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# How buildings can be health promoters

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# INDOOR AIR QUALITY

***Indoor air quality (IAQ) is the air quality within buildings.***

***IAQ affects health, comfort and well-being of building occupants.***

***Poor indoor air quality has been strictly related to Sick Building Syndrome.***

**OUTDOOR AIR < INDOOR AIR**

**INDOOR CONCENTRATIONS – OUTDOOR CONCENTRATIONS =**

**----------**

**INDOOR CONCENTRATIONS related to indoor sources**

*Image from BASF Catalysts*

# INDOOR AIR QUALITY

**Physical factors**
Microclimatic parameters, Radon, Ionizing radiations, non-ionizing radiations, etc.

**Chemical factors**
Volatile Organic Compounds – VOCs (i.e. Benzene, Formaldehyde, etc.), Nitrogen Dioxide, Sulfur Dioxide, Ozone, Polycyclic Aromatic Hydrocarbons, CO, $PM_{10}$, $PM_{2.5}$, ..

**Biological factors**
Fungi, Bacteria, Viruses, Dust mites, Pollens, etc.

# GUIDELINE VALUES in generic ENVIRONMENTS

*Settimo et al., 2017*

| Inquinante unità di misura | OMS aria ambiente | OMS aria *indoor* | Francia | Germania | Paesi Bassi | Regno Unito | Belgio Regione fiamminga | Finlandia *** | Austria | Portogallo | Norvegia | Polonia residen-ziale | Polonia uffici pubblici |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $NO_2$ $\mu g/m^3$ | 200 (1 h)<br>40 (1 a) | 200 (1 h)<br>40 (1 a) | 200 (1 h)<br>40 (1 a) | 350 (30 min) RWI<br>60 (7 gg) RWI | 200 (1 h)<br>40 (1 a) | 300 (1 h)<br>40 (1 a) | 135 (1 h)<br>VI: 200 (1 h) | – | – | – | 200 (1 h)<br>100 (24 h) | – | – |
| Naftalene $\mu g/m^3$ | – | 10 (1 a) | 10 (1 a) | 20 (7 gg) RWI<br>200 (7 gg) RWII | 25 | – | – | – | – | – | – | 100 (24 h) | 150 (8 h) |
| Stirene $\mu g/m^3$ | 260 (7 gg)<br>70 (30 min) | – | – | 30 (7 gg) RWI<br>300 (7 gg) RWII | 900 | – | – | 1 | 40 (7 gg)<br>10 (1 h) | – | – | 20 (24 h) | 30 (8 h) |
| IPA (BaP) $ng/m^3$ | No VG<br>0,012 (UR/lifetime) $10^{-6}$<br>0,12 (UR/lifetime) $10^{-5}$ | No VG<br>0,012 (UR/lifetime) $10^{-6}$<br>0,12 (UR/lifetime) $10^{-5}$ | – | – | 1,2 | 0,25 (1 a) | – | – | – | – | – | – | – |
| Tetracloro-etilene $\mu g/m^3$ | 250 (1 a)<br>8000 (30 min) | 250 (1 a) | 1380 (1-14 gg)<br>250 (1 a)<br>VR: 250<br>LP: 250 dal 1/1/ 2015 | 1 (7 gg) | 250 | – | ≤ 100 | – | 250 (7 gg) | – | – | – | – |

# GUIDELINE VALUES in generic ENVIRONMENTS

| POLLUTANT | GUIDELINE VALUES | | REFERENCES |
|---|---|---|---|
| ACETALHYDE | 160 µg/m$^3$ | 1 year | ANSES (2011) |
| ACETONE | 11,88 µg/m$^3$ | 1 day | ONTARIO MOE (2012) |
| BENZENE | 5 µg/m$^3$ (outdoor) | 1 year | European Directive 2008/50/EC |
| | 2 µg/m$^3$ (indoor) | 1 year | ANSES (2011) |
| CARBON DIOXIDE | 1000 ppm | 1 week | Rapporti ISTISAN 16/15 (2016) |
| CARBON MONOXIDE | 7 mg/m$^3$ | 1 day | WHO (2010) |
| CHLOROFORM | 10 µg/m$^3$ | 1 year | CIDAD-WHO (2004) |
| DICHLOROMETHANE | 450 µg/m$^3$ | 1 week | WHO (2000) |
| ETHYLBENZENE | 220 µg/m$^3$ | 1 year | IPCS – WHO (1997) |
| FORMALDEHYDE | 100 µg/m$^3$ | 30 minutes | WHO (2000) / WHO (2010) |
| | 30 µg/m$^3$ | 1 year (2018) | ANSES (2011) |
| | 10 µg/m$^3$ | 1 year (2023) | ANSES (2011) |
| NAPHTHALENE | 100 µg/m$^3$ | 1 year | WHO (2010) |
| NITROGEN DIOXIDE | 40 µg/m$^3$ | 1 year | WHO (2000) / WHO (2010) |
| PARTICULATE MATTER - PM $_{2.5}$ | 10 µg/m$^3$ (outdoor) | 1 year | WHO (2000) |
| PARTICULATE MATTER - PM $_{10}$ | 20 µg/m$^3$ (outdoor) | 1 year | WHO (2000) |
| POLYCYCLIC AROMATIC HYDROCARBONS | 0,12* µg/m$^3$ (in/out) | 1 year | European Directive 2008/50/EC |
| STYRENE | 260 µg/m$^3$ | 1 week | WHO (2000) |
| TOLUENE | 260 µg/m$^3$ | 1 week | WHO (2000) |
| TETRACHLOROETHYLENE | 250 µg/m$^3$ | 1 year | WHO (2010) |
| TRICHLOROETHYLENE | 800 µg/m$^3$ | 1 year | ANSES (2011) |
| XYLENE m,p,o | 870 µg/m$^3$ | 1 year | IPCS – WHO (1997) |
| * Missing currently a specific guideline value, the value refers to the Unit Risks defined by European Authorities | | | |

# FACTORS that AFFECT INDOOR AIR QUALITY in INPATIENT ROOM

Gola et al. 2019

# FACTORS that AFFECT INDOOR AIR QUALITY in INPATIENT ROOM

## OUTDOOR and MICROCLIMATIC FACTORS

## MANAGEMENT and CLEANING ACTIVITIES

# FACTORS that AFFECT INDOOR AIR QUALITY in INPATIENT ROOM

## HUMANS and MEDICAL ACTIVITIES

(Qian et al. 2006 and 2008)

(Alocer 2017)

(Qian et al. 2010)

(Kaushal et al. 2015)

## DESIGN FACTORS

| | Wall surface in hospital room | | |
|---|---|---|---|
| | Painted | Oak | Birch |
| Aliphatic hydrocarbons | 7.8 | 7.6 | 8.1 |
| Aromatic hydrocarbons C6–C10 | 4.3 | 5.8 | 4.0 |
| Carboxylic acids | 26.5 | 37.4 | 30.5 |
| Terpene hydrocarbons | 8.8 | 7.0 | 3.4 |
| Aldehydes | 22.0 | 22.2 | 16.3 |
| α-Pinenol | 36.4 | 36.6 | 37.8 |
| Sum of VOCs | 137.1 | 149.7 | 130.2 |

(Wyon et al. 2012)

(Wu et al. 2017)

(Nadeem et al. 2016)

Anti-pollutant and antibacterial materials

# FACTORS that AFFECT INDOOR AIR QUALITY in INPATIENT ROOM

| *criterion* | *field of interest* | *influence* |
|---|---|---|
| **design factors** | they refer to all the components that characterize the inpatient room (room dimensions, furniture, finishing, etc.) | **their emissions are constant**, although in relation to their life the emissions may **decrease over the time** |
| **management and cleaning activities** | they refer to the management and maintenance activities, ventilation systems, cleaning and disinfectant activities, etc. carried out in the room and in the functional units/entire building | they can highly affect the indoor air, but their **emissions can be controlled** through the **applications of strategies**, and in the same time, they can be changes if their actions are dangerous for users |
| **human presence and activities** | they refer to the presence of users, their health status, and the medical activities carried out in the inpatient room | their presence and application can vary, and therefore they can affect the indoor air in different modes. In general this component does **not affect highly the indoor air performances** |
| **outdoor and microclimatic factors** | they refer to the outdoor air, the solar exposure and microclimatic parameters | although these factors can vary, they have a **great influence on the indoor air and the performances of materials** in the room and air fluxes |

# Other frontiers

## SIMULATIONS in INPATIENT ROOM

(Zhu et al. 2017)

(Omrani et al. 2013)

(Lopez et al. 2019)

## MONITORING ACTIVITIES

# PROCEDURES for AIR MONITORING

For the definition of a sampling strategy for air monitoring in confined environments, **it is necessary to clarify the purposes (what, where, when, how often and period of time the monitoring is performed)**.
These aspects depend on **a number of environment-specific features, monitoring aims, and detected environments.**
Sampling methods vary depending on the type of pollutant to be analysed.
They can be subdivided into **active, passive and canister samplings.**

| Parameters | Average concentration | Maximum concentration |
|---|---|---|
| **Temperature** | | |
| | Normal conditions | Normal conditions |
| **Relative humidity** | | |
| | Normal conditions | Normal conditions |
| **Users' occupancy** | | |
| | Normal occupancy | Maximum occupancy |
| **Ventilation system** | | |
| Before the monitoring | Normal condition | No ventilation system<br>door and windows close |
| During the monitoring | Normal condition | No ventilation system<br>door and windows close |
| | | |
| | | |
| **Samplers' positioning** | | |
| | In the center of the room<br>1-2 m of height | Near the activity<br>1 m from the source |
| **Monitoring frequency** | | |
| | In relation to the aims and scope<br>1 during summer season<br>1 in winter one | During the activities |
| **Monitoring duration** | | |
| | > 1 day | 30 – 60 min |
| **Monitoring activity** | | |
| Preliminary analysis | 1 in summer season<br>1 in winter season | 1 in summer season<br>1 in winter season |
| Compliance monitoring | 2 in summer season<br>2 in winter season | 2 in summer season<br>2 in winter season |

# PROCEDURES for AIR MONITORING

# Dacalogue

| [illegible] | [illegible] |
|---|---|
| LOCALIZATION of the HOSPITAL and INPATIENT ROOM | [illegible] |
| HOSPITAL ROOM | [illegible] |
| BIOMECHANICAL PARAMETERS | [illegible] |
| VENTILATION SYSTEMS | [illegible] |
| MATERIALS and FINISHING | [illegible] |
| FURNITURE and EQUIPMENT | [illegible] |
| CLEANING PRODUCTS and ACTIVITIES | [illegible] |
| MAINTENANCE ACTIVITIES | [illegible] |
| MANAGEMENT ACTIVITIES | [illegible] |
| USERS and VISITORS | [illegible] |

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# Useful references


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