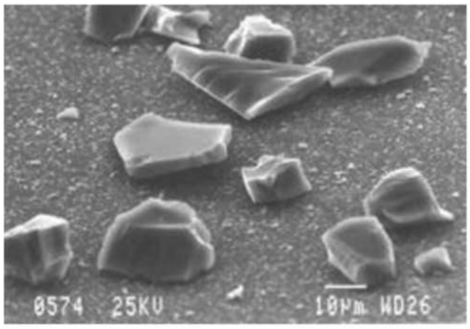
$$m_p(D) = \frac{M}{D\sqrt{2\pi}\cdot \ln\sigma_g}\exp\left[-\frac{(\ln D - \ln D_{50})^2}{2(\ln\sigma_g)^2}\right]$$

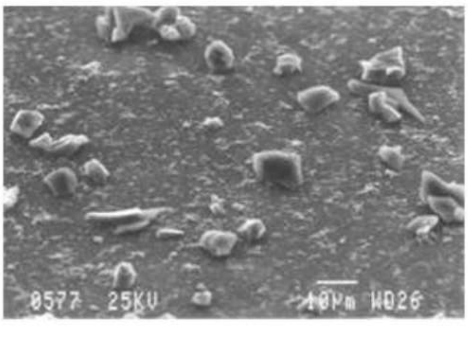


m_p: Mass fraction
D : Particles' diameter
D_{50} : Median particles' diameter
σ_g : standard deviation geometry
- monodisperse (σ_g =1),
- polydisperse (σ_g =2-3)

Particles size and shape







Dangerousness

- chemical composition, crystal structure, shape, size
  -Inhalation, deposition, elimination…

Sedimentation

Main deposition mechanism of (large) particles

$$P-A=4/3\cdot\pi r^3(\rho_{sph}-\rho_{air})\cdot g$$

Weight - Archimedes' thrust

Typical sedimentation rates of particles

d_a (µm)	V_s ($m.s^{-1}$)
0,01	7.10^{-8}
0,1	$8,8.10^{-7}$
1	$3,5.10^{-5}$
10	$3,1.10^{-3}$
100	0,25

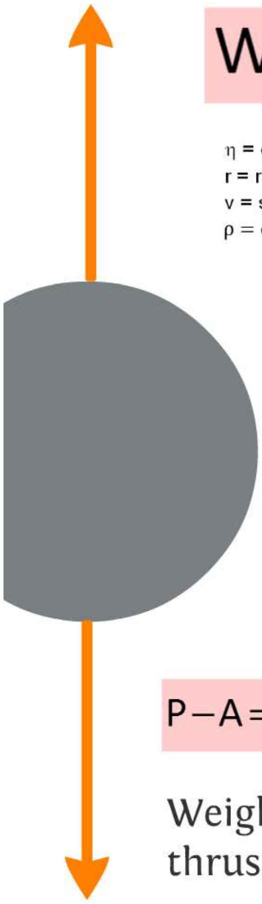
η = dynamic viscosity, air = 1.82 10-5 N s m^{-2}
r = radius (m)
v = speed (m s^{-1})
ρ = vouminal masss (kg m^{-3})

Dragging force

A spherical particle in a moving fluid experiences a drag force (1/3 pressure forces, 2/3 friction)

$$W=-6\pi r\eta v$$

η = dynamic viscosity, air = 1.82 10-5 N s m^{-2}
r = radius (m)
v = speed (m s^{-1})
ρ = density (kg m^{-3})



$$W = -6\pi r \eta v$$

η = dynamic viscosity, air = 1.82 10-5 N s m^{-2}
r = radius (m)
v = speed (m s^{-1})
ρ = density (kg m^{-3})

$$P - A = 4/3 \cdot \pi r^3 (\rho_{sph} - \rho_{air}) \cdot g$$

Weight - Archimedes' thrust

$$v = \frac{2}{9} \frac{(\rho_{sph} - \rho_{air})}{\eta} gr^2$$

The falling speed limit is reached when the two forces are in balance

Falling speed limit

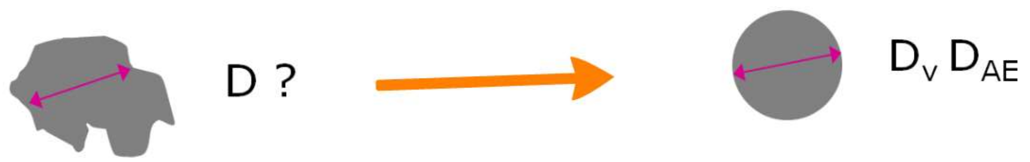
Falling speed limit

Different expressions of the falling speed

Diamètre	*Modèle physique*
> 200 µm	Pesanteur $v = \sqrt{2gh}$
1 - 100 µm	Stokes $v = \frac{2}{9} \frac{(\rho_{sph} - \rho_{air})}{\eta} gr^2$
0.1 - 1 µm	Correction de Cunningham $V = V_{Stokes} \left(1 + 0.85 \frac{\ell}{r}\right)$
0.001 - 0.1 µm	Mouvement Brownien rms="root mean square" $V_{rms} = \sqrt{\frac{3RT}{Na \cdot m}}$

N : number of molecules
N_a : number of Avogadro
rms: "root mean square"
m : mass of the molecule
ℓ : mean free path

Aerodynamic diameter

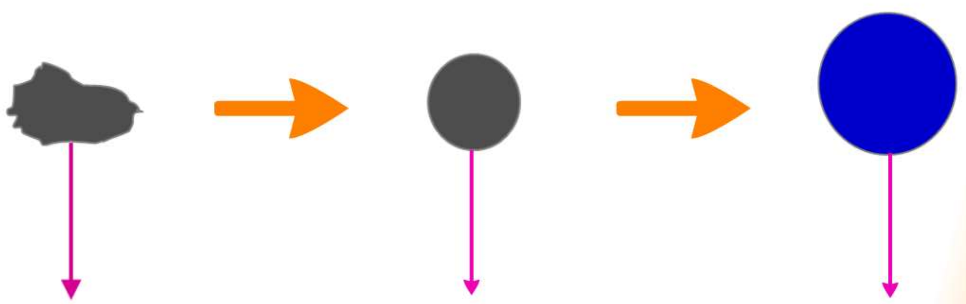


Diameter of a sphere with a density of 1 g/cm3 whose falling speed in still air is identical to that of the particle under the same conditions of pressure, temperature and relative humidity.

Similar dynamic behavior

Aerodynamic diameter

Actual diameter and density	Equivalent diameter and real density	Equivalent diameter and density
D_p = 5,0 µm ρ_p = 4 g/cm³	D_v = 4,3 µm ρ_p = 4 g/cm³	D_{ae} = 8,6 µm ρ_p = 1 g/cm³



v_s = 0,22 cm/s	v_s = 0,22 cm/s	v_s = 0,22 cm/s

Dae: Equivalent aerodynamic diameter

Aerodynamic diameter

Approximation of the aerodynamic diameter in the 1-10 um range

$$D_{AE} = D \cdot (d/F)^{1/2}$$

D = Observable diameter
d = Density (-), relative to water
F= Dynamic form factor (-)

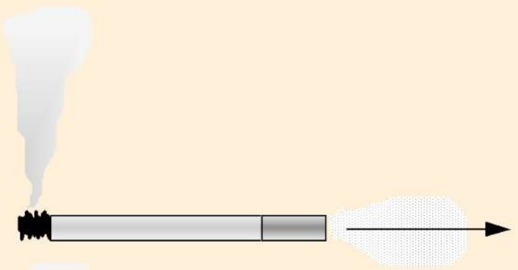
Shape	Dynamic shape factors
spherical	1.0
cubical	1.08
spherical aggregates	1.15
quartz particles	1.36
talcum powder particles	2.04
fibers	<<1.0

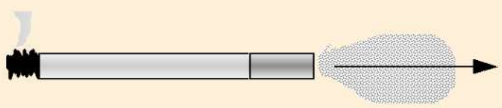
Dynamic shape factors for different particle morphologies

Aerodynamic diameter

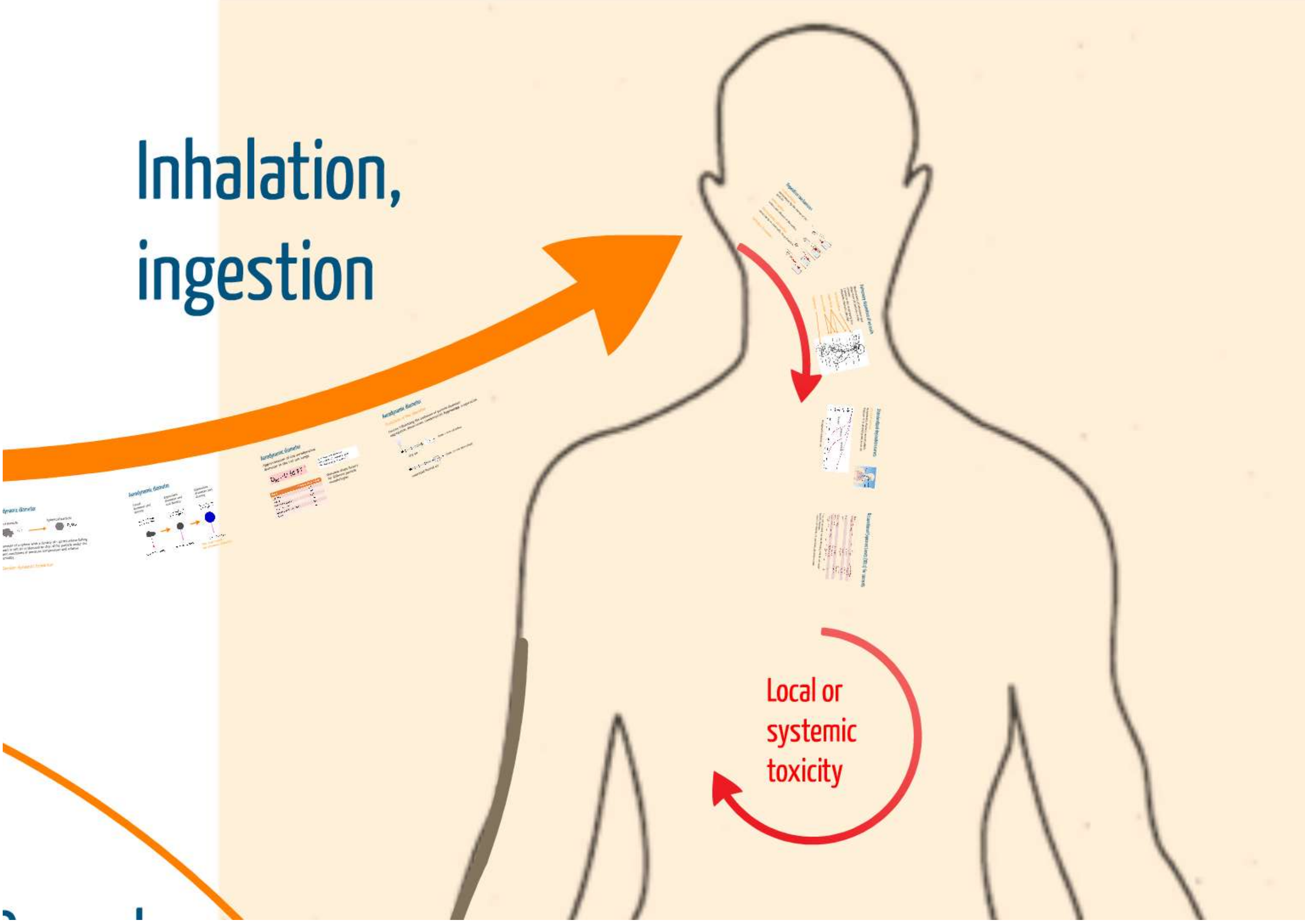
Evolution of the diameter

Factors influencing the evolution of particle diameter: aggregation, dissociation, condensation, **hygroscopy**, evaporation





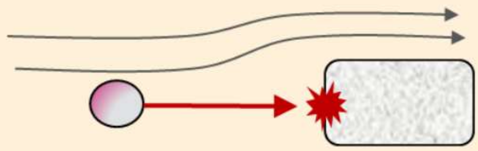
Inhalation, ingestion



Deposition mechanisms

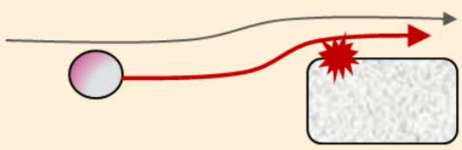
Sedimentation

entrainment by the inertia of the particle



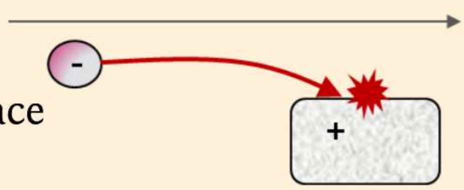
Interception

contact and adhesion to the surface

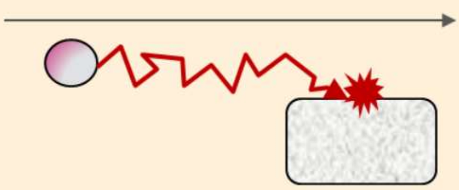


Electrostatic attraction

attraction by an electrically charged surface



Diffusion (Brownian)



Pulmonary deposition of aerosols

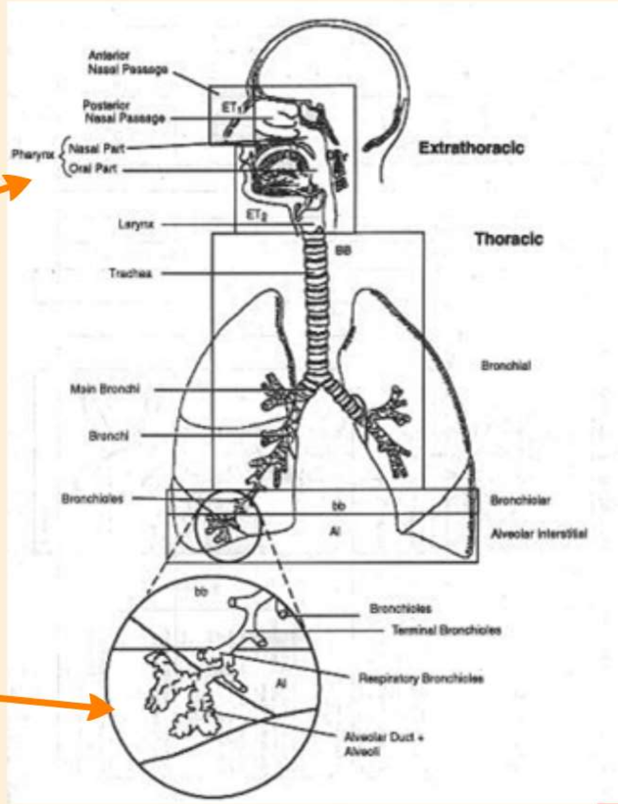
Mechanisms of inhalation and deposition of particles in the airways
3 zones in the respiratory tree: inhalable, thoracic, alveolar

Sedimentation

Impaction

Interception

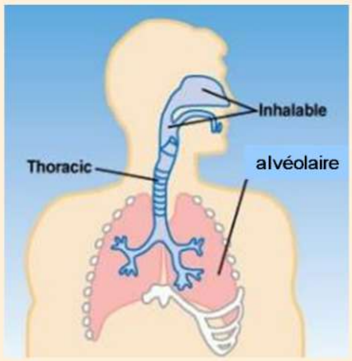
Diffusion

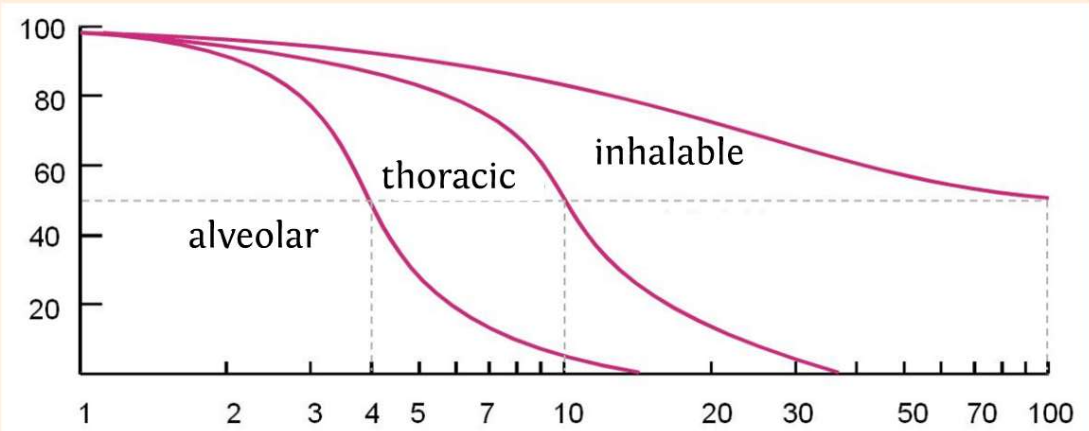


Standardized deposition curves

ISO-CEN curves

Respiratory, thoracic and inhalable fraction in % of total particles in air





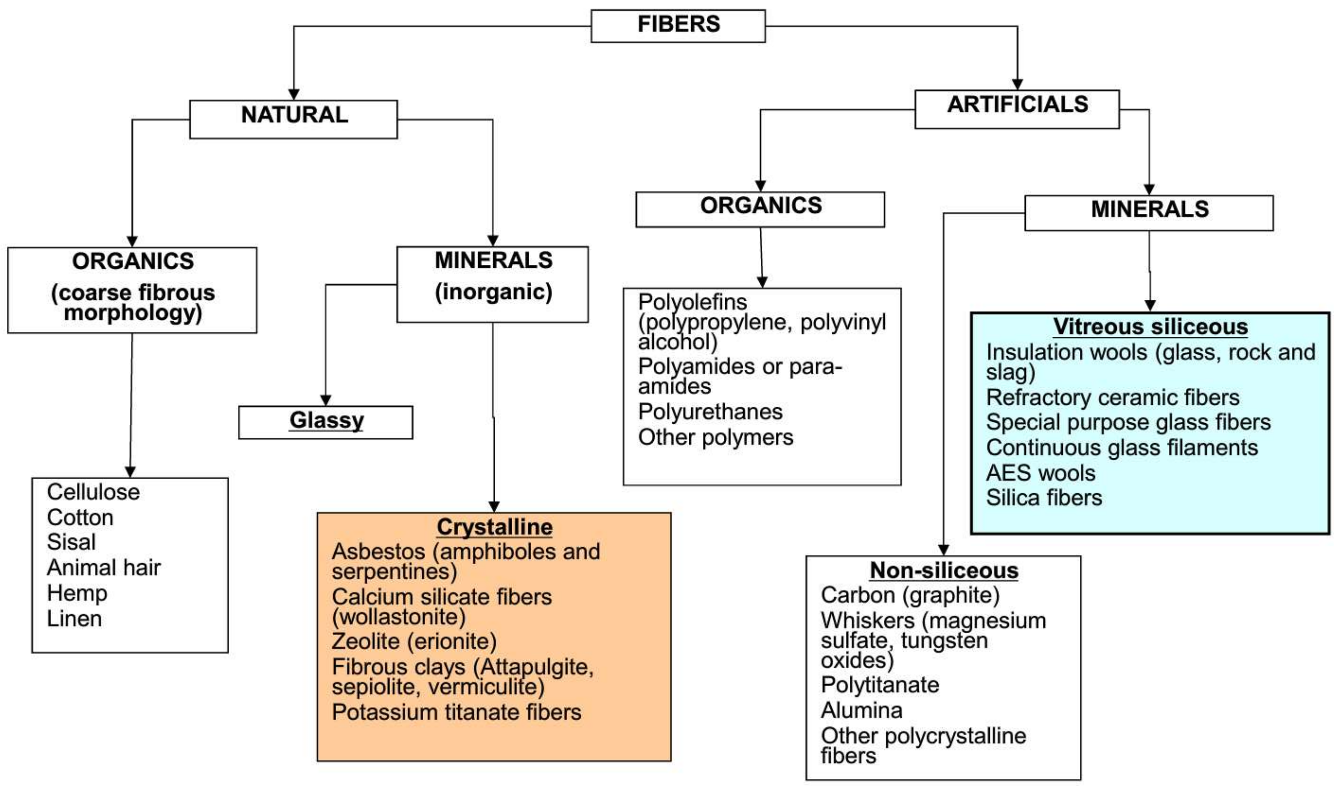
Aerodynamic diameter um

Occupational Exposure Limits (OELs) for aerosols

Forme	VME	commentaire
Poussières inertes *	3 mg/m^3	alvéolaire
	10 mg/m^3	Inhalable
Bois	2 mg/m^3	inhalable
Farine	<1 mg/m^3	Sensibilisant respiratoire
Silice cristalline	0.15 mg/m^3	alvéolaire
Fibre de verre	0.5 fibres/ml	
Fibres céramiques réfractaires	0.25 fibres/ml	C2
Fibres d'amiante	0.01 fibres/ml	C1

* are not resorbed, are not fibrosing, and do not cause specific diseases:
- starch, tin dioxide, Ca carbonate, aluminum oxide

The fiber family



Refractory ceramic fibers

- Insulating wool with high thermal resistance (1250 and 1430° C)
- Classified as a category 2 carcinogen by the EU and as a group 2B carcinogen by IARC

Asbestos

A little history

- Historical use in construction
- Mainly during the 50s and 70s
- Diseases in asbestos workers known since the beginning of the (past) century

- intense lobbying by the fiber industry
- general ban in Switzerland in 1989
- 100'000 deaths per year according to the WHO
- In 2015, the reopening of the Jeffrey mine (closed in 2010) was still being discussed

Jeffrey asbestos mine in Asbestos (Canada)

Where is there any left?

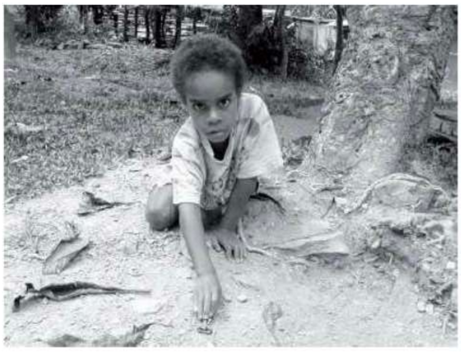
In the materials

- More production/importation
- Public and private buildings
  - *insulation, plastering, mastics, false ceilings...*
- In technical/industrial facilities
  - *ovens, heating systems, vehicles*
- In the waste

Natural sources

- Rocks, underground deposits
- Surface outcrop (e.g. Corsica, New Caledonia)

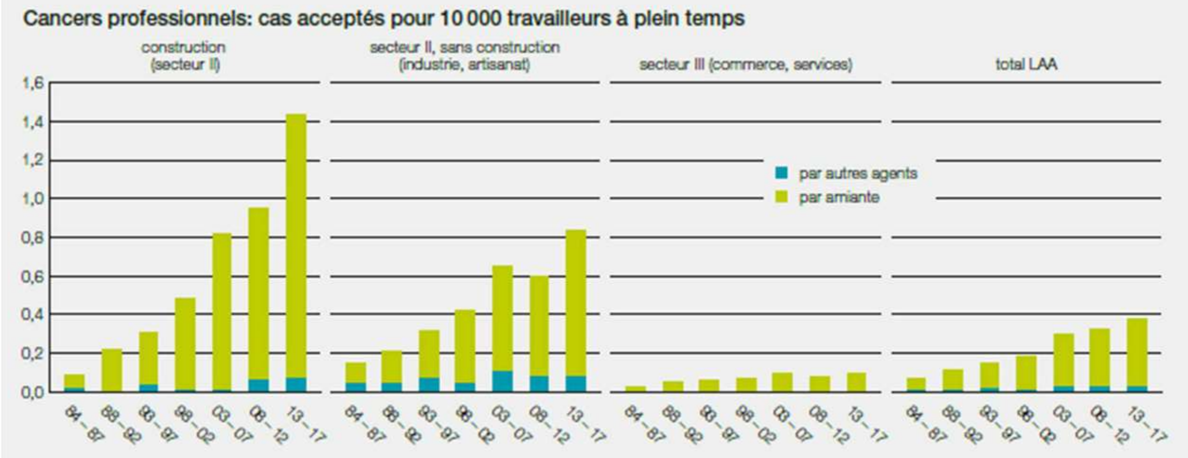
A professional nuisance, really?



Les Cahiers d'Outre-Mer, Number 252

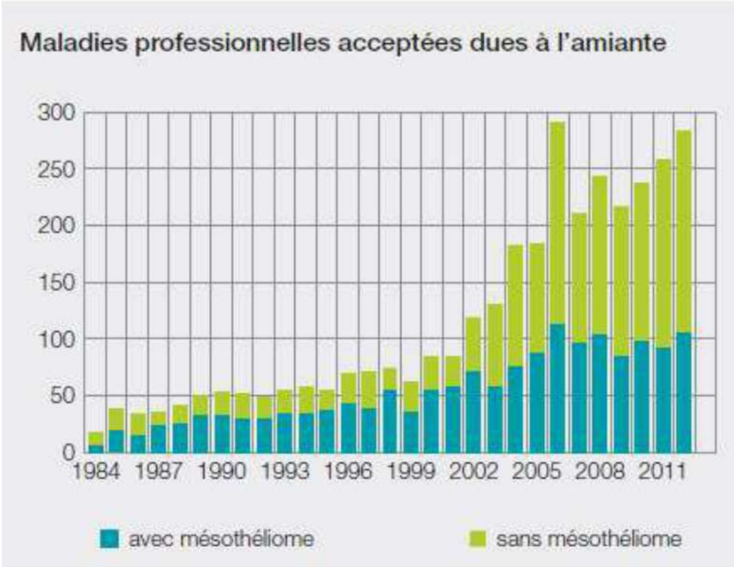
Asbestos-related pathologies

Distribution by sector of activity



Asbestos fibers

Two specific diseases: asbestosis and mesothelioma.
Contribution: lung cancer



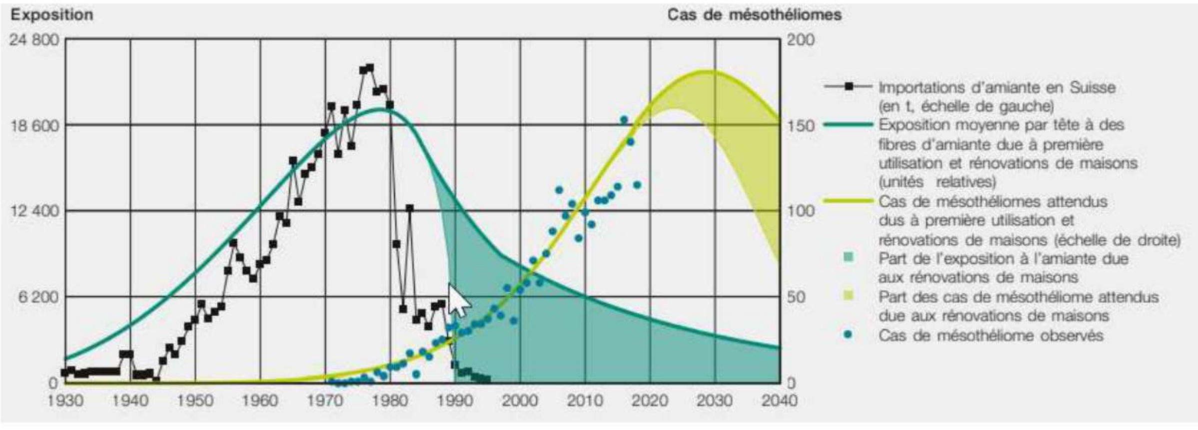
Asbestosis: Increased connective tissue in the lungs; functional impairment, respiratory disability.

Malignant mesothelioma: Cancer of the **pleura** or peritoneum (almost always fatal).

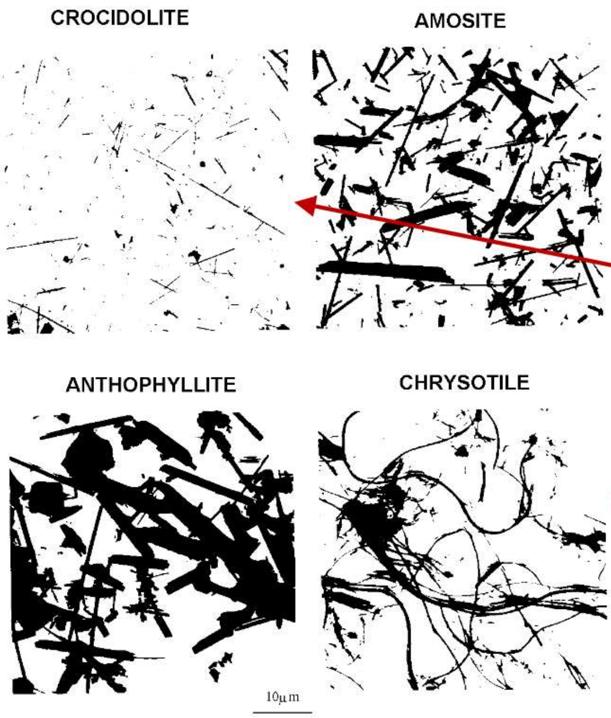
The particular case of asbestos

Very slow development
– We are currently in the peak period

Evolution of asbestos exposure and expected mesothelioma in Switzerland



Asbestos fibers



Appearance of asbestos fibers under the optical microscope

Blue asbestos

White asbestos