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SUSTAINABLE INDOOR AIR QUALITY (IAQ) IN HOSPITAL BUILDINGS

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Abstract

In the past decade, a growing interest of scientific researches has indicated that the air within the buildings can be more seriously polluted than the outdoor air. Indoor pollution has increased due to variety of factors including the construction of more tightly sealed buildings, the use of synthetic finishes and furnishings, and the use of chemically formulated personel care products. The presence of the sources that release gases or particles into the air are the main causes of indoor pollution in buildings, and in this context in hospital buildings. The indoor pollution bounds the indoor air quality (IAQ). To identify sustainable IAQ of the hospitals, the determinants of IAQ such as "indoor pollutants", "indoor pollutant sources", "indoor pollutant removal mechanisms", and "the health effects of indoor pollutants" are discussed within the context of indoor pollution in the current paper. Furthermore, a comprehensive approach to hospital building design dealing with the sustainability criteria from cradle to grave process is presented.

1. Introduction

In the past decade, most of building designers are involved in "sustainable building design" in response to user requirements. Some designers initate "sustainable desgns" based on their own recognition of the need for reducing human impacts on the local and global environment. Designing buildings with low environmental impacts are both a necessary and a challenging part of building designers work nowadays. The challenging opportunity facing designers today is to implement the measures in the context of a "sustainable building design" [1]. The goal of sustainable building design is to find architectural solutions [2,3] which prevent the building related environmental impacts listed in the following [4]:

- Global Warming
- Stratospheric ozone depletion
- Acidification
- Nutrification
- Human toxicity
- Eco-toxicity
- Depletion of sources
- Photochemical oxide formation
- Habitat deterioration
- Water pollution
- Soil pollution
- Air pollution (Indoor/outdoor)

One of the architectural solutions in order to remove building related environmental impacts listed above is to prevent indoor air pollution in all types of buildings by sustainable design criteria. Indoor air pollution is one of the risks to our health as we go about our day-to-day lives. In the last several years, scientific researches have indicated that the air within the buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities. The researchers indicate that people spend approximately 90 percent of

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their time indoors [5, 6]. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors. Over the past several decades, exposure to indoor air pollution has increased due to variety of factors, including the construction of more tightly sealed buildings, the use of synthetic finishes and furnishings, and the use of chemically formulated personnel care products [7]. In order to decrease these factors, it is important to determine the design consideration of indoor air quality (IAQ) within the context of sustainability.

2. Sustainable Indoor Air Quality

Good indoor air quality (IAQ) enhances occupant health, comfort and workplace productivity [8]. According to sustainable design criteria, the designers should undertake overall design consideration of IAQ from cradle to grave [9-11] process with the function of spaces, finishes and furnishings, building equipment (machines and appliances), occupants, and occupant activities, and maintenance in buildings. This process consists of three phases: before usage, usage, and after usage.

One of the major causes of IAQ problems is pre-occupancy of buildings "before usage phase [12]". Buildings are occupied before construction is complete, related to installation of finishes and furnishings, or testing and adjusting of heating, ventilation, and air conditioning (HVAC) systems [13] of the building. The IAQ problems which may occur during the curing of new products and the verification of a properly functioning ventilation system should be avoided.

The building designers must document the operating procedures by preparing operational schedules about the use of the building for the operators of the building in the "usage phase [14]". These schedules must be adequate not only to control thermal conditions but also to remove pollutants accumulated during the usage of the building. The buildings require maintenance periodically in order to remove pollutants. Neglected or deferred maintenance is often the source of IAQ problems. Maintenance consists of inspection, repair and cleaning processes. The building design should provide access to all components of HVAC systems for these processes. Cleaning of surfaces, especially periodic control of accumulated dust from concealed surfaces above a suspended ceiling is essential. In order to remove the accumulated emissions, the maintenance involves the application of chemicals such as cleansers, waxes, disinfectants, air fresheners, adhesives, drain cleaners, vacuuming, paints and coatings, solvents, pesticides, or lubricants. Vertical fabric covered surfaces such as walls or panels should be vacuumed since small, concentrating dust of particles deposit as easily on vertical as on horizontal surfaces.

Construction dust, fumes, and vapors must be contained and not allowed to contaminant building surfaces or the air in occupied spaces during construction "after usage phase [15]". Temporary ventilation and isolation barriers should be employed. When the use of a space or building is significantly changed, it is essential to determine whether the building can support the new activities and occupancy loads. This can be done by reviewing operational schedules, record drawings, and other related documents. If such documents are not available, an engineering assessment should be conducted. It is also essential to take care to avoid contamination of occupied spaces or of surfaces that will remain in use or be reused during demolition when buildings or portions of buildings will be demounted and replaced. [1]

As the IAQ is mentioned from cradle to grave process, this point of view should be acceptable in any type of buildings. In this context the aim of the paper is to provide to better understand indoor air pollution, and to reduce human's exposure to air pollutants in hospital buildings where people go for medical treatment, visit and work. Hospital buildings are complex environments that require specialized pollutant removal mechanisms for the comfort of occupants (patients, visitors, administrative staff, and health staff) to control hazardous emissions [16]. People generally go to hospitals for medical treatment in the cases of minor/ serious illnesses. However, a life-threatening infection could be acquired in hospital buildings that would contradict the purpose of their visits and cause great concern to everyone. In addition, given the appropriate set of circumstances, any patient could acquire an infection, as could hospital visitors or administrative and health staff [17]. In this case, some prevention ways of indoor air pollution should be found.

In order to prevent indoor air pollution, and improve IAQ in hospital buildings the determinants of indoor air quality such as indoor pollutants, pollutant sources, pollutant removal mechanisms and health effects of indoor pollution should be identified first.

3. Determinants of Indoor Air Quality in Hospital Buildings

The indicators of indoor air pollution are the indoor pollutants. For removal of these pollutants, the sources of them must be determined first. The presence of indoor air pollution sources that release gases or particles into the air are the primary causes of IAQ problems in hospital buildings. While pollutant levels from individual sources may not pose a significant health risk by themselves, most hospitals have more than one source that contributes to indoor air pollution. The relative importance of any single source depends on how much pollutant it emits and how hazardous those emissions are [18]. In this case it is important to identify the determinants of IAQ which might be listed as indoor pollutants, indoor pollutant sources, indoor pollutant removal mechanisms, and health effects of indoor pollutants.

3.1. Indoor Pollutants

The provision of thermally comfortable indoor environment for the occupants is only one aspect in achieving better indoor air quality. However, indoor pollutants are other factors that have impact on the quality of indoor air [8]. They are the indicators of indoor air pollution, and one of the determining factors of IAQ. These pollutants are combustion pollutants, biological pollutants, microbial pollutants (fungi, bacteria, viruses), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), formaldehyde, soil gases (radon, sewer gas, methane), pesticides, particles, fibers, asbestos, carbon monoxide, formaldehyde, radon, pesticides, and molds [19-21].

3.2. Indoor Pollutant Sources

The most effective strategy for achieving good IAQ is the source control. The major indoor pollutant sources include function of spaces, finishes and furnishings, building equipment (machines and appliances), occupants and occupant activities, and maintenance. In this context, the indoor pollutant sources commonly found in hospital buildings are identified, and some measures for controlling these sources are offered in Table 1.

Table 1. Indoor Pollutant Sources and Measures for Indoor Pollutant Control

Indoor Pollutant Sources	Measures For Pollutant Control [22]
Function of Spaces in Hospital Buildings	
▪ Print / photocopy shop ▪ Dry cleaning ▪ Science laboratory ▪ Medical office ▪ Cafeteria ▪ Underground/attached garage	▪ Using exhaust ventilation and pressure control ▪ Using exhaust hoods where appropriate ▪ Checking hood airflows ▪ Maintaining garage under negative pressure relative to the building ▪ Checking air flow patterns frequently ▪ Monitoring
Finishes and Furnishings in Hospital Buildings	
▪ Plywood / compressed wood ▪ Construction adhesives ▪ Asbestos products ▪ Insulation ▪ Wall / floor coverings (vinyl / plastic) ▪ Carpets / carpet adhesives ▪ Wet building products ▪ Transformers ▪ Upholstered furniture ▪ Renovation / remodeling	▪ Using low emitting products ▪ Airing out in an open / ventilated area before installing ▪ Increasing ventilation rates during installing and after installing ▪ Keeping materials dry prior to enclosing
Building Equipment (Machines and Appliances) in Hospital Buildings	
▪ Polluted filters ▪ Polluted duct lining ▪ Dirty drain pans ▪ Humidifiers ▪ Lubricants ▪ Refrigerants ▪ Mechanical room	▪ Cleaning drain pans; proper slope and drainage ▪ Using potable water for steam humidification ▪ Keeping duct lining dry; moving lining outside of duct ▪ Fixing leaks / cleaning spills ▪ Maintaining spotless mechanical room ▪ Checking / maintaining flues from boiler to outside ▪ Keeping combustion appliances properly tuned

▪ Maintenance activities ▪ Combustion appliances (boilers /furnaces, generators, stoves)	▪ Disallowing unvented combustion appliances ▪ Performing polluting activities during unoccupied hours
Occupants and Occupant Activities in Hospital Buildings	
▪ Tobacco products ▪ Office equipment (printers, copiers) ▪ Cooking / microwave ▪ Art supplies ▪ Marking pens ▪ Paper products ▪ Personal care products (e.g. perfume)	▪ Using exhaust ventilation with pressure control for major local sources ▪ Lowering emitting art supplies / marking pens ▪ Avoiding paper clutter ▪ Training occupants and staff
Maintenance in Hospital Buildings	
▪ Cleansers ▪ Waxes ▪ Disinfectants ▪ Air fresheners ▪ Adhesives ▪ Janitor's/storage closets ▪ Wet mops ▪ Drain cleaners ▪ Vacuuming ▪ Paints and coatings ▪ Solvents ▪ Pesticides ▪ Lubricants	▪ Using low emitting products ▪ Avoiding aerosols and sprays ▪ Diluting to proper strength (manufacturer's instructions) ▪ Using during unoccupied hours (not overusing) ▪ Using proper procedures when diluting and mixing ▪ Storing properly with containers closed and lid tight ▪ Using exhaust ventilation for storage spaces (eliminating return air) ▪ Cleaning mops ▪ Storing mops dry ▪ Avoiding air fresheners (cleaning and exhausting instead) ▪ Using high efficiency vacuum bags / filters

3.3. Indoor Pollutant Removal Mechanisms

There are some mechanisms in order to prevent indoor pollutants and new indoor air quality problems. These are the removal mechanisms of pollutants such as *heating, ventilating* and *air conditioning.* Indoor thermal conditions may be controlled and removed by the heating, ventilating, and air conditioning (HVAC) systems.

How well the thermal environment is controlled depends on the design and operating parameters of the HVAC system, and on the heat gains and losses in the space being controlled. These gains and losses are principally determined by indoor sources of heat, the heat gains from sunlight, the heat exchange through the thermal envelope, the outdoor conditions and the outdoor air ventilation rates [23].

Mechanical ventilation systems in hospital buildings are designed and operated not only to heat and cool the air, but also to draw in and circulate outdoor air. However these systems can contribute to indoor air problems in several ways if they are poorly designed, operated, or maintained. Ventilation systems can be a source of indoor pollution themselves by spreading biological contaminants that have multiplied in cooling towers, humidifiers, dehumidifiers, air conditioners, or the inside surfaces of ventilation duct work [18] which necessitates appropriate maintenance.

3.4. Health Effects of Indoor Pollutants

As mentioned in Part 3.1., the common indoor pollutants in hospitals are environmental tobacco smoke, combustion pollutants, biological pollutants, microbial pollutants (fungi, bacteria, viruses), volatile organic compounds (VOCs), environmental tobacco smoke, combustion pollutants, biological pollutants, volatile organic compounds (VOCs) semi-volatile organic compounds (SVOCs), formaldehyde, soil gases (radon, sewer gas, methane), pesticides, particles and fibers, asbestos, carbon monoxide, formaldehyde, radon, pesticides, and molds [19-22]. These pollutants are abundant in most indoor air, although the concentrations are generally far lower than known thresholds for health effects [1]. Nevertheless, the huge number of pollutant sources may cause serious health effects. These effects can range from irritation and discomfort to disability or life threatening diseases which may be listed as in Table 2.

Table 2. Health Effects of Indoor Pollutants [18, 24-27]

Eye Findings	Irritant or allergic conjunctivitis (burning, sensation of dryness, redness)
Ear Findings	Ear infection, fluid in the middle ear
Nasal Manifestations	Rhinorrhea, nasal obstruction
	Irritant rhinitis
	Allergic rhinitis, chronic sinusitis
Respiratory Manifestations	Chest tightness, cough +/- fever, shortness of breath with exertion
	Nonspecific abnormalities
	Asthma
	Hypersensitivity pneumonitis
	Infectious pneumonia - *Legionella* pneumonia - Aspergillus pneumonia (inimmunosuppressed persons) - Tuberculosis - Others (most common inimmunosuppressed persons)
Oropharyngeal Manifestations	Dryness, irritation of the throat
Lung Cancer	
General Symptoms	Headaches, lethargy, fatigue, dizziness, weakness, poor concentration
	Non-specific complaints
	Systemic effects of hypersensitivity pneumonitis
	Variant of organic dust toxic syndrome (humidifier fever)
	Carbon monoxide poisoning
	Nausea, tingling sensation, muscle twitching
Skin Manifestations	Dryness, irritation, rash
Mental Manifestations	Coma
Sick Building Syndrome – SBS [25, 26]	
Building Related Illness- BRI [26]	
Multiple Chemical Sensitivity [26, 27]	

4. Conclusion

One of the architectural solutions in order to remove building related environmental impacts in hospital buildings, where people go for medical treatment, visit and work, is to prevent indoor air pollution, and improve IAQ by sustainable design criteria. Hospitals are complex buildings that require specialized pollutant removal mechanisms to control hazardous emissions for the comfort of patients, visitors, administrative staff, and health staff. Besides, hospital building design and IAQ issues must be considered from cradle to grave process. The measures for controlling indoor pollutants should be cared in all phases of this process. In this context the aim of the paper is to provide to better understand indoor air pollution, and to reduce human's exposure to air pollutants in hospital buildings where people go for medical treatment, visit and work. In further scientific researches, these issues should again be addressed by solutions in order to reduce the risks to occupant's health.

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