IAQ and ventilation criteria

HEATING VENTILATION AIR CONDITIONING SYSTEMS
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Indoor Environmental Quality

Dimensions

1) Thermal comfort
2) Indoor Air quality (IAQ)
3) Noise control
4) Visual comfort

Health, comfort and productivity

Energy Performance of Buildings

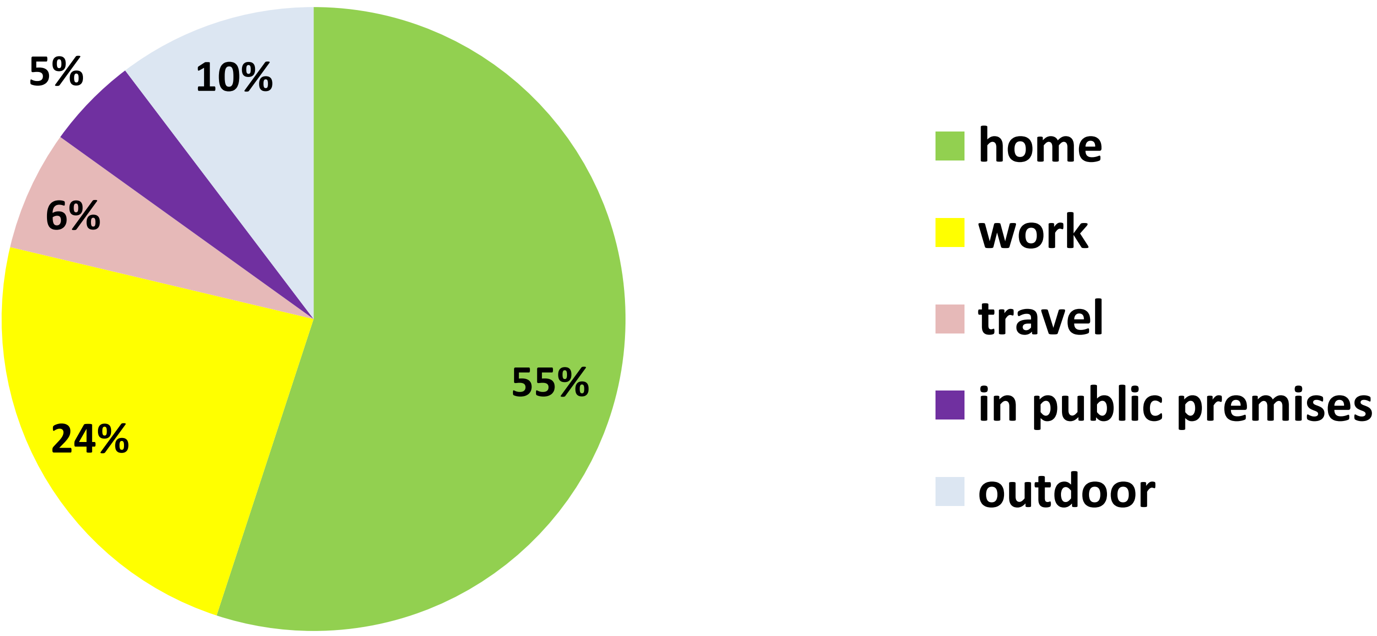
EPBD Directive (Art. 1)

The objective of the European Energy Directive for Buildings is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as **indoor climate requirements** and cost-effectiveness.

Indoor environment

Exposure to indoor environments

People spend ~90 % of the time indoor (work, travel, home)



Indoor Air Quality

Health vs Comfort

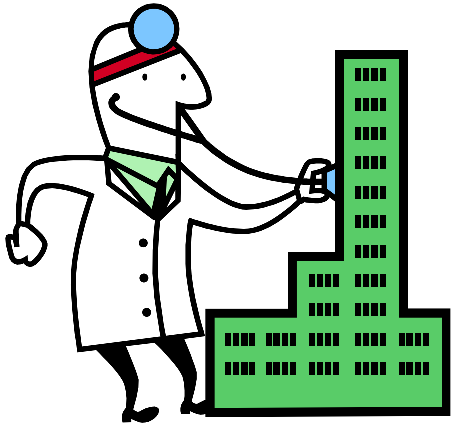
Pathogenic aspects can have acute and long-term effects on occupants (health issues).

Disturbing factors such as odor and irritation have a short-term effect (comfort issues).

Indoor Air Quality

Sick building syndrome

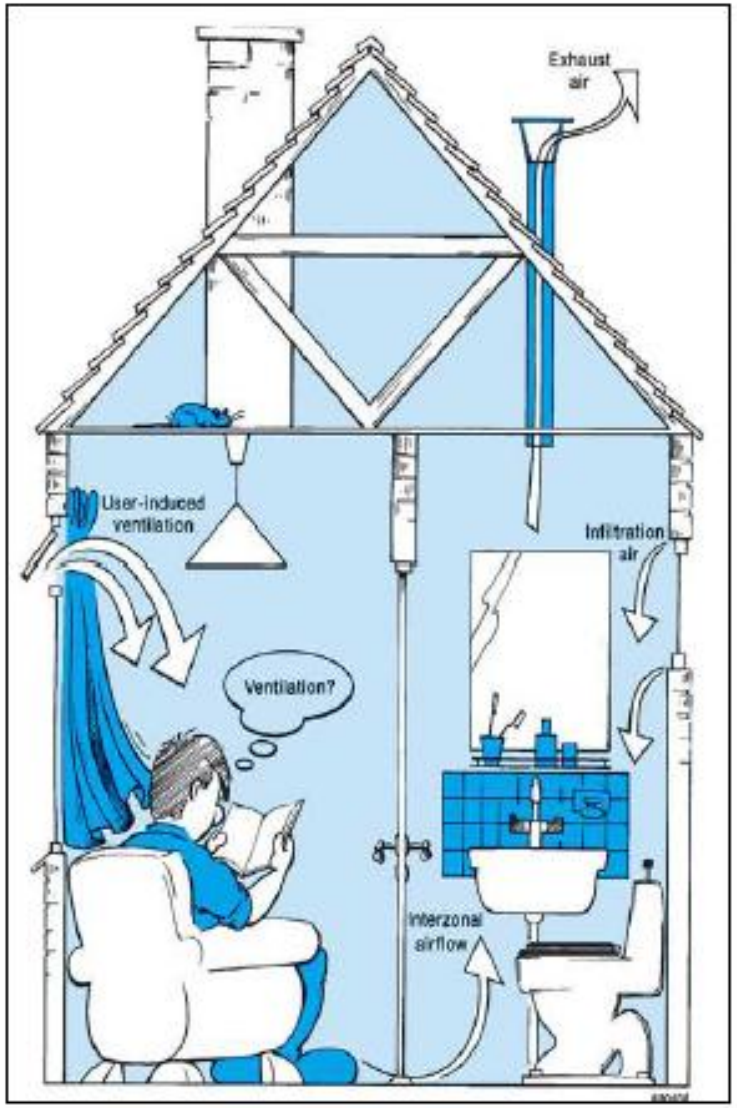
Exposure to poor air quality (high concentration of pollutants such as bioaerosols) can lead to pathogenic aspects such as irritated eyes, headaches, heavy breathing, nausea, vertigo, fadigue, lethargy, sore throat and memory problems.



Indoor Air Quality

Ventilation

The process of supplying outdoor air to or removing indoor air from a dwelling in order to control the pollutant levels, humidity or temperature (ASHRAE 62).



Indoor Air Quality

Ventilation

The time spent indoor influences the exposure to a certain pollutant

Exposure = **Concentration** x **Time**

The exposure risk is well established for some chemicals and depends on the occupant (children, elderly, asthmatic, chronic disease, immuno-suppressed individuals).

Indoor Air Quality

Contaminant sources

Sources	Contaminants / pollutants
Construction materials and indoor equipment Human emissions Equipment Cleaning Combustion External sources	Carbon dioxide (CO_2) Carbon monoxide (CO) Volatile Organic Compounds (VOCs) Formaldehyde Radon Airborne particulate matter (PM) Microbial pollutants

Indoor Air Quality

Ventilation rates

Air with known contaminants below dangerous concentrations (as established by local authorities) and with the majority of exposed persons satisfied (percentage of dissatisfied, PD < 20%).

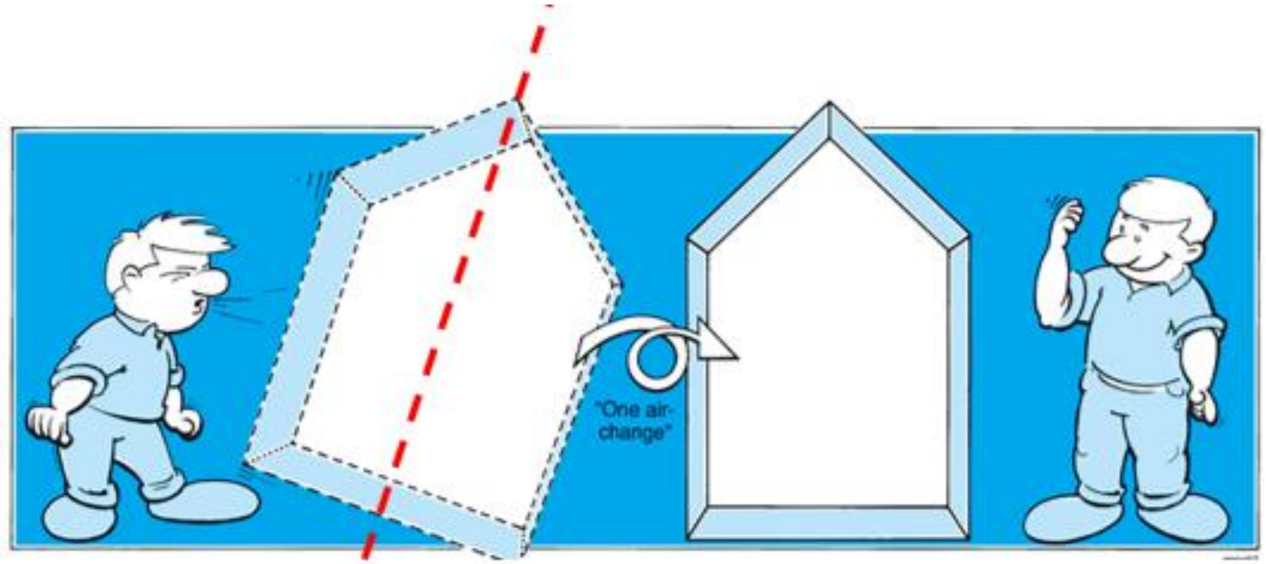
Ventilation rates can be provided in different measurement units:

- Volumetric flow rate per person [l/(s px)]
- Volumetric flow rate per area [l/(s m^2)]
- Air changes per hour (ACH) or air change rate (ACR)

Indoor Air Quality

Air Change Rates

Air changes per hour (ACH) or air change rate (ACR)

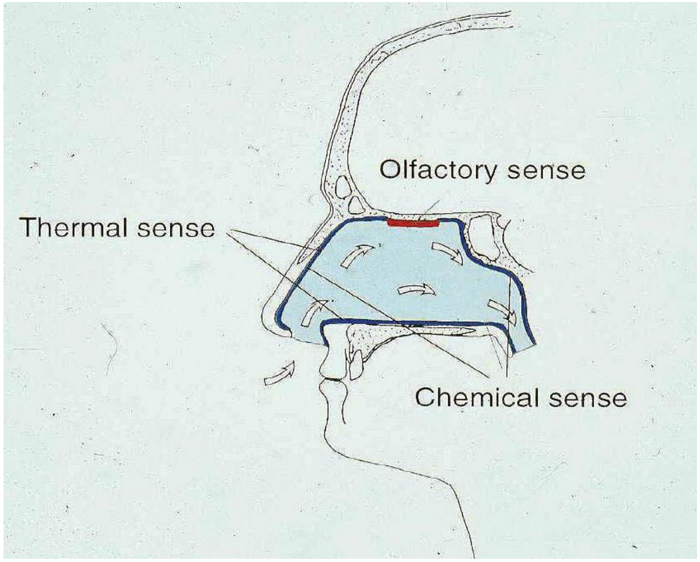


$$ACR\ [h^{-1}] = \frac{q_v\ \left[\frac{m^3}{h}\right]}{V\ [m^3]}$$

Indoor Air Quality

Sensing air pollution

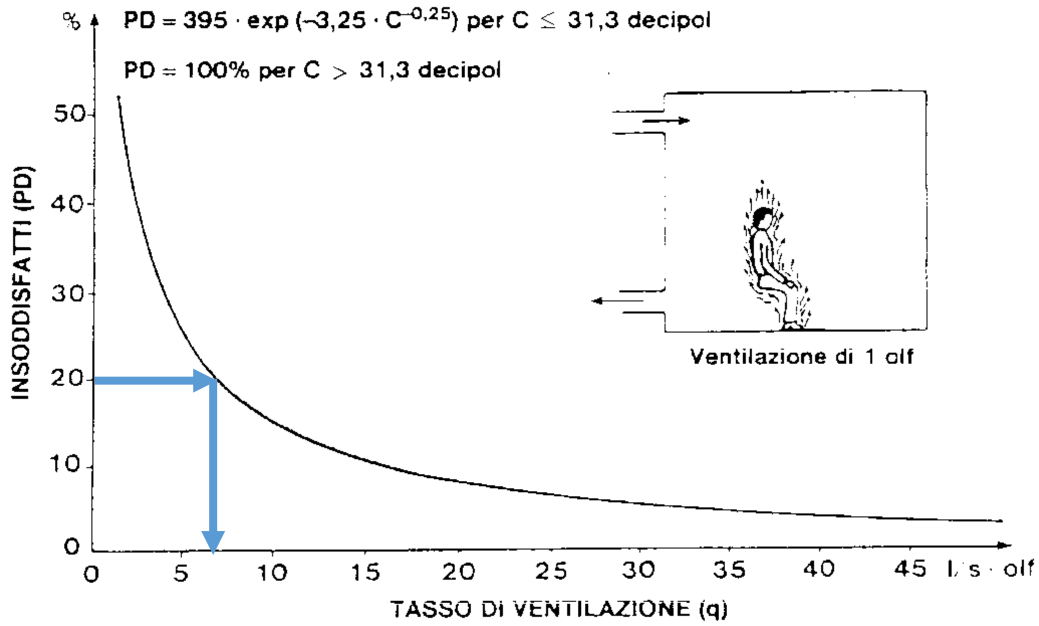
Smells are composed of a large number of different substances and we interpret the varying signals from our receptors as specific scents through the olfactory sensory neurons in our noses.



Indoor Air Quality

Recommended ventilation rates

Ventilation rates should be aimed at reducing the percentage of people dissatisfied with the perceived air quality.



Indoor Air Quality

Recommended ventilation rates

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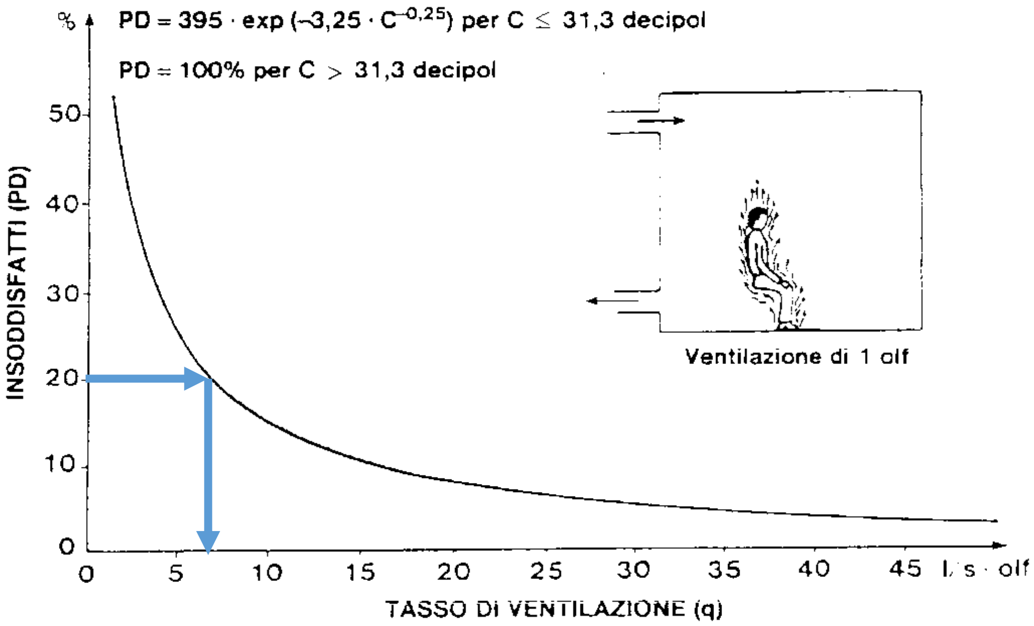


Classical comfort theory

PD = 20% → 7 l/(s px)

PD = 15% → 10 l/(s px)

PD = 10% → 15 l/(s px)

PD = 5% → 25 l/(s px)

Indoor Air Quality

Recommended ventilation rates

In Italy the reference standard was UNI 10339 which indicated 10 l/(s px) as suggested flow rate. Usually the lowest limit is 6 l/(s px).

Classical comfort theory

PD = 20% → 7 l/(s px)

PD = 15% → 10 l/(s px)

PD = 10% → 15 l/(s px)

PD = 5% → 25 l/(s px)

Indoor Air Quality

Adaptive comfort theory

The previous values consider external persons who evaluate the environment by means of olfactory analysis.

If the olfactory analysis is done by persons living inside the room (namely adapted persons), the percentage values of dissatisfied persons can be considered 1/3 of the previous suggested values.

Indoor Air Quality

Recommended ventilation rates

If the olfactory analysis is done by persons living inside the room (namely adapted persons), the percentage values of dissatisfied persons can be considered 1/3 of the previous suggested values.

Adaptive comfort theory

PD = 20% → 2.5 l/(s px)

PD = 15% → 4 l/(s px)

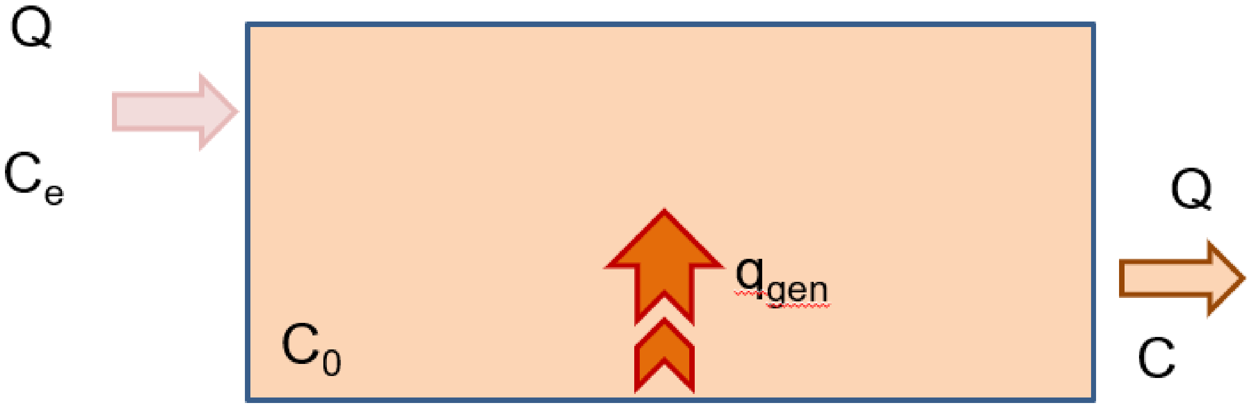
PD = 10% → 7 l/(s px)

PD = 5% → 10 l/(s px)

Indoor Air Quality

Pollutant concentration

The concentration of a pollutant in a limited space as a room, container, tank etc. depends on:



Q: fresh air flow rate [m^3/h]

q_{gen}: contamination rate [l/h]

C_0 : initial concentration [ppm]

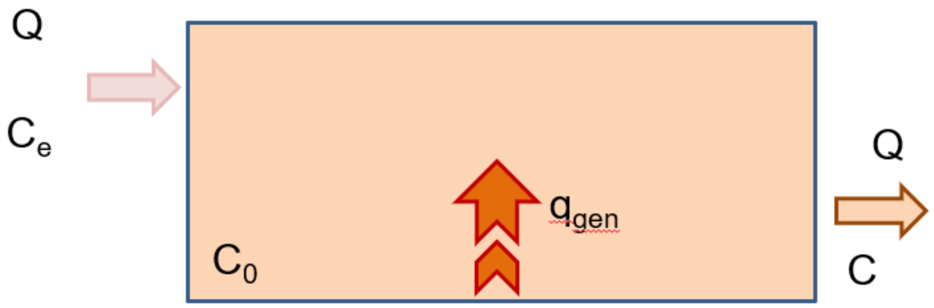
C_e : outdoor concentration [ppm]

Indoor Air Quality

Pollutant concentration

The concentration of a pollutant in a limited space as a room, container, tank etc. evaluated in steady state conditions:

$$\boldsymbol{C}[ppm] = \boldsymbol{C_e}[ppm] + 10^3 \frac{\boldsymbol{q_{gen}}\,[l/h]}{\boldsymbol{Q}\,[m^3/h]}$$



C_e : outdoor concentration [ppm]

Q: fresh air flow rate [m^3/h]

q_{gen}: contamination rate [l/h]

Indoor Air Quality

Pollutant concentration

CO_2 is the most common pollutant to assess IAQ .

q_{gen} →
- 12 l_{CO2}/(h px) in rest
- 18 l_{CO2}/(h px) in sedentary activity

$$\boldsymbol{C}[ppm] = \boldsymbol{C_e}[ppm] + 10^3 \frac{\boldsymbol{q_{gen}}\ [l/h]}{\boldsymbol{Q}\ [m^3/h]}$$

Indoor Air Quality

Pollutant concentration: Example 1

Office 4 m x 4 m x 3 m with 4 occupants

Estimate the concentration of CO_2.

$$\boldsymbol{C}[ppm] = \boldsymbol{C_e}[ppm] + 10^3 \frac{\boldsymbol{q_{gen}}\,[l/h]}{\boldsymbol{Q}\,[m^3/h]}$$

Hyp. 1: Q = 10 l/(s px) = 36 m^3/(h px)

Q = 36*4 = 144 m^3/h

V = 4*4*3 = 48 m^3 → ACR = Q/V = 144/48 = 3 h^{-1}

q_{gen} = 4*18 = 72 l/h

C_e = 420 ppm → C = 420 + 1000*72/144 = 420 + 500 = 920 ppm

Indoor Air Quality

Pollutant concentration: Example 1

Office 4 m x 4 m x 3 m with 4 occupants

Estimate the concentration of CO_2.

$$\boldsymbol{C}[ppm] = \boldsymbol{C_e}[ppm] + 10^3 \frac{\boldsymbol{q_{gen}}\,[l/h]}{\boldsymbol{Q}\,[m^3/h]}$$

Hyp. 2: Q = 4 l/(s px) = 14.4 m^3/(h px)

Q = 14.4*4 = 57.6 m^3/h

V = 4*4*3 = 48 m^3 → ACR = Q/V = 57.6/48 = 1.2 h^{-1}

q_{gen} = 4*18 = 72 l/h

C_e = 420 ppm → C = 420 + 1000*72/57.6 = 420 + 1250 = 1670 ppm

Indoor Air Quality

Pollutant concentration: Example 2

Apartment 9.5 m x 10 m x 2.7 m with 4 occupants

Estimate the concentration of CO_2.

$$\boldsymbol{C}[ppm] = \boldsymbol{C_e}[ppm] + 10^3 \frac{\boldsymbol{q_{gen}}\,[l/h]}{\boldsymbol{Q}\,[m^3/h]}$$

Hyp. 1: Q = 10 l/(s px) = 36 m^3/(h px)

Q = 36*4 = 144 m^3/h

V = 9.5*10*2.7 = 256 m^3 → ACR = Q/V = 144/256 = 0.56 h^{-1}

q_{gen} = 4*15 = 60 l/h

C_e = 420 ppm → C = 420 + 1000*60/144 = 420 + 416 = 836 ppm

Indoor Air Quality

Pollutant concentration: Example 2

Apartment 9.5 m x 10 m x 2.7 m with 4 occupants

Estimate the concentration of CO_2.

$$C[ppm] = C_e[ppm] + 10^3 \frac{q_{gen}\ [l/h]}{Q\ [m^3/h]}$$

Hyp. 2: Q = 4 l/(s px) = 14.4 m^3/(h px)

Q = 14.4*4 = 57.6 m^3/h

V = 9.5*10*2.7 = 256 m^3 → ACR = Q/V = 57.6/256 = 0.22 h^{-1}

q_{gen} = 4*15 = 60 l/h

C_e = 420 ppm → C = 420 + 1000*60/57.6 = 420 + 1040 = 1460 ppm

Indoor Air Quality

Pollutant concentration

The concentration of a pollution in a limited space as a room, container, tank etc. evaluated in dynamic conditions:

$$\boldsymbol{C}(\tau) = \underbrace{\boldsymbol{C_e} + 10^3 \frac{\boldsymbol{q_{gen}}}{\boldsymbol{Q}}}_{\text{Steady-state concentration}} + \underbrace{\left(\boldsymbol{C_0} - \boldsymbol{C_e} - 10^3 \frac{\boldsymbol{q_{gen}}}{\boldsymbol{Q}}\right) e^{-n\tau}}_{\text{Dynamic term (conc. increase / drop over time)}}$$

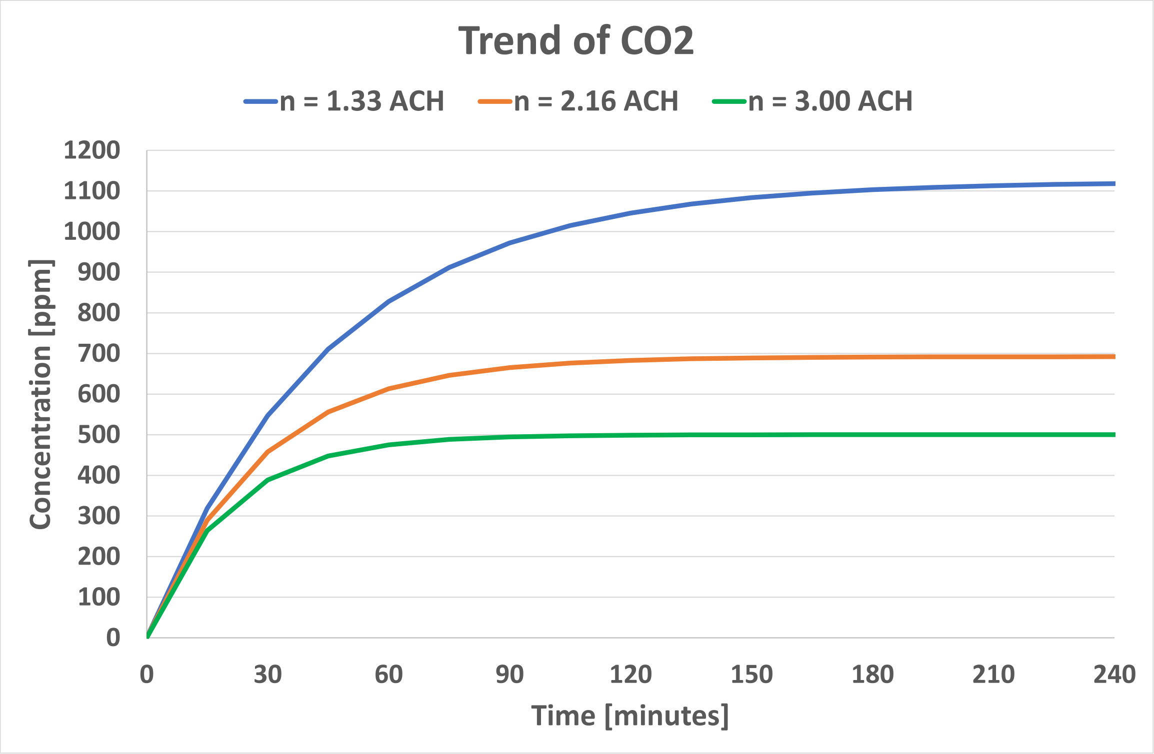
Steady-state concentration

Dynamic term
(conc. increase / drop over time)

Indoor Air Quality

Pollutant concentration: Example 3

4 emploees entering the 48 m^3 office



Indoor Air Quality

Pollutant concentration: Example 4

4 occupants leaving their home (256 m^3 apartment)