IAQ and ventilation criteria

The environmental quality

- **Thermal comfort**
- **Indoor Air Quality**
- **Noise control**
- **Visual comfort**

Health, comfort and people productivity

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EUROPEAN DIRECTIVE EPBD (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.

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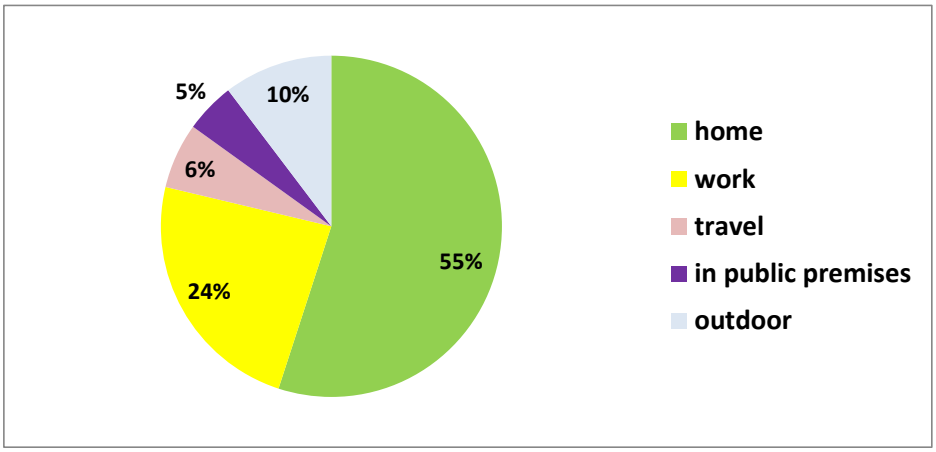
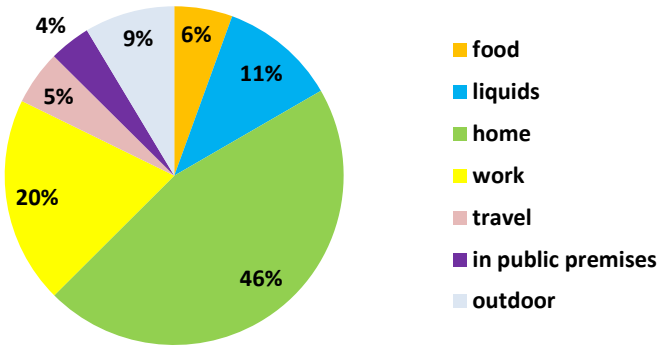
INDOOR - OUTDOOR

- The highest exposure: indoor environment
- People spend ~90 % of the time indoor (work, travel, home)



Average intake for one person per day:

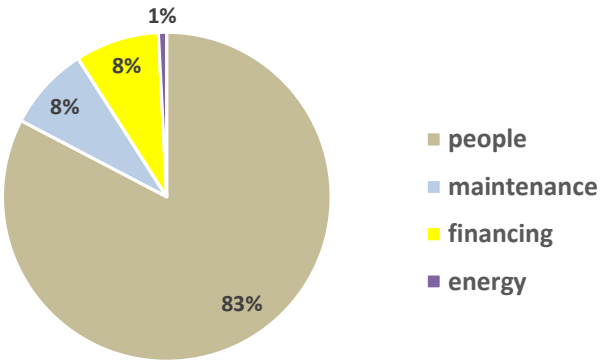
- 1 kg FOOD
- 2 kg LIQUIDS
- 15 kg AIR



Importance of the air:

Survival time:
4-6 weeks without food
Few days without liquids
Few minutes without breathing

BUDGET IN A COMPANY PROVIDING SERVICES



Increasing the energy costs by 20% leads to +0.2% of overall costs

Increasing efficiency of people by 5% leads to -4.3% of overall costs

IAQ: health and comfort

- Pathogenic aspects
  - Acute
  - Long term

  } **health**

- Disturb (Perceived Air Quality – PAQ)
  - Odor
  - Irritation

  } **comfort**

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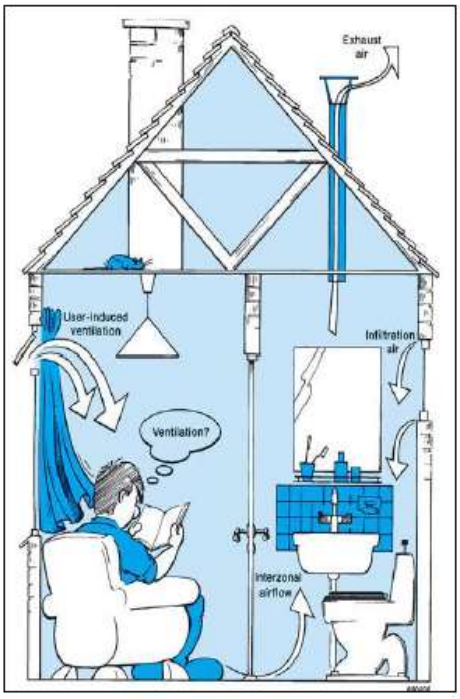
Too much enphasis on IEQ?

Sick Building Syndrome

- ✓ Irfritated eyes
- ✓ Headaches
- ✓ Breathe heavily
- ✓ Nausea, vertigo
- ✓ Fadigie, lethargy
- ✓ Sore throat
- ✓ Memory problems

What is 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 (Standard ASHRAE 62)



Why is it necessary to ventilate?

To supply fresh air to limit the concentration of pollutants due to different sources

The time spent indoor influences the exposure to a certain pollutant

Exposure = Concentration x Time

The exposure risk is well established for some chemicals.

The exposure risk is particularly susceptible (children, elderly, asthmatic, chronic desease, immunosuppressed).

Usual contaminant sources

- ✓ emissions from building materials
- ✓ emissions from forniture
- ✓ from finishing materials (paintings, tapestry)
- ✓ VOC
- ✓ formaldehyde
- ✓ asbestos
- ✓ radon
- ✓ microorganisms

Pollutants from building/ environment

- ✓ produced by HVAC system
- ✓ produced by electric applainces
- ✓ combustion products (CO, CO2, NO_x, O_3, …)
- ✓ VOC
- ✓ microorganisms
- ✓ vapour

Pollutants from plants and machines

Indoor Air Quality (IAQ)

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

How much air?

Recommended values

l/(s person)

l/(s area)

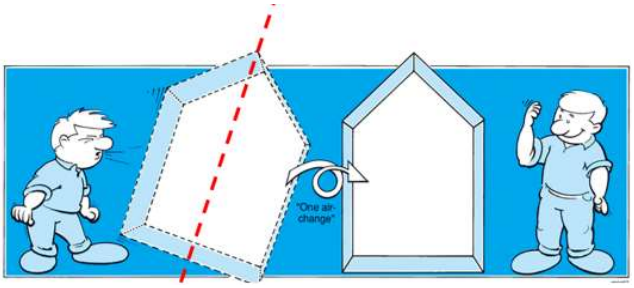
air changes per hour (ACH), air change rate (ACR)

What is the air change rate (ACR or ACH)?

$$n = ACR = \frac{q_v}{V} \quad [h^{-1}]$$

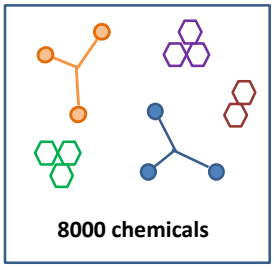
q_v: Air flor rate [m^3 / h]

V: Volume of the room [m^3]

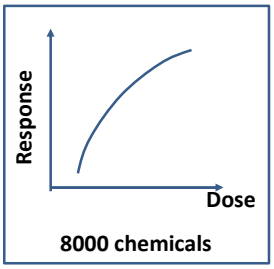


Example: Room of 300 m^3
Flow rate 150 m^3/h
ACR = 150/300 = 0.5 h^{-1}

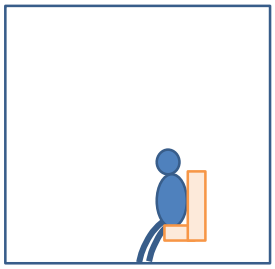
Effect of air on human being



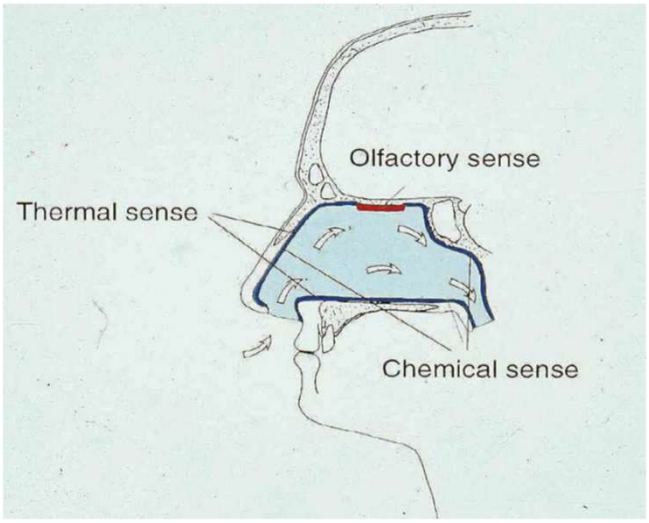
Chemical analysis

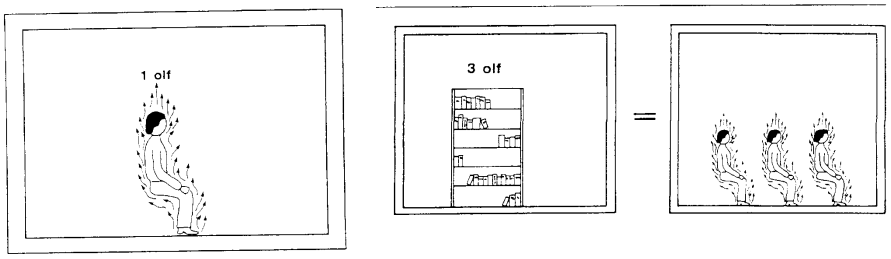


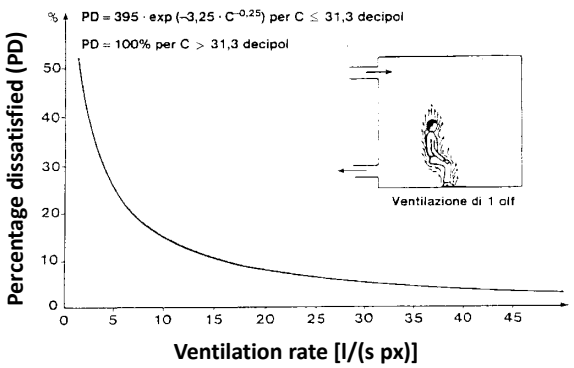
Combination with other 7999 chemicals?



The best indicator for the indoor pollution is the nose (Nobel prize 2004 Richard Axel e Linda B. Buck for their research in the field of «odorant receptor and the olfactory system»)

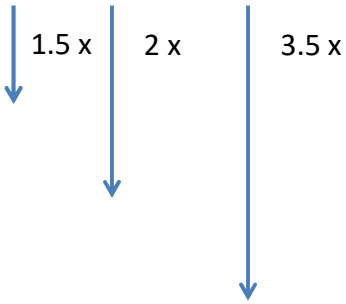






Reference values

- PD = 20% → 7 l/(s px)
- PD = 15% → 10 l/(s px)
- PD = 10% → 15 l/(s px)
- PD = 5% → 25 l/(s px)



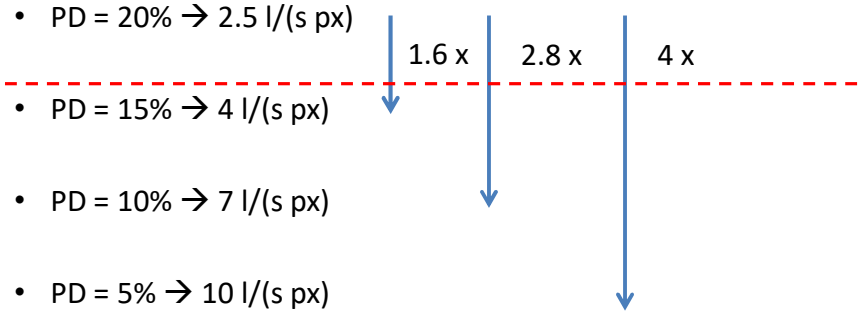
In Italy the reference standard was the UNI 10339 which indicated 10 l/(s px) as suggested flow rate. Usually the lowest limit is 6 l/(s px)

Adapted persons

- The previous values consider external persons who evaluate the environment by means of olfactory analysis
- There are rooms where the olfactory analysis has to be done by persons living inside the room (namely adapted persons)
- In this case the reference value can be considered 1/3 of the previous suggested values

Approximate reference values

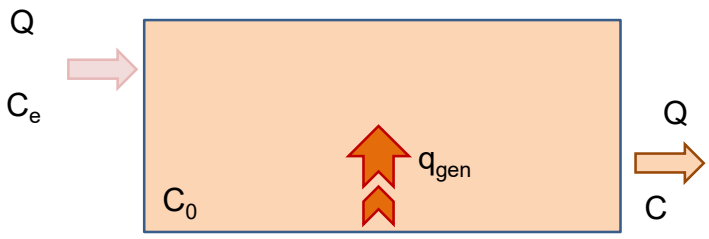
- PD = 20% → 2.5 l/(s px)
- PD = 15% → 4 l/(s px)
- PD = 10% → 7 l/(s px)
- PD = 5% → 10 l/(s px)



Pollutant concentration in rooms

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

- pollution rate in the room (q_{gen})
- amount of fresh supply air (Q)
- initial concentration in the room (C_0)
- outdoor concentration (C_e)



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

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

C_0 : initial concentration [ppm]

C_e : outdoor concentration [ppm]

$$C(\tau) = \underbrace{C_e + 10^3 \frac{q_{gen}}{Q}}_{\text{Steady state conditions}} + \underbrace{\left[C_0 - C_e - 10^3 \frac{q_{gen}}{Q} \right] e^{-(n\,\tau)}}_{\text{Dynamic term}}$$

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

In steady state conditions:

$$C - C_e = 10^3 \frac{q_{gen}}{Q}$$

q_{gen} → 12 l_{CO2}/(h px) in rest

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

Example 1: Steady state in an office

Office:
4 m x 4 m x 3 m (height) = 48 m^3

Occupants: 4 px
CO_2 emitted: 18 l_{CO2}/(h px) = 4 x 18 = 72 l_{CO2}/h

$$C - C_e = 10^3 \frac{q_{gen}}{Q}$$

Q = 36 m^3/(h px): $C - C_e = 10^3 \frac{72}{(36 \times 4)} = 500$ ppm

n = 36 x 4 /48 = 3 ACH

Q = 16 m^3/(h px): $C - C_e = 10^3 \frac{72}{(16 \times 4)} = 1'125$ ppm

n = 16 x 4 /48 = 1.33 ACH

Example 2: steady state in a home

Home:
9.5 m x 10 m x 2.7 m (height) = 256 m^3

Occupants: 4 px
CO_2 emitted: 15 l_{CO2}/(h px) = 4 x 15 = 60 l_{CO2}/h

n = 0.5 Vol/h $Q = 0.5 \times V = 0.5 \times 256 = 128\ m^3/h$

n = 0.3 Vol/h $Q = 0.3 \times V = 0.3 \times 256 = 77\ m^3/h$

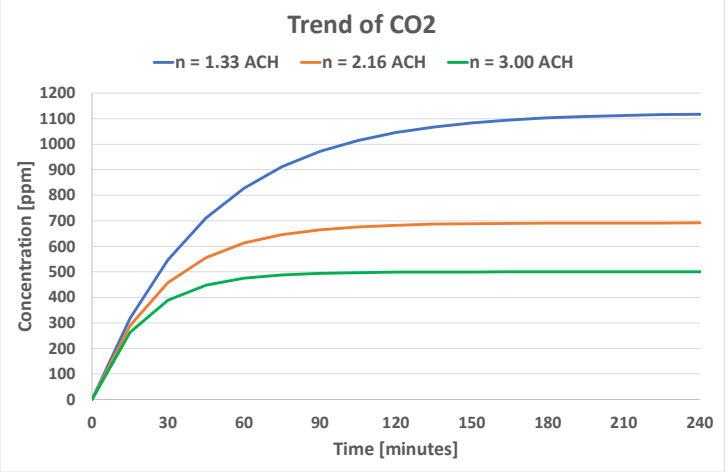
Q = 128 m^3/h $C - C_e = 10^3 \frac{60}{128} = 469$ ppm

Q = 77 m^3/h $C - C_e = 10^3 \frac{60}{77} = 779$ ppm

Example 3: dynamic (increase)

$$C(\tau) - C_e = 10^3 \frac{q_{gen}}{Q} + \left[C_0 - C_e - 10^3 \frac{q_{gen}}{Q} \right] e^{-(n\,\tau)}$$

Office 48 m^3, 4 occupants (72 l_{CO2}/h) entering with $C_0 = C_e$

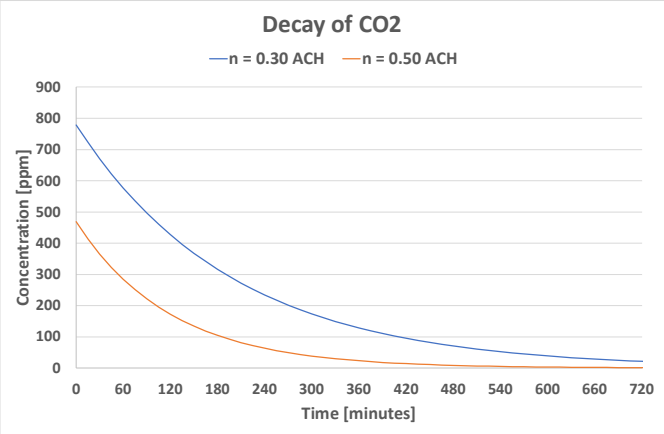


Example 4: dynamic (decrease)

$$C(\tau) - C_e = 10^3 \frac{q_{gen}}{Q} + \left[C_0 - C_e - 10^3 \frac{q_{gen}}{Q} \right] e^{-(n\,\tau)}$$

Example 2 (256 m^3) when the occupants leave their home

$C_0 - C_e = 469$ (if n = 0.50 ACH), $C_0 - C_e = 779$ (if n = 0.30 ACH)



Standard EN 16798-1

- **Replaces the standard EN 15251 of 2006**
- **Energy and IEQ evaluation need to be assessed at the same time**
- **Definition of IEQ parameters in 4 categories:**

Category	Level of expectation
IEQ_I	High
IEQ_{II}	Medium
IEQ_{III}	Moderate
IEQ_{IV}	Low

- **These categoriues define both indoor parameters (temperatures, CO_2 livels, PD, humidity, etc.) and design parameters (ventilation flow rates)**
- **To use in both calculations (design) and operation (monitoring activity)**

Comfort levels EN 16798-1

Category	Thermal state of the body as a whole	
	Predicted Percentage of Dissatisfied PPD %	Predicted Mean Vote PMV
I	< 6	−0,2 < PMV < + 0,2
II	< 10	−0,5 < PMV < + 0,5
III	< 15	−0,7 < PMV < + 0,7
IV	< 25	−1,0 < PMV < + 1,0

IAQ levels EN 16798-1

Category	Corresponding CO_2 concentration above outdoors in PPM for non-adapted persons
I	550 (10)
II	800 (7)
III	1 350 (4)
IV	1 350 (4)

IAQ levels in previous examples:

Office with 36 $m^3/(h\ px)$ = 500 ppm LEVEL 1

Office with 16 $m^3/(h\ px)$ = 1’125 ppm LEVEL 3

Home with 0.5 ACH = 469 ppm LEVEL 1

Home with 0.3 ACH = 779 ppm LEVEL 2

Standard EN 16798-1

- **Definition of fresh air flow rates to size the ventilation system;**
- **Minimum flow rate: 4 L/(s person).**

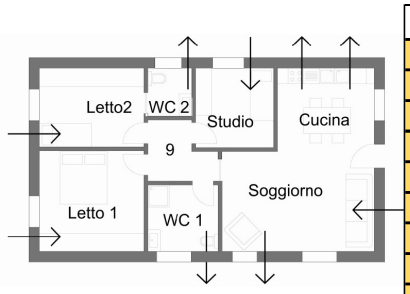
Category	Level of expectation	
I	High	⇨ High level for specific cases (elderly, sick people)
II	Medium	⇨ Medium/average value
III	Moderate	⇨ Lowest admissible value (possible discomfort)
IV	Low	⇨ To be avoided. Tollerated for limited time

For healthy reasons, **the minimum flow rate** in occupied rooms **should never go below 4 l/(s px)**

4 l/(s px) = 14.4 m^3/(h px)

Example: Design flow rate for residential buildings

There are **3 different methods** **as an alternative to one another**.
We will analyse them and we compare the resulting values in a typical dwelling.



N.	Nome	Sup. [m^2]	Vol. [m^3]
1	Soggiorno	22,70	68,10
2	Studio	9,00	27,00
3	CucinaPranzo	11,00	33,00
4	CameraM – Letto 1	15,40	46,20
5	Camera – Letto 2	12,00	36,00
6	WC1	6,80	20,40
7	Bagno	3,20	9,60
8	Disimpegno	5,00	15,00
	TOTALE	**85,10**	**255,30**

METHOD 1 – Flow rate per specific floor area or as ACR

Level	L/(s m²)	h⁻¹ (ach)
I	0,49	0,7
II	0,42	0,6
III	0,35	0,5
IV	0,23	0,4

The values are the same if the height of the room is 2.5 m

Remember that:
Af = 85 m²
Volume = 255 m³

	Resulting flow rate			Flow rate per person L/(s px)			
Level	m³/h			3 persons		4 persons	
I	150	179		13,9	16,6	10,4	12,4
II	129	153		11,9	14,2	8,9	10,6
III	107	128		9,9	11,8	7,4	8,9
IV	70	102		6,5	9,5	4,9	7,1

METHOD 2 – Flow rate per person

Level	Specific flow rates
I	10 l/(s px) - 36 m³/(h px)
II	7 l/(s px) - 25 m³/(h px)
III	4 l/(s px) - 14 m³/(h px)
IV	-

	3 persons	4 persons
Level	m³/h	
I	108	144
II	76	101
III	43	58
IV	-	-

Remember that:
Af = 85 m²
Volume = 255 m³

METHOD 3 – Flow rate as a function of perceived air quality for adapted persons

Level	Q_p – L/(s px)	Q_B – L/(s m²)
I	3,5	0,25
II	2,5	0,15
III	1,5	0,1
IV	-	-

Remember that:
Af = 85 m²
Volume = 255 m³

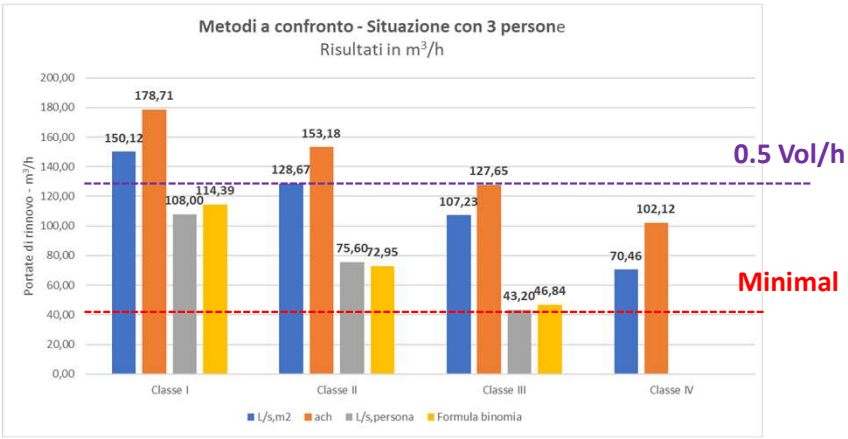
3 persons	Q_p	Q_B	TOTAL
Level	m³/h		
I	37,8	76,6	114
II	27	46,0	73
III	16,2	30,6	47
IV	-	-	

Check: = 4,34 L/(s px) - **OK**

4 persons	Q_p	Q_B	TOTAL
Classe	m³/h		
I	50,4	76,6	127
II	36	46,0	82
III	21,6	30,6	52
IV	-	-	

Check: = 3,63 L/(s px) - **NO**

	Method 1		Method 2	Method 3
	L/(s m²)	ach	L/(s px)	Binomial equation
Classe	m³/h (referred to **3 persons**)			
I	150	179	108	114
II	129	153	76	73
III	107	128	**43**	47
IV	71	102	-	-



	Method 1		Method 2	Method 3
	L/(s m²)	ach	L/(s px)	Binomial equation
Classe	m³/h (referred to **4 persons**)			
I	150	179	144	127
II	129	153	101	82
III	107	128	**58**	52
IV	70	102