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Chemicals Assessment

David Vernez

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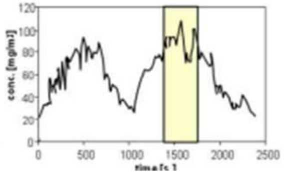
Exposure assessment & control

Strategy

Measuring

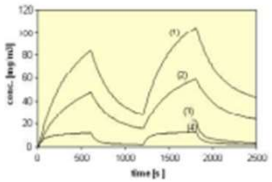


Reference value

Evaluation

Acceptance ?

Modelling



Control
- Substitution
- Ventilation
- …

Exposure variability

Due to the emission source

- Process used, rate, quantities
- Physical properties of the material, energy used
- Emissions linked to other processes

Due to the work environment

- General ventilation (weather conditions)
- Air currents, local mixing, thermal effects
- Distance from the source (displacement)

Due to the measurement

- Inaccuracy of the equipment or sampling

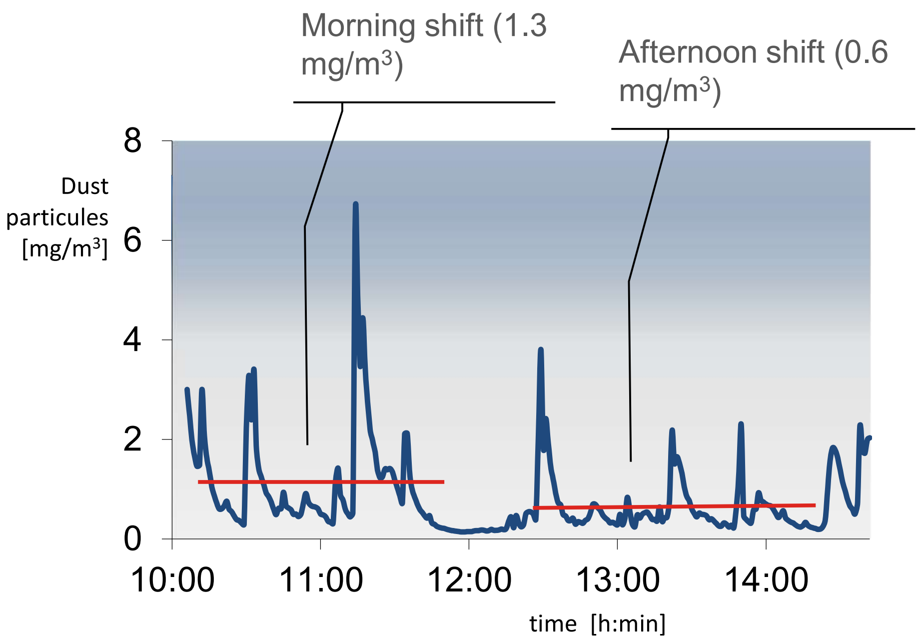
Exposure variability

Individual related

- Specific tasks (posture, body movements, moving around…
- Work habits, training
- Measurement, control

Metal industry

- Direct reading (*nephelometry*)
- Stationary position



Airborne measurements

Integrative measurements (dose)

Mechanical
- Syringes
- Vacuum containers
- Plastic bags
- Cryogenic methods

Chemisorption
- Solubilization
- Activated charcoal Chemical transformation (e.g. impregnated filters)
- Porous polymers

Physisorption
- Various solid supports
- SPME (microextraction)

Airborne measurements

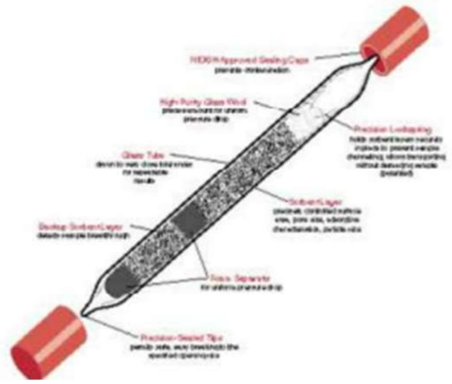
Integrative measurements – chemisorption

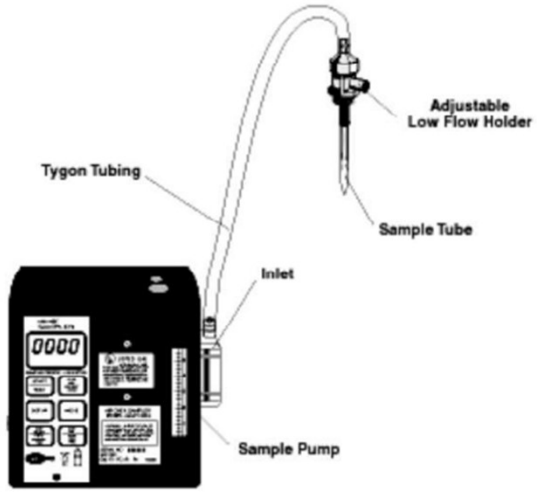
Activated charcoal tube

- Limited capacity
  - Different sizes
  - Typically 100- 1000 mg
- Control area
- Desorption
  - Solvent (often CS_2)
  - Efficiency to be determined

Various other sampling tubes

Requires laboratory analysis after desorption





Airborne measurements

Continuous measurements (concentration)

Photoionization detector

- Versatile, most organics
- Direct reading
- Non-specific

ToxiRAE photo-ionization Monitor

Electrochemical detector

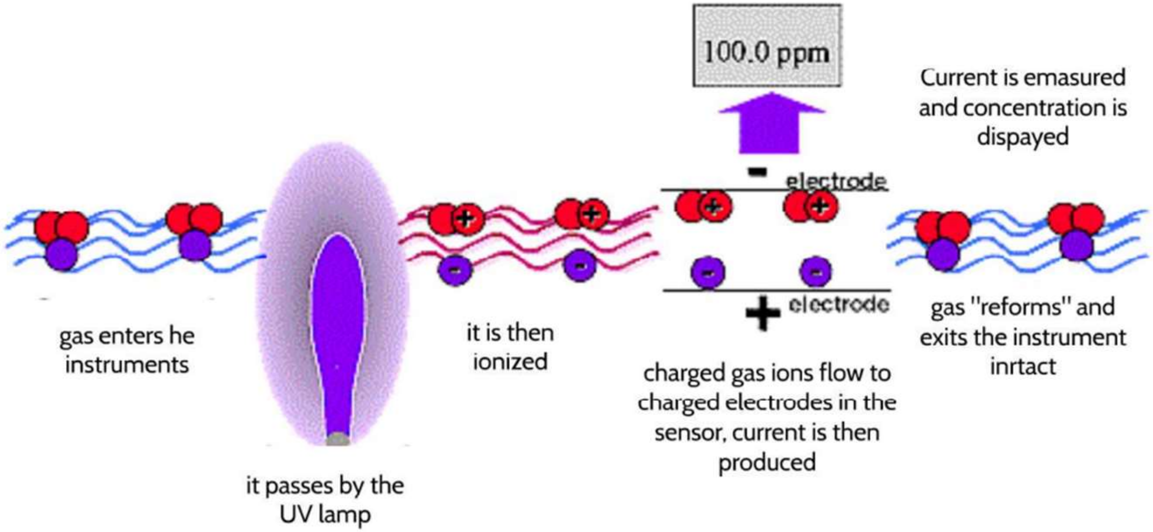
- Direct reading
- Specific
- Only common gases (CO, H_2S, O_2, SO_2…)

Dreager electrochemical detector

Airborne measurements

Photoionization detector

UV light (typically 10.6 eV)



Airborne measurements

Continuous measurements

Some examples

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

Case study

The printing industry

An industrial hygienist was tasked with assessing the inhalation exposure of press operators in a printing facility. The worker handles inks containing Toluene (C_7H_8). OEL (TWA) : 50 ppm 8-h

Monitoring was conducted over 8-hour for 1 worker, with the following results:

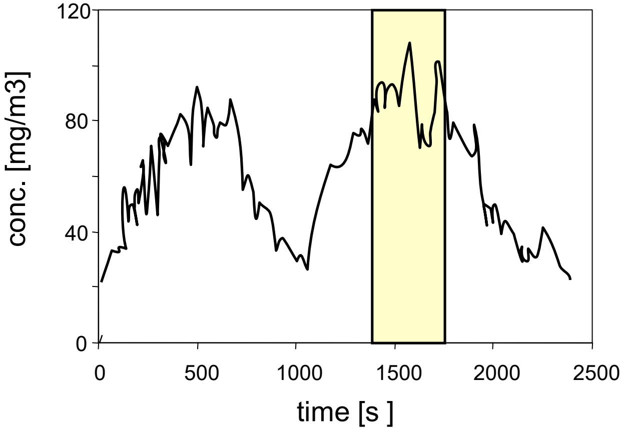
Measurement	Duration (hour)	Concentration (ppm)
1	100	15
2	50 min	75
3	60	No measurement
4	150 min	120
5	40	No measurement

Question (2.3a)

Do you think these data could be representative of the exposure?

Representativeness of the measurements

Are the realized exposure measurements representative of the real exposure situation?



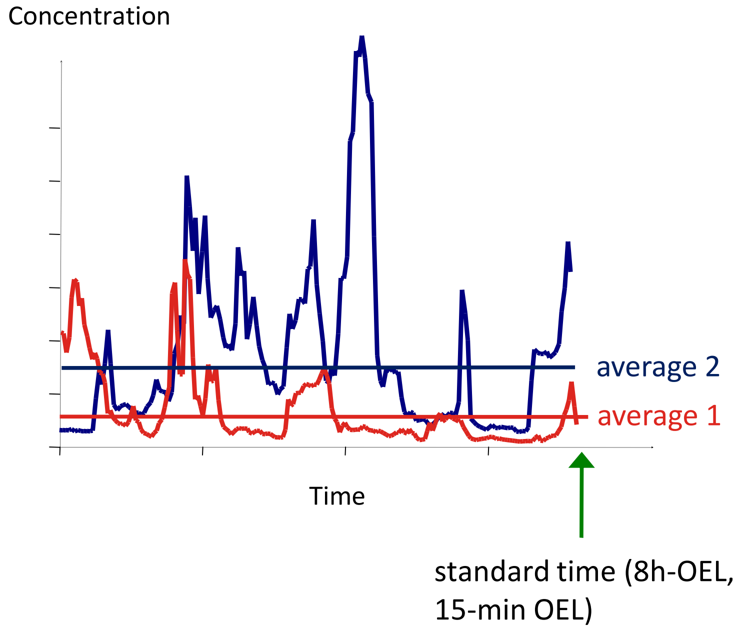
- Exposure variability
  - intra-individual, inter-individual
- Measurement error
  - Analytical sampling

Never measure twice on the same spot, the result will always be different

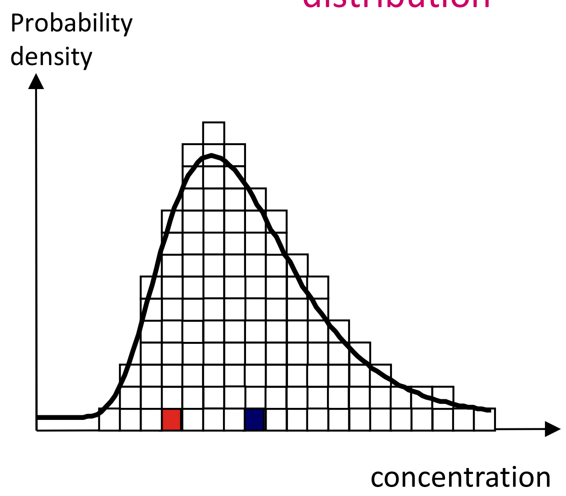
Tinnenberg 2001

Exposure distribution

To take the variability into account, we characterize the exposure distribution



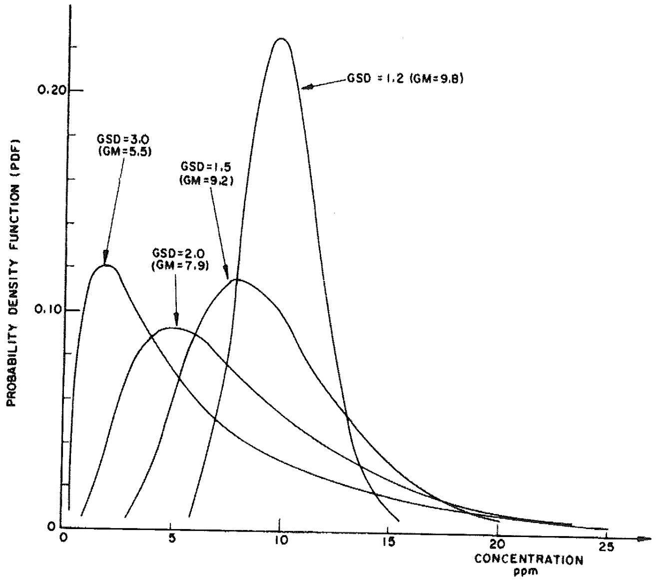
In general, a lognormal distribution



Measurements distribution

Observed distribution

- Widely spread GSD 1.5-3.0
- Typically GSD 2.0-2.5



For a geometric mean 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

Statistical approach (simplified)

- sampling
  - Number of samples required to ensure that at least one sample will belong to the most exposed (percentile 10%)

    confidence indice of 95% (short-term measurement)

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

Practical approach: “action level”

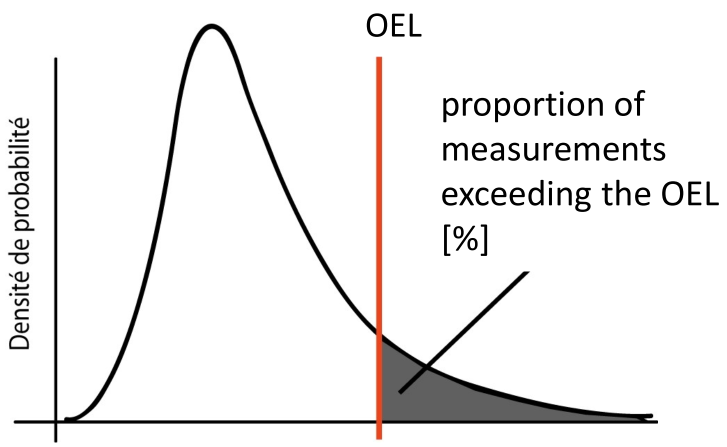
An « action level » is a level at which preventive actions have to be taken. This level is usually equivalent to the half or the third, sometimes the quarter of the OEL.

For what reason?

- taking into account exposures variability (day, week, month, year)
- taking into account the limited knowledge about OEL
- the company corporate image
- quality procedures (ISO and OSHAS standards)

Statistical approach

Probabilistic approach: Assuming a given distribution of (μ, σ), what are the chances to exceed the reference value?

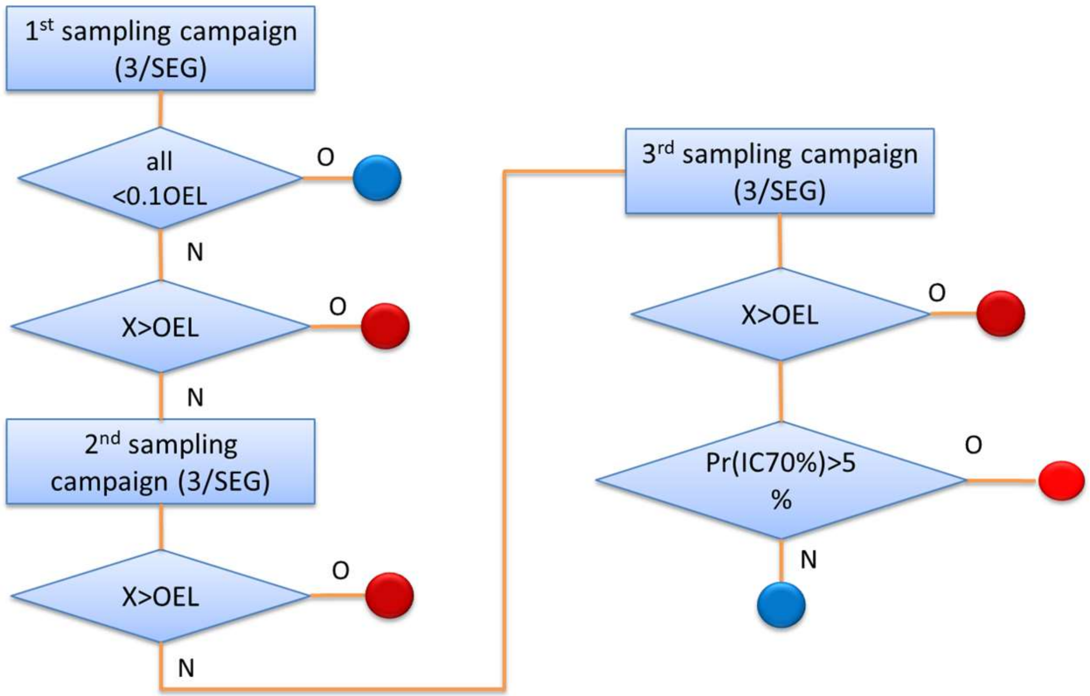


to keep in mind:

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

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

Statistical approach



- Iterative strategy to reduce the number of samples
- Based on the notion of SEG (Similar Exposure Groups)

HC0

Case study

The industrial hygienist continued the assessment and conducted continuous personal exposure measurements during 8 hours in a group of operators performing the same tasks under comparable conditions.

- OEL (TWA) : 50 ppm 8-h

Measure 1: 25 ppm
Measure 2: 2 ppm
Measure 3: 3 ppm
Measure 4: 35 ppm
Measure 5: 45 ppm
Measure 6: 12 ppm

Question (2.3b)
Compare the exposure (95th percentile) with the OEL (assuming the group is homogeneous) and comment the results

Question (2.3c)
Is the exposure group homogeneous ?

- Z-score for the 95th percentile : 1.645

$$GM = \left(\prod_{i=1}^{n} x_i\right)^{\frac{1}{n}} \quad GSD = \exp\left(\sqrt{\frac{\sum_{i=1}^{n}(\ln x_i - \ln GM)^2}{n}}\right)$$

Diapositive 19

HC0 After slide 23

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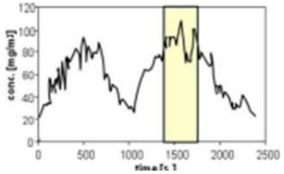
Exposure assessment & control

Strategy

Measuring

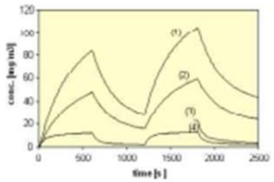


Reference value

Evaluation

Acceptance ?

Modelling



Control

- Substitution
- Ventilation
- …

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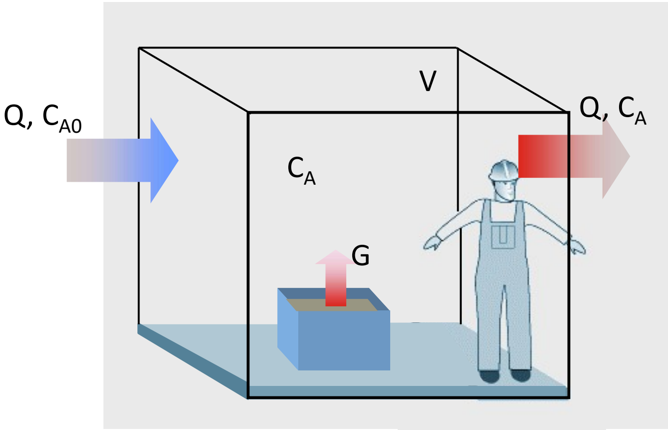
Exposure modelling

1 - box model

- the gas/vapour is homogeneously diluted in a single compartment (with a general ventilation)



- Parameters:
  - Volume V [m^3]
  - initial conc. CAi [mg/m^3]
  - incoming air conc. CA0 [mg/m^3]
  - ventilation Q [m^3 /s]
  - emission rate G [g/s]

- Characteristics :
  - easy to use
  - underestimates exposures close to the source

Exposure modelling

1 - box model

MASS BALANCE

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

Hypothesis:

- no sinking, (Ksink= 0)
- constant emission rate
- small emission volume
- constant conc. in the incoming air

ALGEBRAIC SOLUTION

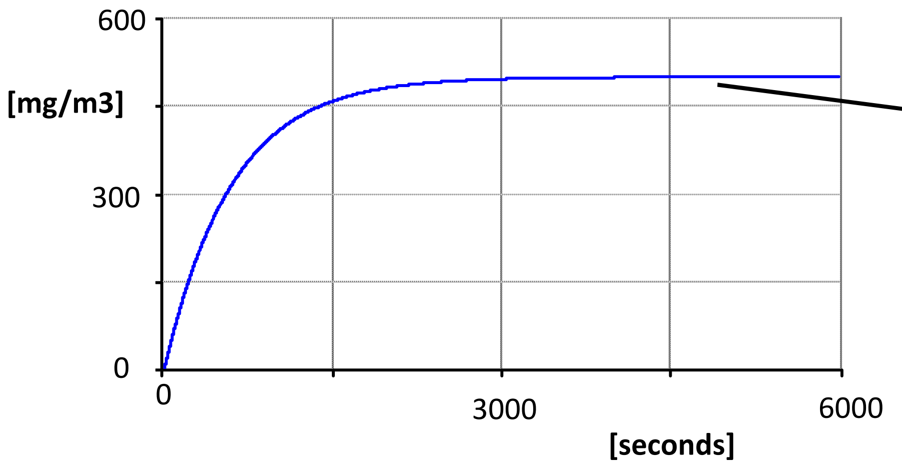
- integrative solution

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

Exposure modelling

1 - box model

EXAMPLE



- Stationary state

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

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

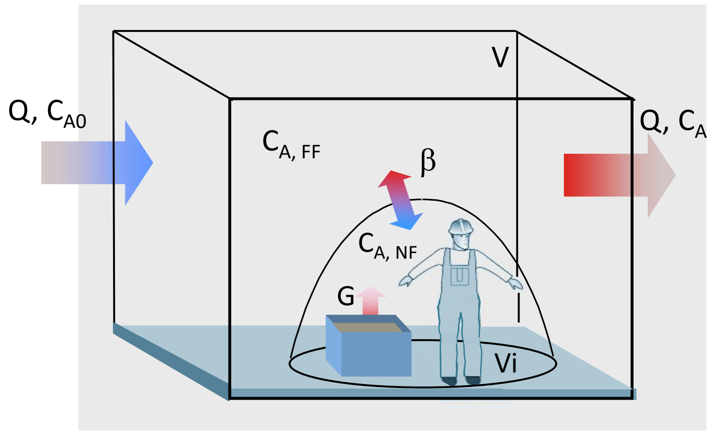
- Parameters
  - Q = 0.1 m^3/s
  - G = 50 mg/s
  - V=60 m^3
  - CA0 = 0 mg /m^3
  - CAi = 0 mg /m^3

Exposure modelling

2 - boxes model

TWO HOMOGENOUS VOLUMES:

- the Near-Field compartment (NF)
- the Far-Field compartment (FF)



- Initial conditions
  - initial conc. CAi [mg/m^3]
  - incoming air conc. CA0 [mg/m^3]
- Air exchanges
  - ventilation Q [m^3 /s]
  - room volume V [m^3]
  - near-field volume Vi [m^3]
  - inter-compartment exchange rate : β [m^3 /s]
- Emission
  - emission coefficient G [g/s]

Exposure modelling

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

With

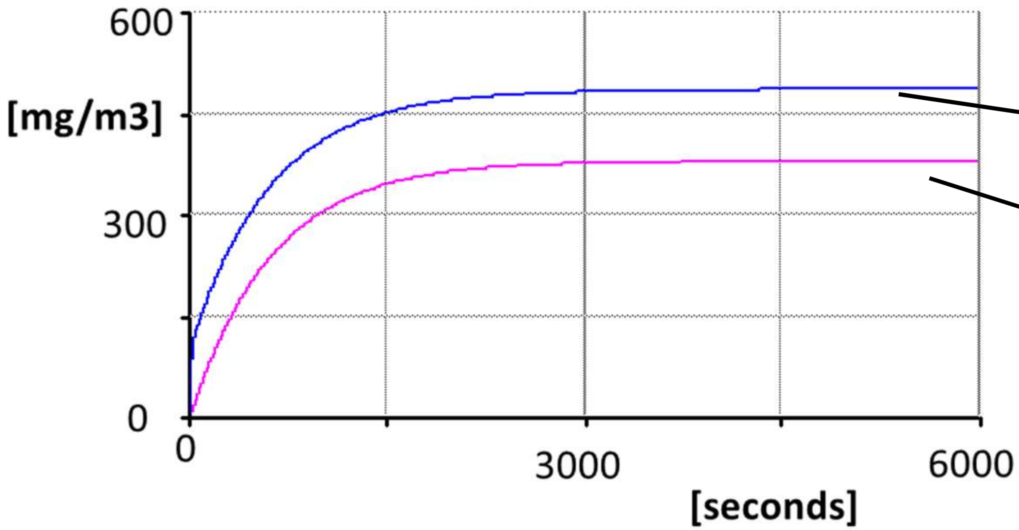
$$C_{A0} = 0$$
$$C_{Ai} = 0$$

- an analytical solution exists

Exposure modelling

2 - boxes model

EXAMPLE



- Parameters
  - Q, G, V
  - VNF = 2 m^3
  - β = 0.35 m^3/s

- stationary state

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

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

HC0

Case study

It is assumed that the printing facility is not equipped with ventilation and that:

- The air exchange rate of the room is low (0.5 h^{-1}).
- The emission rate G [mg/h] of the solvent can be estimated by assuming that over the 8 working hours. The operator uses a total volume of 250 ml of toluene ($d_{toluene}$ = 0.8669 g/mL).
- The volume of the facility is 50 m^3.

Question (2.3d)

From the one-compartment model, evaluate if the toluene TWA of 50 ppm (190 mg/m3) is exceeded at equilibrium.

Diapositive 27

HC0 After slide 30

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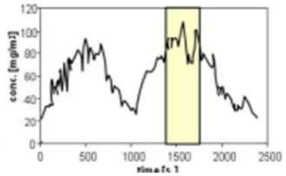
Exposure assessment & control

Strategy

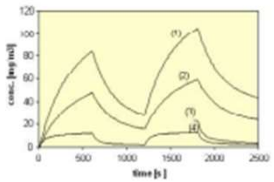
Measuring



Reference value

Evaluation

Modelling



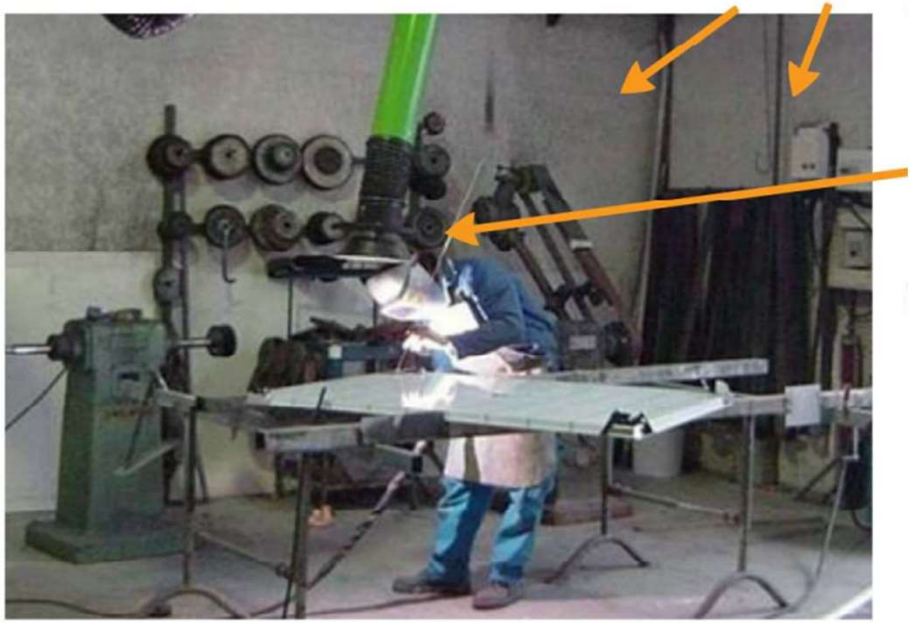
Acceptance ?

Control

- Substitution
- **Ventilation**
- ...

Airborne measurements

Ventilation



Ventilation, principles

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

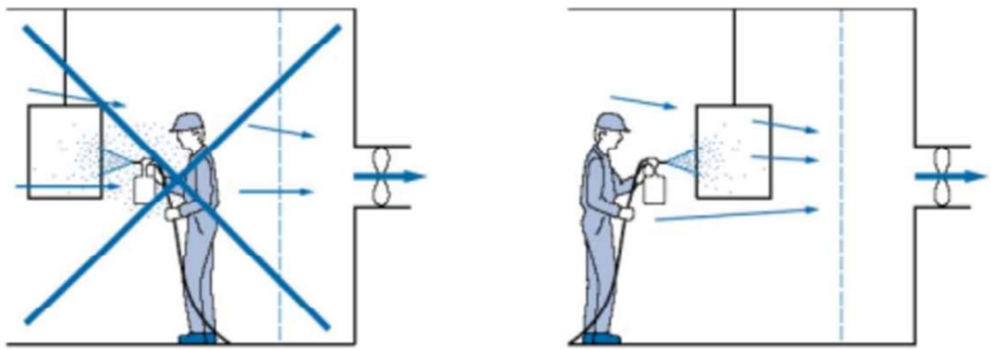
Legal basis: OLT3, OLT4 (approval of plans)

- 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, 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



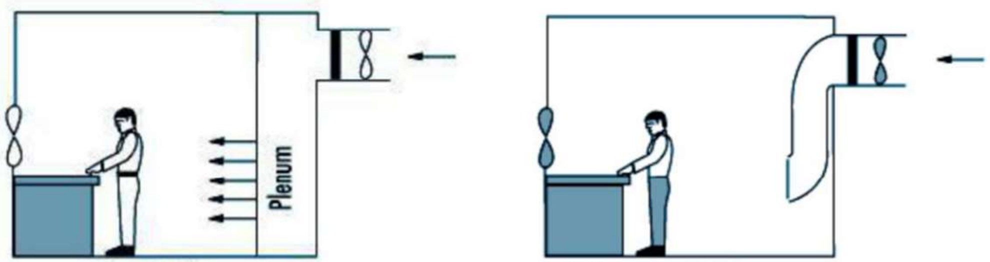
Ventilation, general ventilation

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

Ventilation, general ventilation

Drawbacks

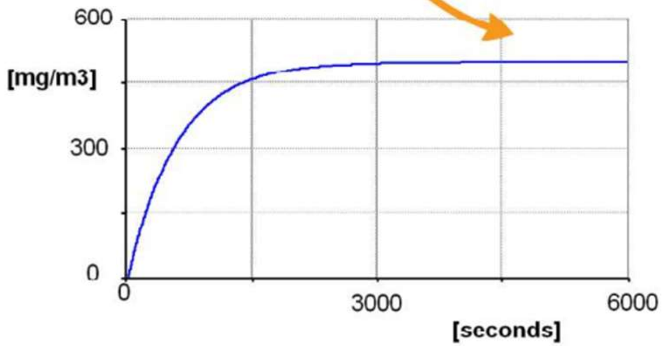
- Residual pollution
- Poor protection of individuals close to the pollution source
- Requires large flows
- Difficulties to absorb concentration peaks
- Air treatment

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, 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

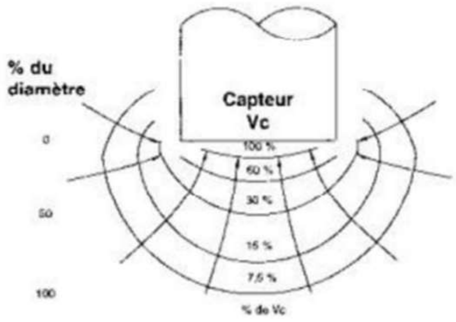
Ventilation, local ventilation

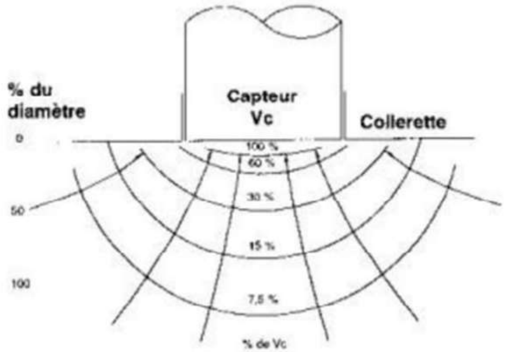
Aspiration

- 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)

Ventilation, 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

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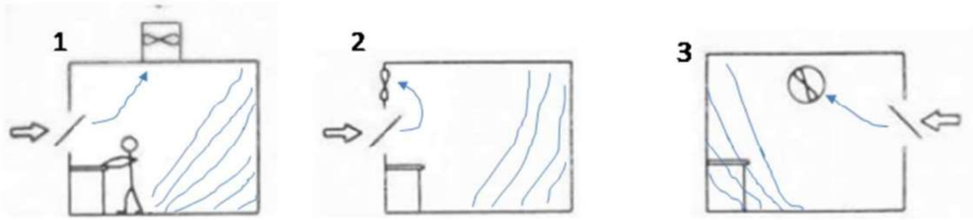
Case study

Three ventilation designs are considered to reduce the exposure close to the printing machine.



Question (2.3e)
What are the pros and cons of these 3 options ?

Diapositive 37

HC0 After slide 30

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