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Indoor Air Quality in Healthcare Facilities



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Foreword: Improving the Hospital's Indoor Air Quality

Among hospitals-related health risks, environmental factors play a key-role; this accounting for different rooms' specific use, patients' vulnerability and risk of overcrowding. For these reasons, air quality control in hospitals—and in healthcare facilities—in general—deserves scientific attention. This collection of papers offers a multidisciplinary perspective on the topic, starting from presenting the general concepts of indoor air quality, chemical, biological and physical risk factors in living and working places, then describing the most effective preventive measures that can (and must!) be implemented in order to ensure users' safety and adverse events' reduction and including healthcare-associated infections (HAIs).

General Concepts of Indoor Air Quality

The indoor air quality is an issue of growing scientific interest both because the risks due to exposure to air pollution in indoor environments become more evident and—also stated by WHO—of improving public health and quality of life (Settimo and D'Alessandro 2014). The European Union and more specifically the European Environmental Agency (EEA) highlighted, in the reports “*Environment and Human Health*” and “*Environmental Signals 2013*”, that indoor pollution levels are affected by air quality, materials, rooms' ventilation, type of furniture, equipment and products, occupants' habits (including passive smoking) and the overall building management (European Commission 2014). The introduction of measures for energy saving also had a great importance, sometimes able to negatively influence several parameters that affect the health and well-being of occupants (Santarsiero et al. 2014; Signorelli et al. 2016).

The Italian Ministry of Health, with the Regions and the Autonomous Provinces, by the agreement of the September 27, 2001, have defined confined indoor “spaces and workplaces as non-industrial environments, such as housing, public and private

offices, community facilities (hospitals, schools, barracks, hotels, banks, etc.), spaces for recreational and social activities (cinemas, cafés, restaurants, shops, sports facilities, etc.) and public and private transport (car, train, plane, ship, etc.)” (Italy 2001). In 2013, the European General Directorate for Environment in the report “*Cleaner Air for All*,” stated that the indoor air quality requires a specific policy response to the EU’s broader strategy on air quality. The same document suggested valid options that are very expensive, such as the improvement of construction and ventilation systems, as well as buildings’ monitoring (European Commission 2014).

Currently, some European countries, such as France, Germany, The Netherlands, UK, Belgium, Finland, Austria, Portugal and Norway have already introduced regulations regarding indoor pollutants for environmental and hygienic assessments. In this context, the WHO activities are of great utility, realizing for the first time guidelines, at the European level, regarding indoor air quality with reference to nine specific atmospheric pollutants present in confined environments: benzene, formaldehyde, carbon monoxide, nitrogen dioxide, radon, trichlorethylene, tetrachlorethylene, naphthalene and aromatic polycyclic hydrocarbons (WHO 2010).

Also the work done by technical committees, such as the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN), is of particular relevance: they have undertaken developments of specific standardized methods with which to carry out the measurements in indoor environments. In particular, the norm “*EN ISO 16000: Air in confined environments*” is constituted by several specific parts; many of these have been adopted in Italian Organization for Standardization (UNI), and this is a further advancement than previously realized.

Even in Italy, the awareness on indoor issues has grown significantly, and in recent years, several technical committees and research groups have worked on this topic, but they still have not developed a framework law on indoor air quality, and therefore, the reference is the Legislative Decree No. 81/2008 regarding too general workplaces’ safety (Settimo and D’Alessandro 2014). The scientific community has been concerned specifically with this issue since 1990, when the first National Commission for pollution of indoor environment was established. The National Study Group on Indoor pollution, sponsored by the *Istituto Superiore di Sanità* (National Institute of Health, ISS), is working to provide shared technical and scientific documents, with the aim to promote common strategies at the national level, waiting for the framework law.

Currently, there are numerous organizations that are trying to improve the knowledge on indoor air quality’s issues and to set priorities or objectives to be achieved. However, all of them tend to draw results concerning generic confined environments and not specific ones, such as healthcare facilities, that ought to have priority because of the vulnerability of their users and their health conditions, and

because they are characterized by particular pollutants related to specific activities as disinfectants, cytotoxic, anesthetic gases, etc. (Capolongo et al. 2015).

The Air Quality in Hospitals

To get a good quality within healthcare facilities, in addition to satisfying acoustic, visual, psychological and social comfort, the thermal comfort should be ensured and, especially, the air quality and the absence of environmental risk factors that represent the first requirement for quality and safety. The indoor air quality is influenced by the presence of biological and chemical contaminants that do not occur naturally in outdoor air, which modify its composition altering the quality.

The requirements of the air quality in healthcare facilities vary by health function and often even from room to room in relation to its use. Some areas, such as operating rooms, intensive care units, and isolation rooms, require a high efficiency filtration for protecting patients, staff and visitors, while other areas require the elimination of substances gaseous contaminants, chemical ones and odors to provide a more safe and pleasant workplace.

Indoor air quality in healthcare facilities is a growing concern resulting from changes in medical activities, the obsolescence of the structures and the presence of vulnerable users. The design of these architectures and their organization must be set up in order to meet their primary role, i.e. the health of occupants.

In order to reach an adequate air quality, a primary aspect is the hospital localization that must be as far away from pollution sources, such as factories, traffic congestion, parking lots, and waste deposits. Two other important features are the adequate design of façades and ventilation systems (HVAC). Moreover, the control of airborne microorganisms is crucial in hospitals' indoor spaces because the air can represent an important vehicle of infections (Pasquarella et al. 2008, 2012). In hospitals, where the microclimate control is associated with a strong need for sterilization, it is necessary to introduce air conditioning systems which, if poorly designed, managed and maintained, can become a source of indoor air contamination by themselves. In fact, many studies on air quality in artificial air-conditioned buildings showed an increasing focus on those diseases well known as *Sick Hospital Syndrome* (Cabo Verde et al. 2015).

Many disorders, such as allergies and irritations, up to pathological forms and respiratory infections, can arise from the presence of contaminants in the air, such as the well-known *Legionella pneumophila*, within cooling towers and various sections of HVAC systems (Montagna et al. 2014). Among the components of the air system, for which specific performance levels relating to air quality must be verified, air ducts are crucial because they convey the replacement of air towards

the healing environments with levels of purity and quantity, such as to reach conditions of comfort.

Conclusions

Currently, ISS is carrying out various reports, according to WHO recommendations. Among the national scientific societies, the *Società Italiana di Igiene* (Italian Society of Hygiene, Preventive Medicine, and Public Health, S.It.I.), and especially the working groups GISIO (Italian Group of Hospital Hygiene Studio) and “*Building Hygiene*” are working and collaborating with several research groups contributing to national and international calls on these relevant issues. This volume aims to provide a number of contributions on indoor air quality in hospitals and in other health facilities where a picture of the current situation is drawn, that is inherent both to the main indoor pollutants, their sources and the risks they generate in hospitals, and, with regards to the comparison between the main international and national legislation and research activities on air quality, on thermal comfort, pollutants concentration and monitoring parameters.

In light of these considerations and currently lacking specific regulatory performance tools for healthcare facilities, this collection of contributions presents through a multidisciplinary approach, practical considerations on the adequate choice of hospital construction site, building materials, finishing and furniture, cleaning products and maintenance activities and up to management strategies. The intent is therefore to provide clear information of proven scientific evidence to all the stakeholders.

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Abbreviations

ACGIH	American Conference of Governmental Industrial Hygienists
AHU	Air Handling Unit
AIA	Associazione Italiana di Aerobiologia (Italian Association of Aerobiology)
AIRMEX	European Indoor Air Monitoring and Exposure Assessment Project
AIRP	Associazione Italiana di Radioprotezione (Italian Radiation Protection Association)
AMAS	Active Microbial Air Sampler
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BRI	Building-Related Illness
BTEX	Benzene exposure, Toulene, Ethylbenzene and Xylene
CDC	Centers for Disease Control
CEI	Comitato Elettronico Italiano (Italian Electronic Committee)
CEN	Comité européen de normalisation (European Committee for Standardization)
CFU	Colony Forming Unit
CTI	Comitato Tecnico Italiano (Italian Technical Committee)
DEFRA	Department for Environment, Food & Rural Affairs
DNPB	Dinitrophenylhydrazin
EC	European Commission
ECA	European Collaborative Action
ECA-IAQ	European Collaborative Action—Urban Air, Indoor Environment and Human Exposure
EDC	Endocrine Disrupting Chemical
EEA	European Environmental Agency
ENHIS	Environment and Health Information System
EnVIE	Indoor Air Quality and Health Effect
EPA	Environmental Protection Agency