Chemical pollutants
Assessment and control

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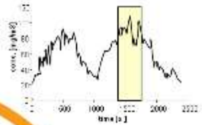
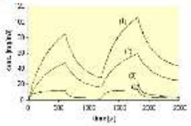
Which exposure ?

Is it acceptable ?

Measuring



Modelling



Evaluation

valeur de
référence

Décision

Contrôle

Ventilation

Variability of exposure

Due to the emission source

- process used, rate, quantities
- physical properties of the material, energy used
- emissions linked to other processes, partitioning

Due to the work environment

- general ventilation (weather conditions)
- air currents, local mixing, thermal effects
- distance from the source (displacement)

Due to measurement

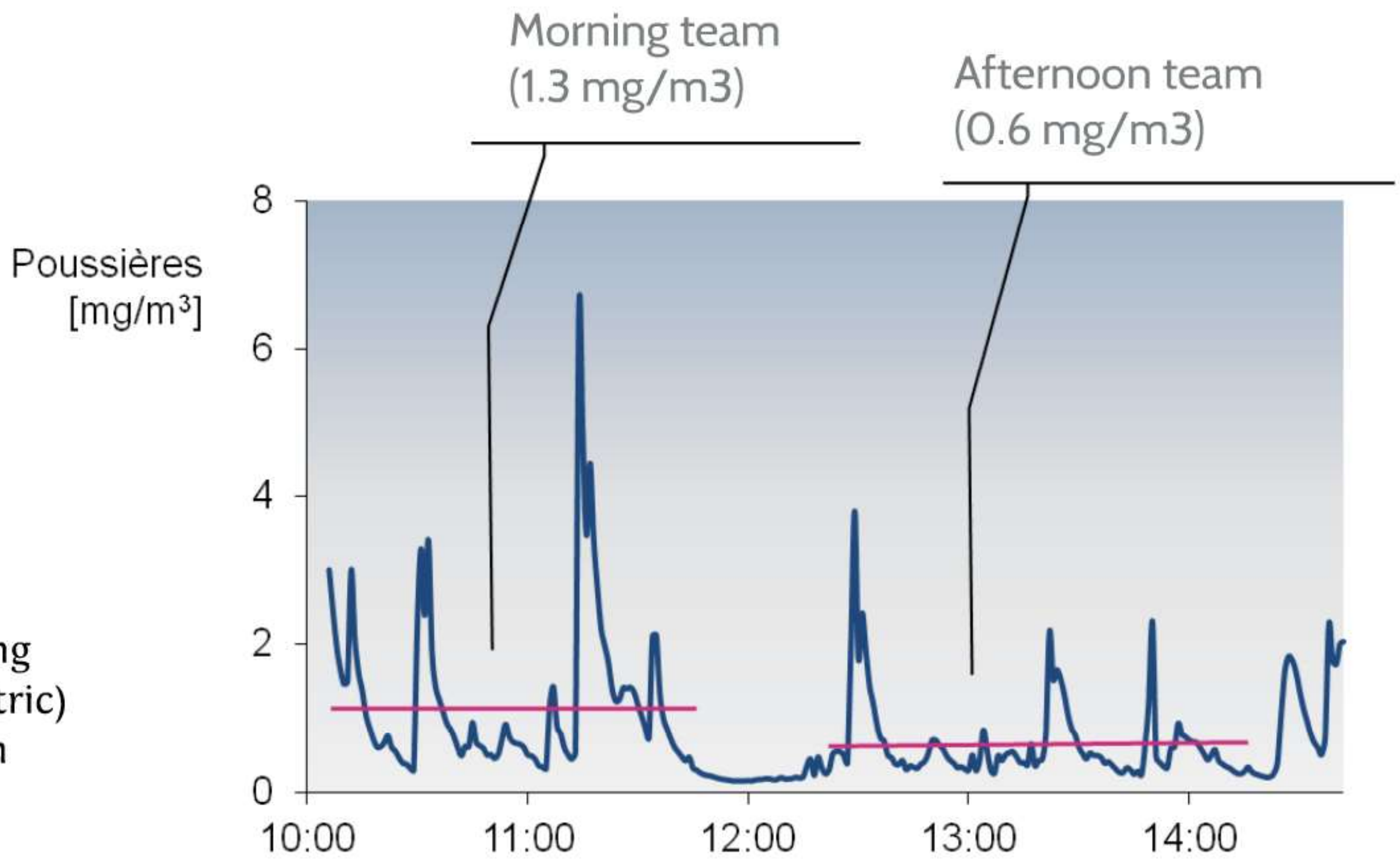
- inaccuracy of the equipment or sampling

Variability of exposure

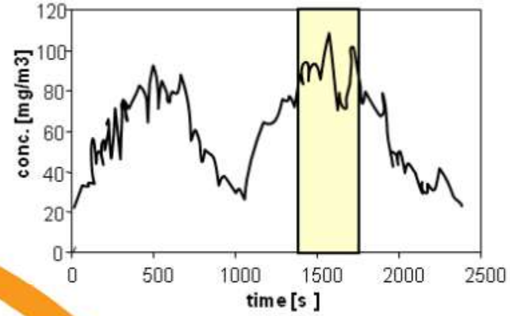
Due to human factors

- specific tasks (postures, movements, movements...)
- work habits, training
- measurement, control...

- Metallurgy
- direct reading (nephelometric)
- Fixed station

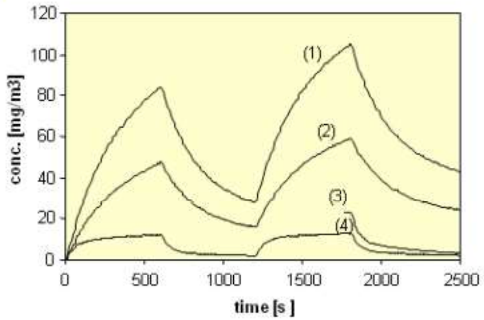


Measuring



Evaluation

Modelling



Integrated measurements, gas and vapor sampling

Mechanical

Syringes
Vacuum containers
Plastic bags
Measuring cells
Cryogenic method

Chemisorption

Solubilization
Activated carbon
Chemical transformation: impinger, impregnated paper, porous polymers

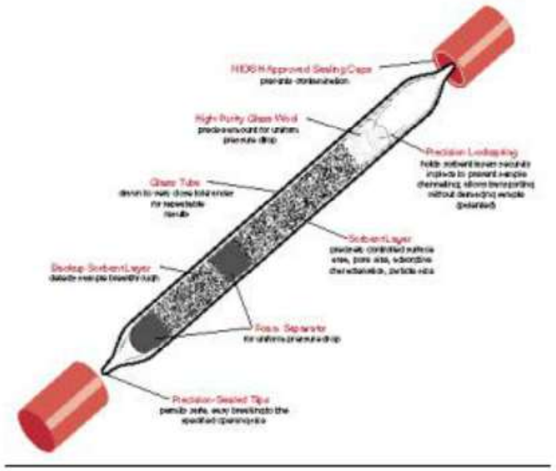
Physisorption

Various solid supports, SPME (microextraction)

Integrated measurements, chemisorption

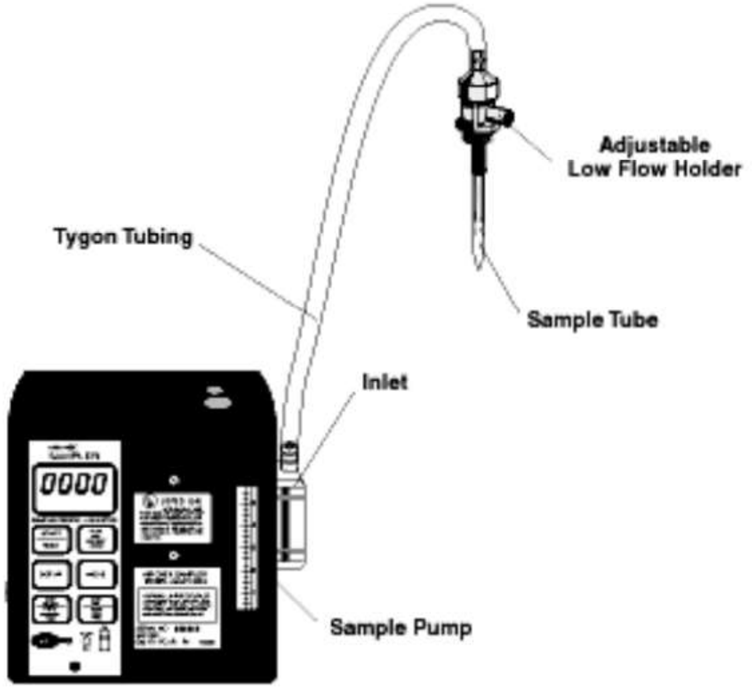
Sampling on activated carbon

- limited capacity
  - generally 10% w/w
  - different sizes
  - 100/50, 1000/500 mg
- control area
- desorption
  - solvent (often CS2)
  - efficiency to be determined



Various other sampling tubes

- Requires laboratory analysis after desorption



Continuous measurements

Photoionization detector

Most of the organics
Direct reading, recording
Non-specific

ToxiRAE photo-ionization Monitor

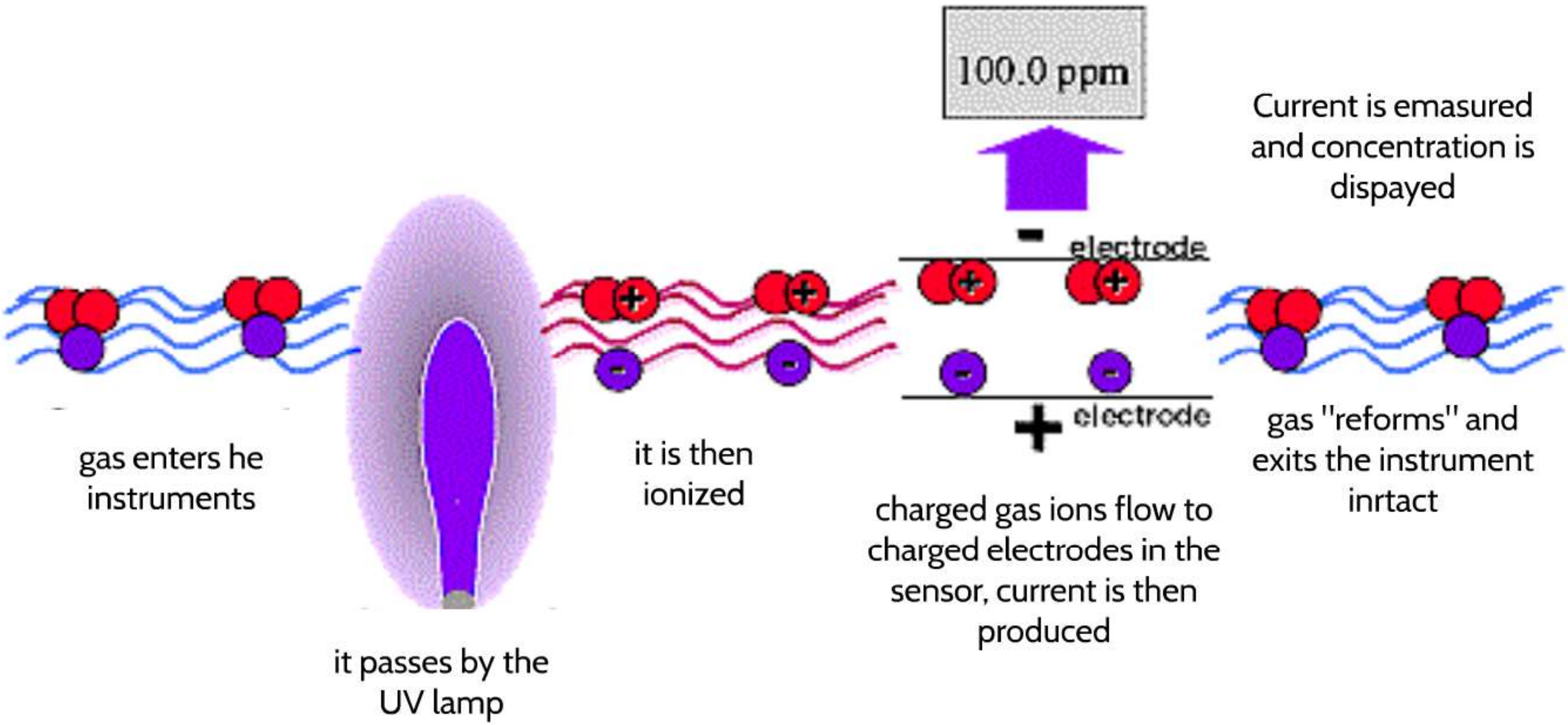
Electrochemical detector

Electrochemical detector
Direct reading
Specific

Common gases: CO, H_2S, O_2, SO_2,...

Dreager electrochemical detector

Photoionisation



Continuous measurements

Some examples
Typical pollutants

Principle	Measured substances
Electrochemical	CO, NO_X, Phosgen, Cl_2
Photoionisation	Most organic substances
Spectrophotometry IR	Organic and inorganic substances
Non dispersive IR	CO_2
Chemiluminescence	Ozone
Combustion	Flammable substances
Spectrophotometry UV	Ozone

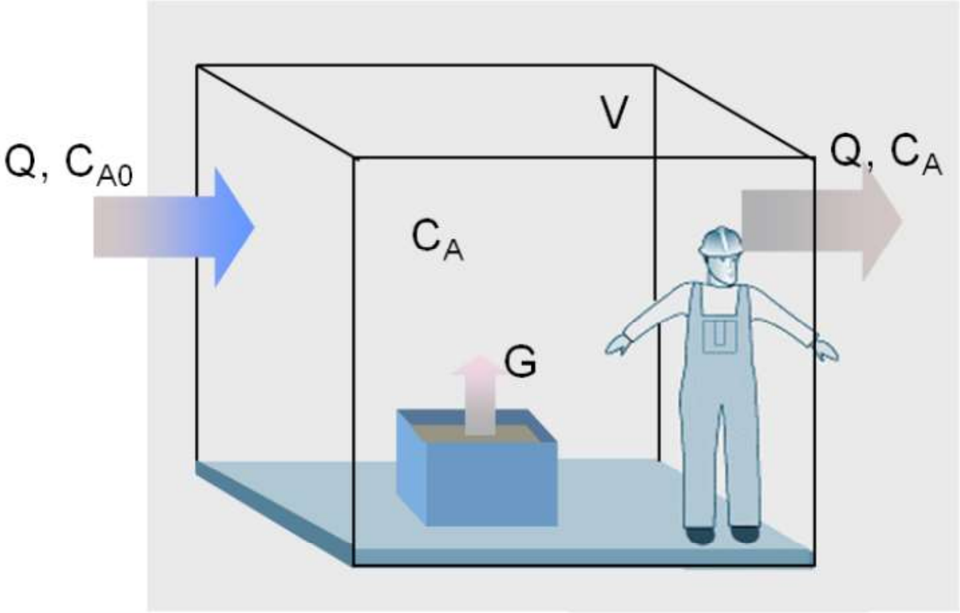
Integrated or continuous measurements ?

What are the advantages and drawbacks of continuous vs. Integrated measurements ?

Physical models

One compartment (1-box model)

Gases ideally mixed in a single compartment (general ventilation)



Parameters:
initial conc. CAi [mg/m3]
incoming conc. CA0 [mg/m3]
ventilation Q [m3 /s]
volume V [m3]
emission G [g/s]

characteristics:
- very simple
- Underestimation of exposures close to the source

Physical models

Mass balance

$$V \cdot \frac{dC_A}{dt} = Q \cdot C_{A0} + G - Q \cdot C_A \underbrace{- K_{\sin k} \cdot C_A}_{\text{Sinking}}$$

Analytical solution

$$C_A = \left(C_{Ai} - C_{A0} - \frac{G}{Q}\right) \cdot e^{-\frac{Q \cdot (t - t_0)}{V}} + C_{A0} + \frac{G}{Q}$$

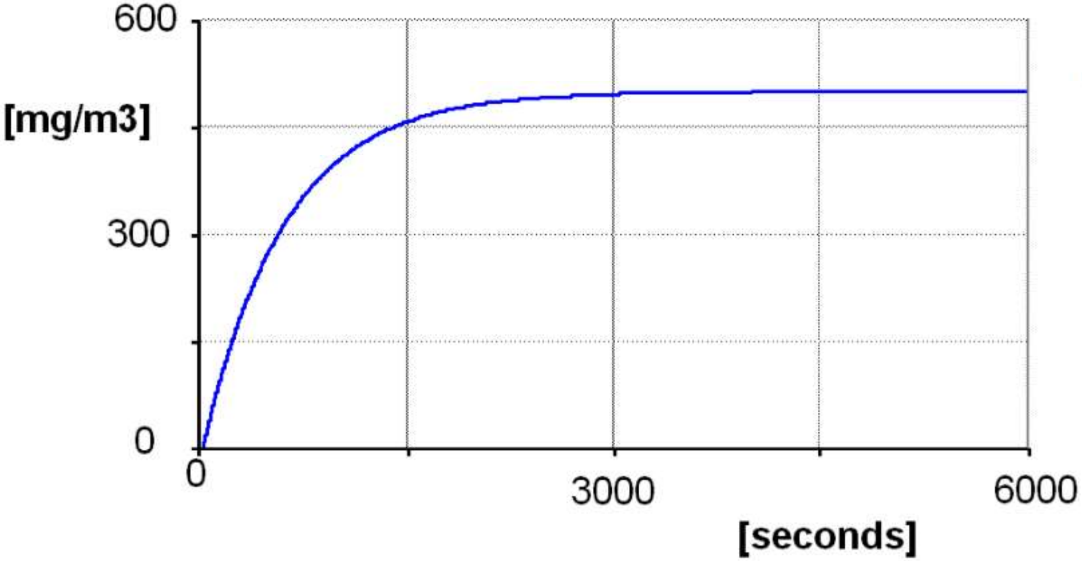
Assumptions:
no sink, (Ksink= 0)
constant emission
small volume of gas generated
external concentrations are constant

without contamination

$$C_A = \frac{G}{Q} \cdot \left[1 - \; e^{-\frac{Q \cdot (t - t_0)}{V}}\right]$$

Physical models

Example



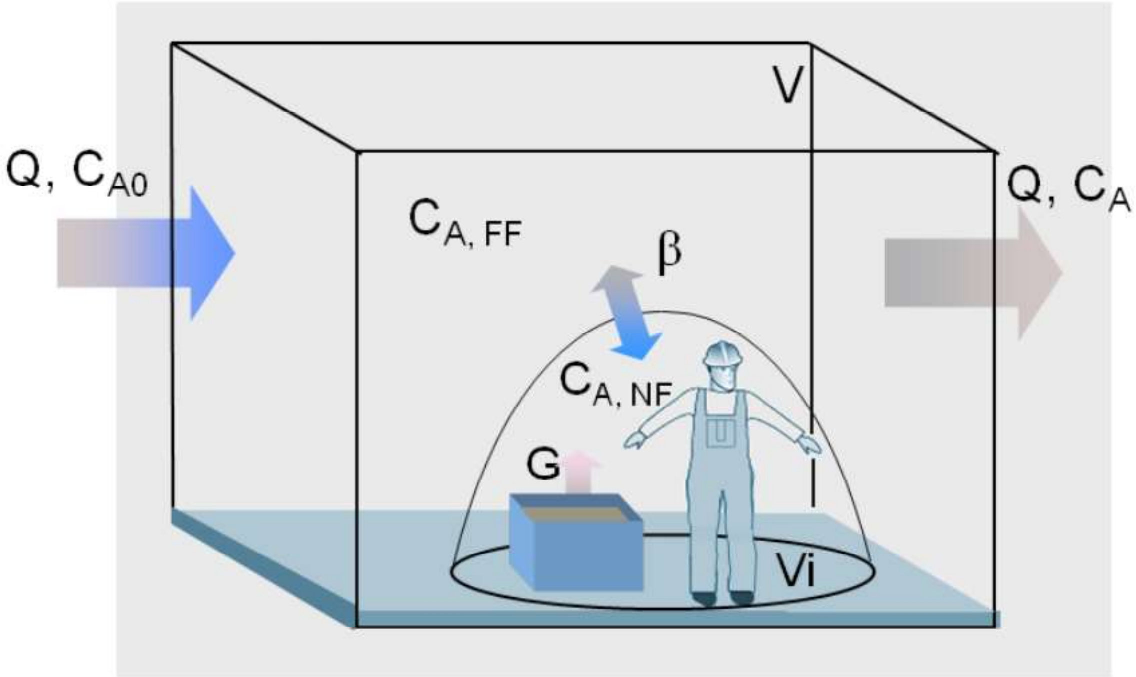
$$\frac{dC_A}{dt} = 0$$

$$C_A = \frac{G}{Q}$$

- Parameters
  - $Q = 0.1\ m^3/s$
  - $G = 50\ mg/s$
  - $V = 60\ m^3$
  - $C_{A0} = 0\ mg/m^3$
  - $C_{Ai} = 0\ mg/m^3$

Physical models

Two-compartments model



Initial conditions

initial conc. CAi [mg/m3]

Incoming conc. CA0 [mg/m3]

Air change

ventilation Q [m3 /s]

compartment volume V [m3]

volume (NF) Vi [m3]

Inter-compartment exchange: B [m3 /s]

Emission

emission coefficient G [g/s]

Two compartments ideally mixed: the near field (NF) and the far field (FF)

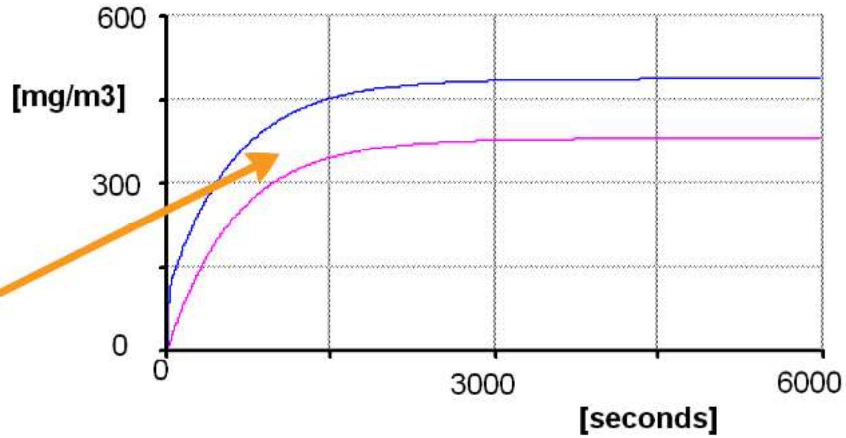
Physical models

Two-compartments model, mass balance

near field $$V_{NF} \cdot dC_{A,NF} = G \cdot dt + \beta \cdot C_{FF} \cdot dt - \beta \cdot C_{NF} \cdot dt$$

far field $$V_{FF} \cdot dC_{A,FF} = \beta \cdot C_{NF} \cdot dt - (\beta + Q) \cdot C_{FF} \cdot dt$$

Example



- État stationnaire

$$C_{A,NF} = \frac{G}{Q} + \frac{G}{\beta}$$

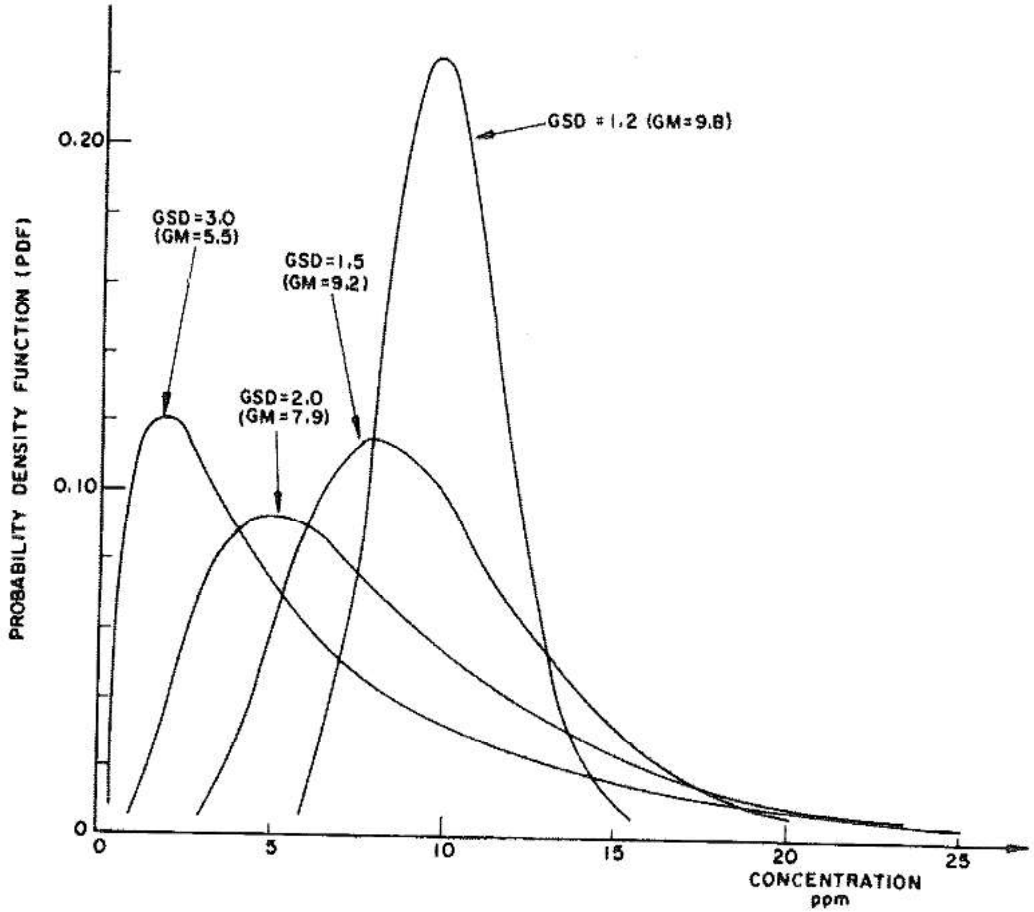
$$C_{A,FF} = \frac{G}{Q}$$

- Paramètres
  - Q, G, V
  - $V_{NF} = 2\ m^3$
  - $\beta = 0.35\ m^3/s$

Sample distribution

Wide range of observed distributions

extended range GSD 1.5-3.0
frequently GSD 2.0-2.5



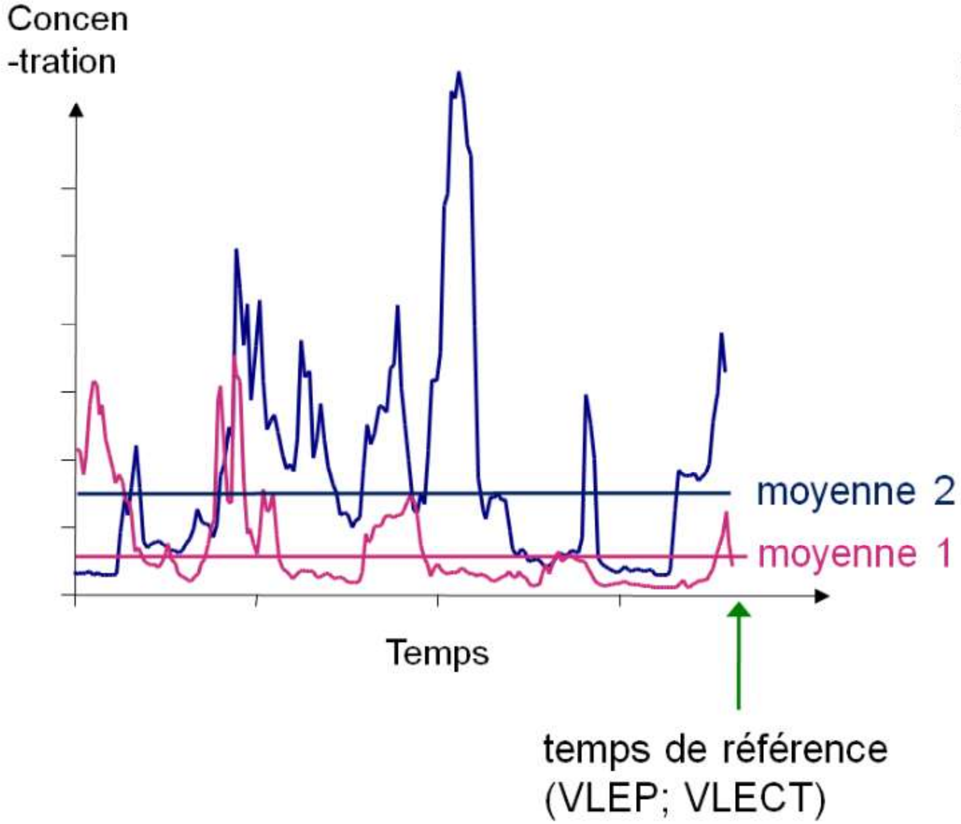
For a geometrical mean (GM) of 10

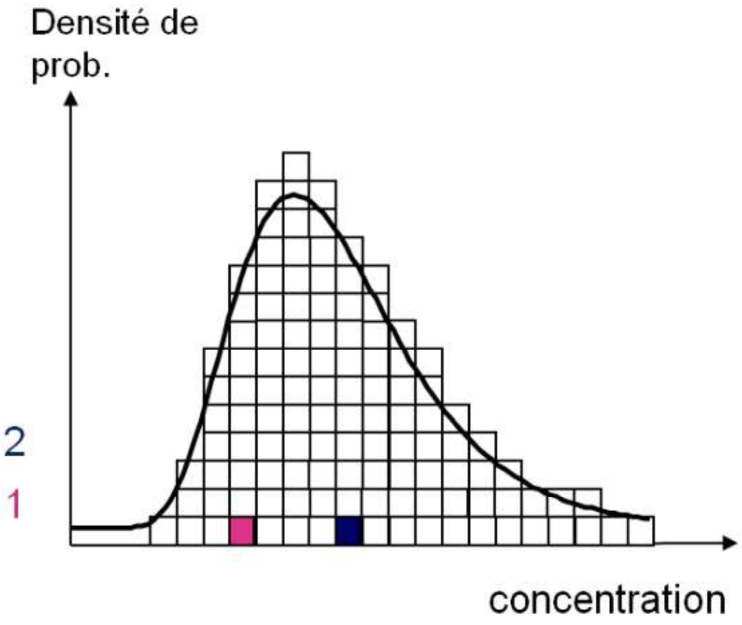
μ	GSD	Percentile 2.5% - 97.5%
11	1.5	4-23
13	2.0	3-40
15	2.5	2-63
18	3.0	1-90
22	3.5	0.8-123

Representativeness of the measurements

Are the measurements performed representative of actual exposure?

"Never measure in the same place twice, you will always get different results"
Tinnenberg 2001





To account for variability, we qualify the **distribution** of exposures

How many samples?

Number of samples required to ensure that at least 1 sample is in the top 10% (95% confidence level)

Taille de la population	12	13-14	15-16	17-18	19-21	22-24	25-27	28-31	32-35	36-41	42-50	∞
Nb échant.	11	12	13	14	15	16	17	18	19	20	21	29

"The more we measure, the more likely we are to exceed the norm."
Tinnenberg 2001

Pragmatic "action level" approach

An "action level" is defined as the level above which preventive measures must be taken. This level is usually set at one-half to one-third, and sometimes even one-quarter, of the official limit.

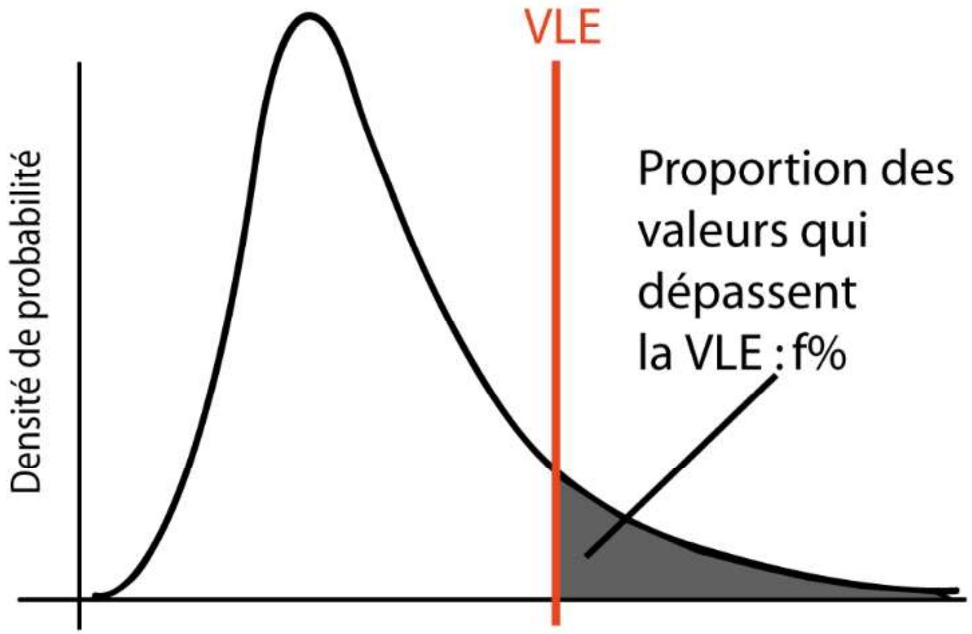
What are the reasons for this?

To take into account

- the variability of exposures (day, weeks, months, years)
- the limited knowledge of values
- Corporate image
- Quality procedures (ISO and OSHAS standards)

Statistical approach

Probabilistic approach: knowing the distribution, what are the chances of exceeding the reference value?



for the record:

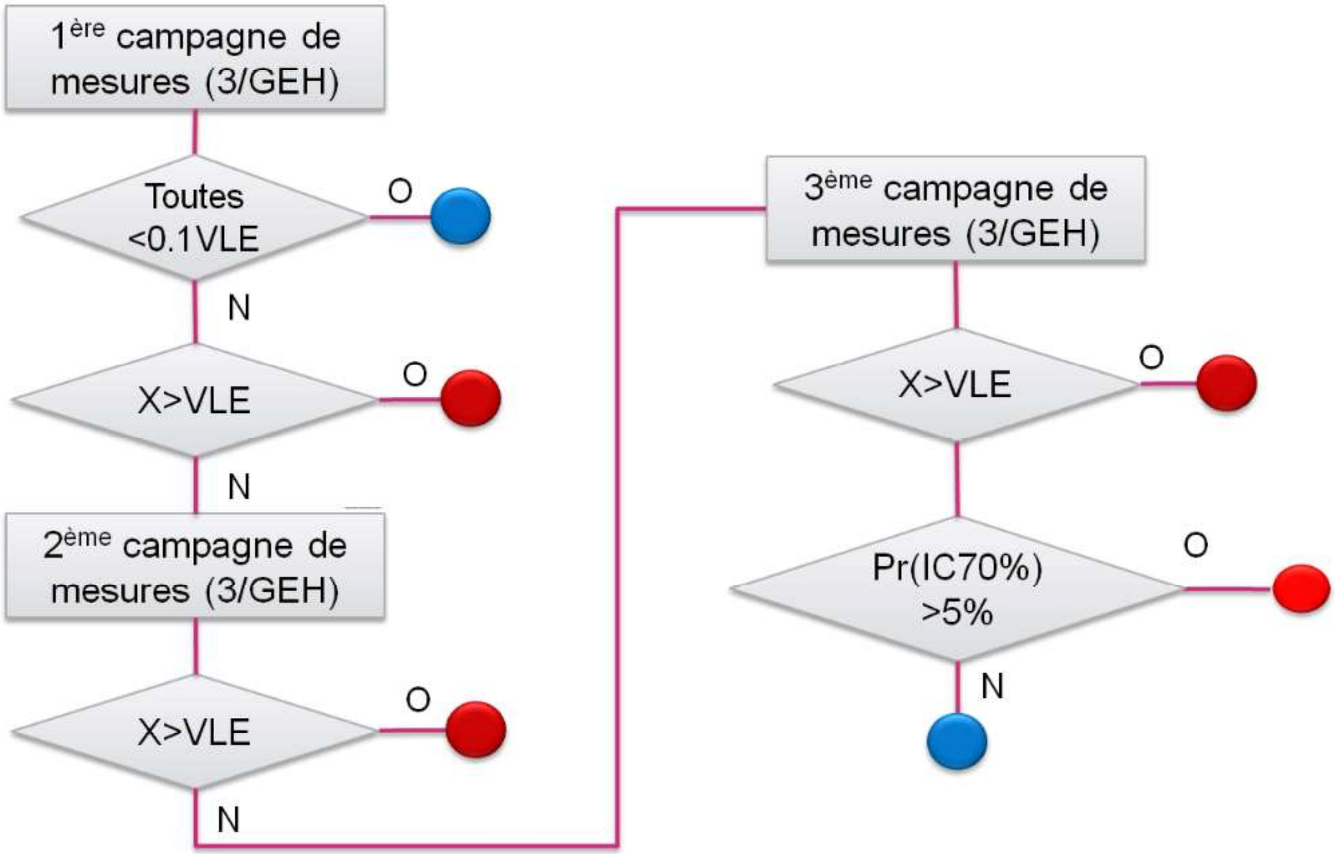
$$\mu \cong \bar{x} = \sum \frac{x_i}{n}$$

$$\sigma \cong s = \sqrt{\frac{\sum(\bar{x} - x)^2}{n-1}}$$

$$CV = \frac{s}{\bar{x}} \cdot 100\%$$

Statistical approach

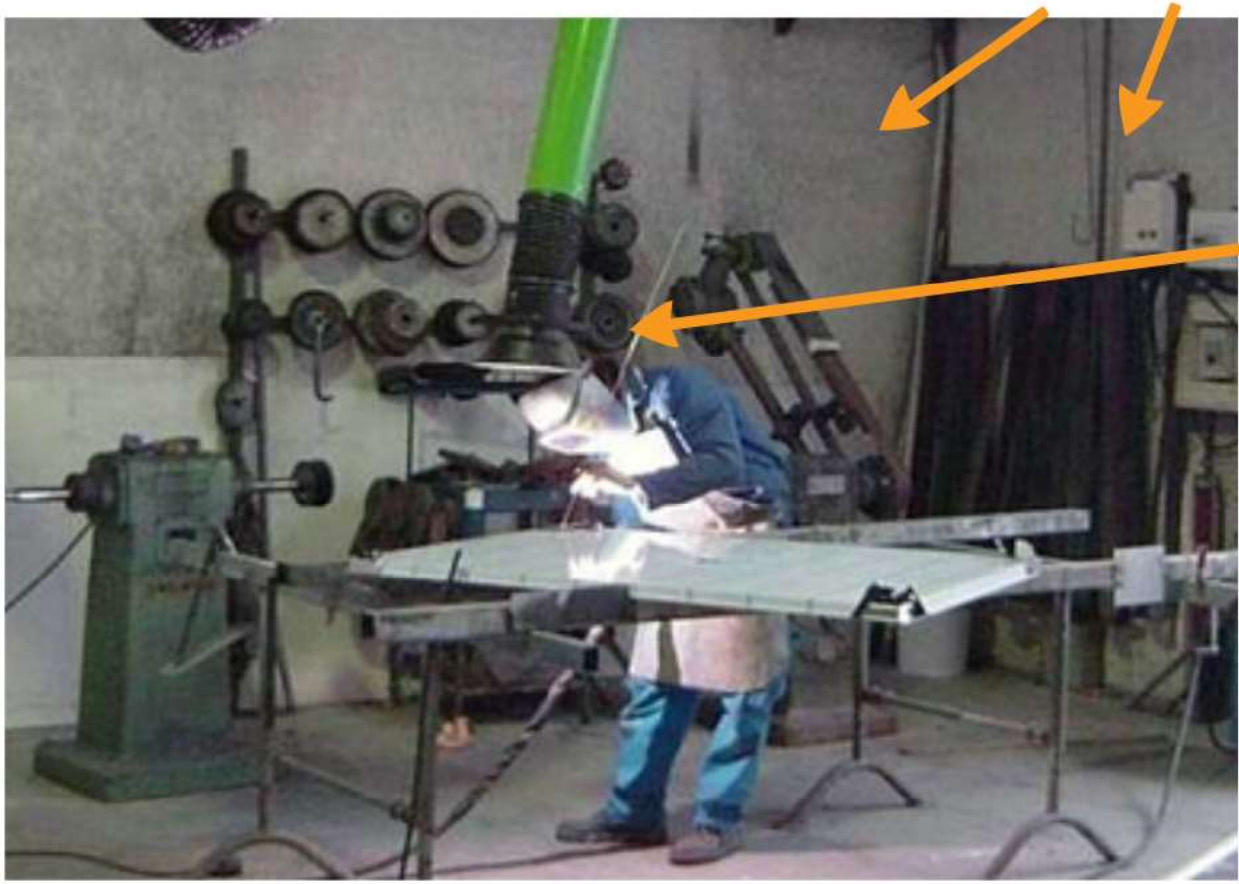
- HEG: homogeneous exposure group (workers exposed under similar conditions):



Ventilation

principles

general ventilation



local ventilation

individual protection

Ventilation: principles

Objective, control :

- Risks of intoxication
- Risk of fire or explosion
- Climate and odor

Allows to:

- Dilute gases, vapors and aerosols (general ventilation)
- Extracting gases, vapors and aerosols (local ventilation)
- Ensure sufficient air velocity
- Supply fresh air
- Provide air conditioning

Legal basis: OLT3, OLT4 (approval of plans)

- Atmosphere of the premises: ventilation and air pollution (art 17 and 18)
- Minimum air volume (art 12)
- Climate of the building (art 16)
- Sunlight and heat radiation (art 20)
- Windows and natural ventilation (art 17)
- Construction materials for ventilation systems, control openings … (art 18)

Ventilation strategy

Gas, vapors and aerosols

Behavior of pollutants similar to air

- Diluted gases, vapors (less than 1% by volume)
- Same temperature
- Aerosols less than 20 um

Local ventilation

- Evacuation of pollutant before its dispersion (low flow rates)
- Priority in all cases and in particular when toxic products are used

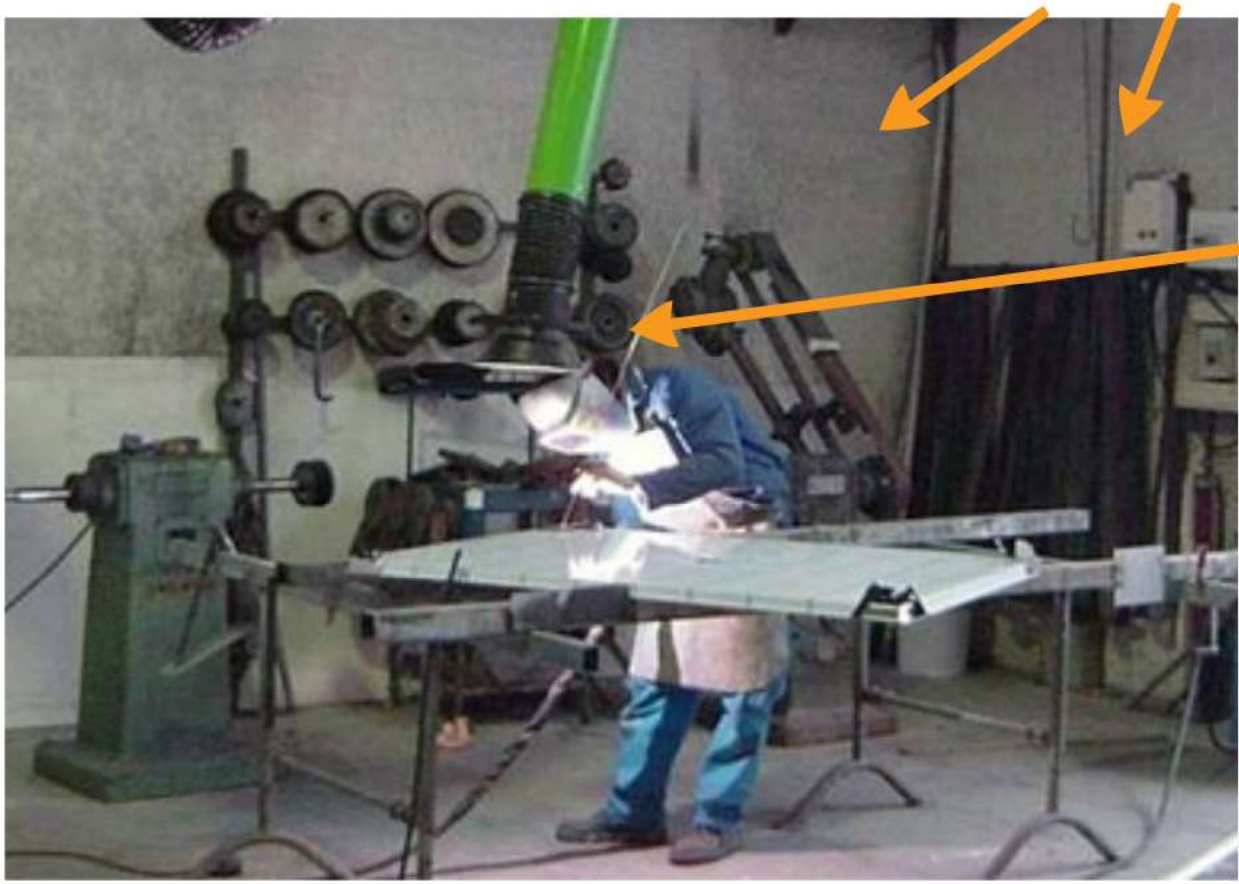
Ventilation générale

- Dilution of pollutants with fresh air (high flow rates), possible if.....
- Controllable pollutant with reasonable air flow
- Low toxicity pollutants
- Uniform emission

Ventilation

principles

general ventilation



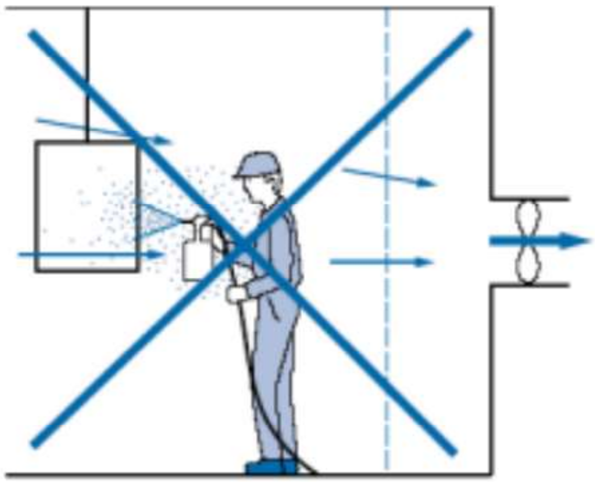
local ventilation

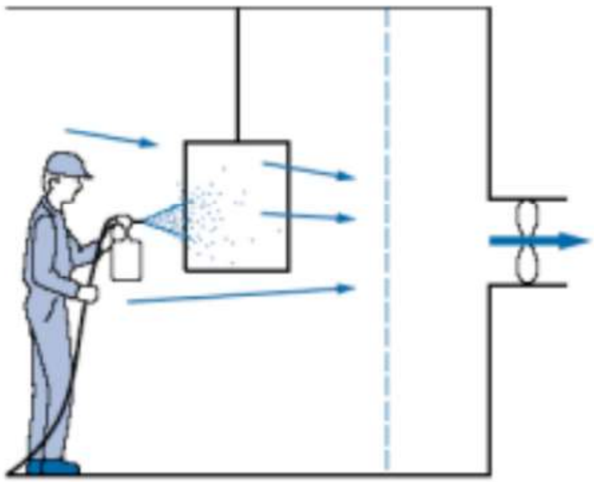
individual protection

General ventilation

The basic principles...

- Correct positioning of the inlet and outlet
- Flow from "clean" to "dirty" areas
- Induce the maximum flow in the polluted areas
- Make sure there are no dead zones
- Do not position individuals between sources and extraction





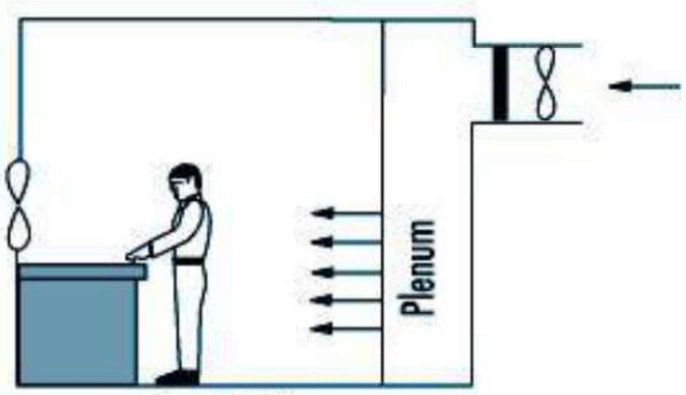
General ventilation

The basic principles..... (continued)

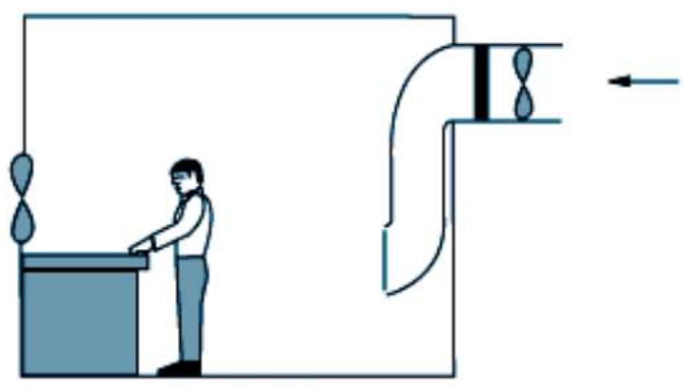
- Use the natural movement of the air
- Remember that the pulse is more directional than the suction
- be careful of air movements

Efficiency

Increase in ventilation rate by the safety factor K, to take into account non-ideal behaviour



Best air inlet
Best exhaust
K = 1.0 minimum



Best air inlet
Best exhaust
K = 1.5 minimum

General ventilation

Drawbacks

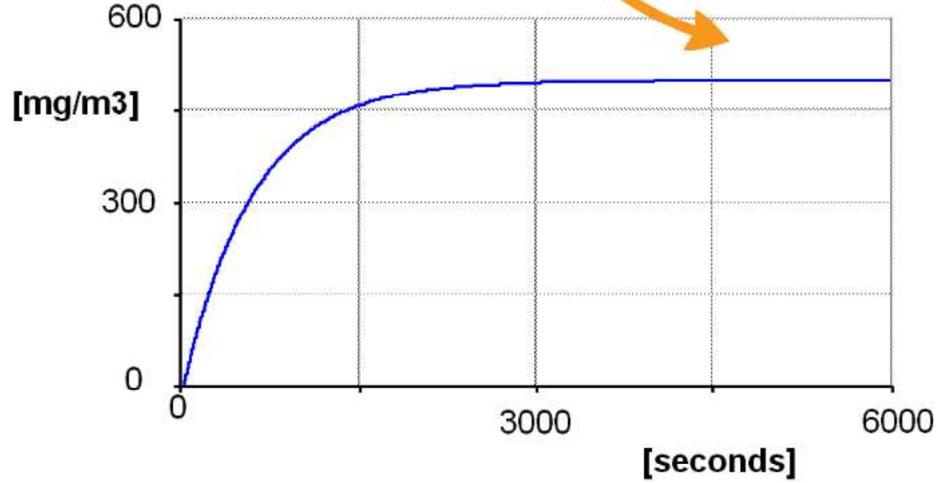
- Residual pollution
- Poor protection of individuals close to the pollution source
- Requires large flows
- Difficulties to absorb concentration peaks
- Air treatment

For a given émission (G) and flow (Q)

- The final (stationary) concentration does not depend on the room volume

$$\frac{dC_A}{dt} = 0$$

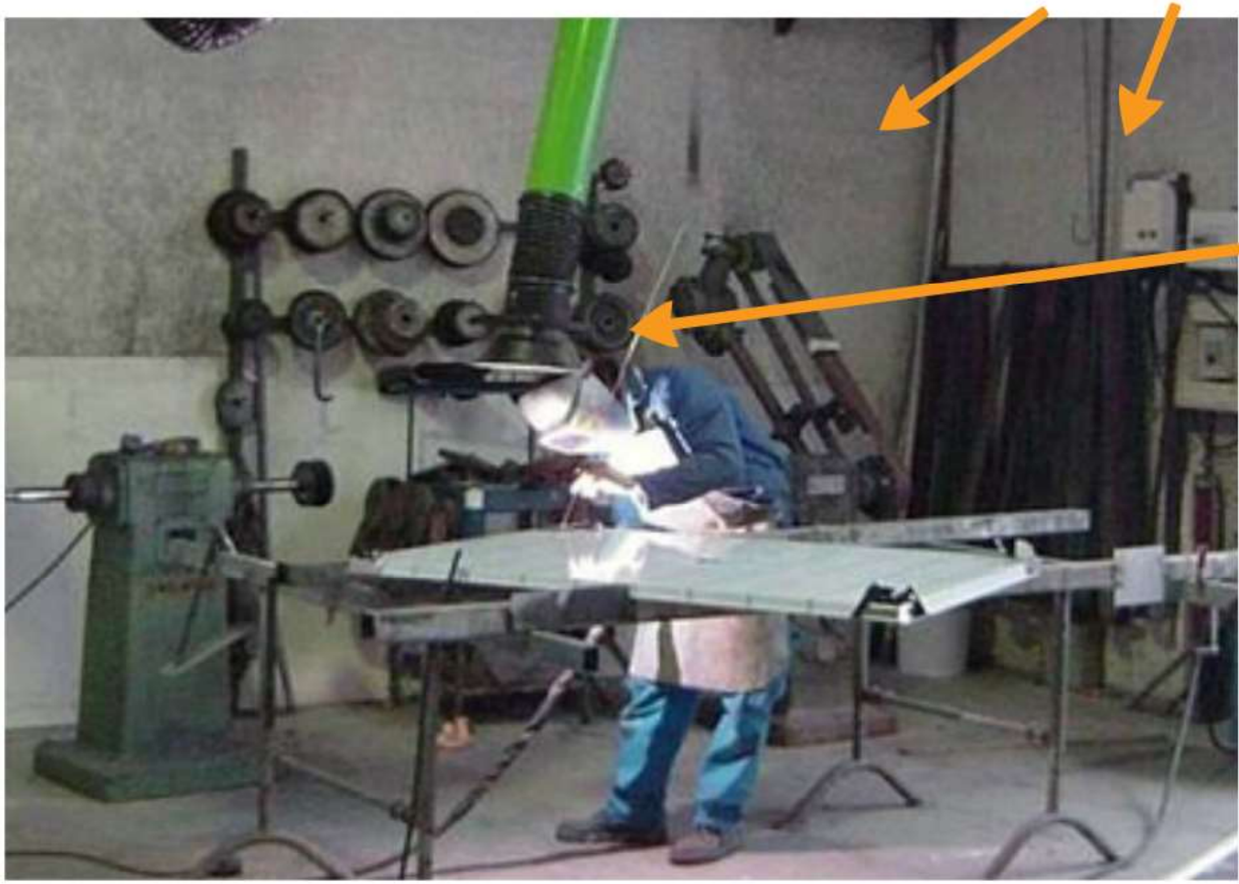
$$C_A = \frac{G}{Q}$$



Ventilation

principles

general ventilation



local ventilation

individual protection

Local ventilation

Benefits

- Reduction of local exposure
- Limitation of the number of exposed individuals
- Reduction of the required flow rates
- Reduction in heating costs
- Improved purification efficiency

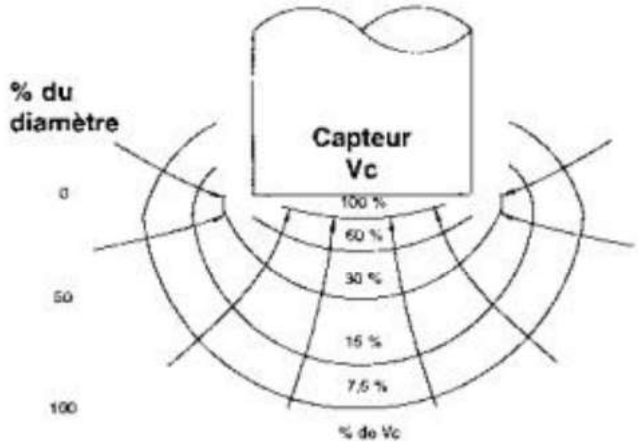
Local ventilation

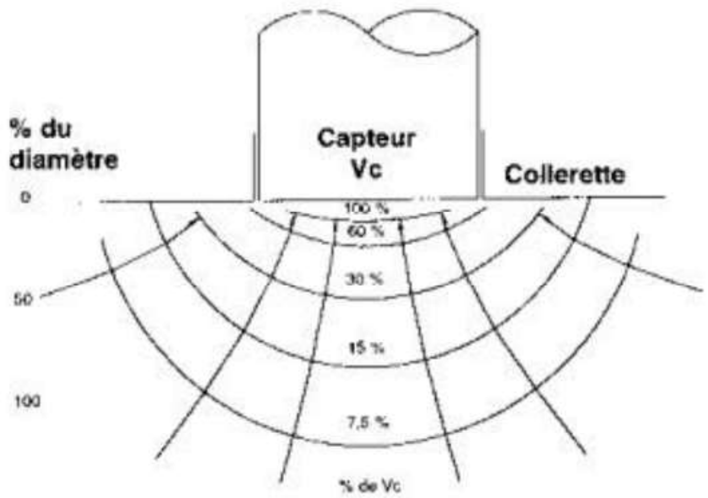
Aspiration

- Flow decrease propotionaly to the square of the distance
- The shape of the aspiration mouth must be taken into account
- 10% of the flow at only 1 diameter of distance

Pulsion

- 10% of the flow at another 60 diameters





(Beaudet et coll., 1998)

Local ventilation

The basic principles

- Enclose the pollutant production area as much as possible
- Capture as close as possible to the emission zone
- Place the aspiration device so that the operator is not between it and the source of pollution
- Use the natural movements of the pollutants
- Induce a sufficient air speed (capture speed 0.5-1 m/s)
- Distribute the air velocities evenly over the collection area
- Compensate each air outflows with corresponding air inlets
- Avoid air movements and thermal discomfort
- Discharge polluted air away from the fresh air intake zones

Example

What are the advantages and disadvantages of each ventilation situation?
It is assumed that the source of the pollutant is located on the work surface (e.g. solvent handling)..