DIPLOMARBEIT

Exploring the indoor air quality requirements according to national and international standards

unter der Leitung von

Univ.-Prof. DI Dr. Ardeshir Mahdavi

E 259-3 Abteilung für Building Science and Technology

Institut für Building Physics and Building Ecology

eingereicht an der

Technischen Universität Wien

Fakultät für Architektur und Raumplanung

von

Apostolos Sakkas

01604686

[redacted]

Wien, April 2022

KURZFASSUNG

Menschen verbringen einen großen Teil ihres Lebens in Innenräumen wie Wohnungen, Büros, Schulen, öffentlichen oder privaten Gebäuden und Einrichtungen, daher besteht ein wachsendes Interesse an der Korrelation zwischen der Gesundheit der Bewohner und der Gebäudegestaltung. In jüngster Zeit wurden mehrere Normen und Richtlinien, in Bezug auf die architektonische Gestaltung, entwickelt, um eine bessere Raumklimaqualität zu ermöglichen.

Indoor Environmental Quality (IEQ) könnte kurz als Indikator beschrieben werden, der die Elemente Indoor Thermal Comfort, Indoor Acoustic Comfort, Indoor Air Quality (IAQ) und Visual Comfort umfasst (Mahdavi et al. 2020). Zu den Adressierungsstrategien (IEQ) gehören solche, die die menschliche Gesundheit schützen, die Lebensqualität verbessern und Stress und potenzielle Verletzungen reduzieren. Eine bessere Umweltqualität in Innenräumen kann das Leben der Gebäudenutzer verbessern, den Wiederverkaufswert des Gebäudes erhöhen und die Haftung der Gebäudeeigentümer verringern (GBC 2022).

Parallel zu national und/oder international etablierten (IEQ) Standards gibt es eine deutliche Zunahme mehrerer Bewertungs-/Zertifizierungssysteme für die Raumklimaqualität. Diese Masterarbeit konzentriert sich auf die Anforderungen und Standards für die Raumluftqualität (IAQ), indem die nationale/internationale Literatur zu Standards und Richtlinien überprüft wird. Ziel der Diplomarbeit ist es, die von Richtlinien und Normen vorgeschlagenen Methoden zu analysieren, um eine ausreichende Raumluftqualität (IAQ) zu erreichen.

ABSTRACT

Since people spend a large part of their lives in indoor environments like homes, offices, schools, public or private buildings and facilities, there has been a growing interest in the correlation between occupant health and building design. In recent times, several standards and guidelines –regarding architectural design- have been developed in order to facilitate a better indoor environmental quality.

Indoor Environmental Quality (IEQ) could be briefly described as an indicator, which includes the elements of indoor thermal comfort, indoor acoustic comfort, Indoor Air Quality (IAQ) and visual comfort (Mahdavi et al. 2020). Strategies for addressing (IEQ) include those that protect human health, improve quality of life, and reduce stress and potential injuries. Better indoor environmental quality can enhance the lives of building occupants, increase the resale value of the building, and reduce liability for building owners (GBC 2022).

Parallel with nationally and/or internationally established (IEQ) standards, there is a noticeable increase of several rating/certification systems for indoor environmental quality. This Master Thesis will focus on indoor air quality (IAQ) requirements and standards, by reviewing the national/international standards and guidelines literature. The thesis aims to analyze the methods proposed from guidelines and standards to achieve sufficient indoor air quality (IAQ).

Keywords

Indoor Environmental Quality; Indoor Air Quality; Standards; Pollutants; Health

ACKNOWLEDGMENTS

I would like to express my appreciation and gratitude to Univ. Prof. DI Dr. Ardeshir Mahdavi, my thesis supervisor, and mentor, for offering me the opportunity to be part of an international master program of TU Wien and have the chance to work with talented people from all over the globe.

My special thanks to my family for believing in me, supporting me, and motivating me to give my best to achieve all my personal goals. My sister Dr. Maria Sakka taught me to never give up, my mother Herta Sakkas help me all the way to see the glass half full, and my father DI Konstantinos Sakkas had always a crucial piece of advice to give me that brought me one step further.

NOMENCLATURE

Abbreviation	Meaning
ACH	Air Changes per Hour
ALTER	Acceptable Long-Term Exposure Range
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BRI	Building Related Illness
CDC	Centers for Disease Control and Prevention
CH_2O	Formaleyde
CO	Carbon monoxide
CO_2	Carbon dioxide
EPA	U.S. Environmental Protection Agency
ETS	Enviromental Tobacco Smoke
HF	Humidifier Fever
HP	Hypersensitivity pneumonitis
HVAC	Heating Ventilation and Air Conditioning systems
IAQ	Indoor Air Quality
IARC	International Agency for Research on Cancer
IEQ	Indoor Enviromental Quality
MDF	Medium Density Fiberboard
NO	Nitrogen monoxide
NO_2	Nitrogen dioxide
O_3	Ozone
OSHA	Occupational Safety Administration
PAHs	Polycyclic aromatic hydrocarbons
Pb	Lead
PCBs	Polychlorinated biphenyls
PM	Particulate Matter
POM	Polycyclic Organic Matter
ppm	parts per million
Rn	Radon
RSP	Respirable Particulates
SBS	Sick Building Syndrome
SO_2	Sulfur dioxide
VOCs	Volatile Organic Compounds
WHO	World Health Organisation

TABLE OF CONTENT

1 INTRODUCTION

1.1 Overview

There is a raised focus on achieving standards-based Indoor Environmental Quality (IEQ). Indoor environmental quality refers to the acceptable levels of thermal, visual, acoustical comfort and Indoor Air Quality (IAQ). Research has established that problems with Indoor Environmental Quality (IEQ) of a building have a direct effect on the comfort, health, and productivity of the occupants. An indicator such as IEQ can aid architects and engineers in the design and modernization of constructions.

Standards and guidelines are tools, that give the architects and engineers indicators and parameters to strongly consider in order to achieve sustainable buildings that are healthy, energy-saving, and environmentally friendly.

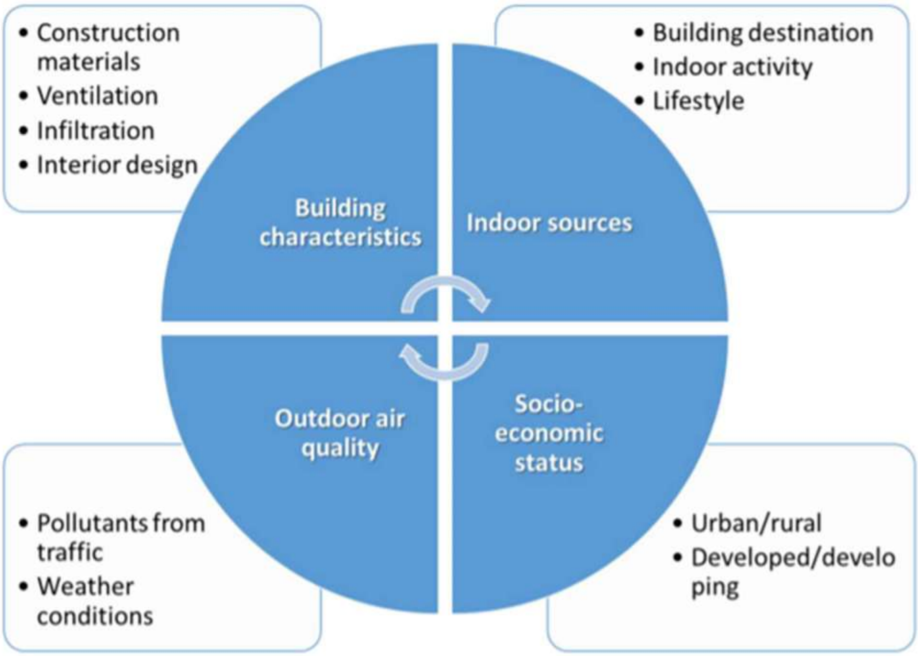


Figure 1 Important factors for indoor air quality (source: Perniu and Manciulea 2007)

Those tools could be in form of national or international standards for design aspects like ventilation rates. Tools which define target values or guide through methods to determine the wanted result. Databases of materials which could act as a potential pollutant source, are useful for the engineers and architect during the selection of them for the construction or renovation of a building.

1.2 Motivation

Indoor environmental quality is an essential determinant of a healthy life, people's well-being, and has a significant impact on modern life. If we consider that for example Americans, on average, spend approximately 90% (EPA 1989) of their time indoors a raise of awareness and interest in the architectural community would be extremely beneficial. Hazardous substances emitted from buildings, construction materials, and indoor equipment or due to human activities indoors, such as combustion of fuels for cooking or heating, could lead to a broad range of health problems that could be even fatal (WHO 2011).

During new construction or renovation, an engineer should investigate and try to achieve a high (IEQ) indicator, because it is very beneficial from different angles and perspectives (occupant health, air quality, etc.). The benefits for the users can be easily observed in terms of higher quality of life, advantages for the building owners and investors through higher value, and lower risks. Furthermore, there are advantages for planners and architects through more efficient planning and benefits for consultants and product manufacturers via the relevance of products used in construction.

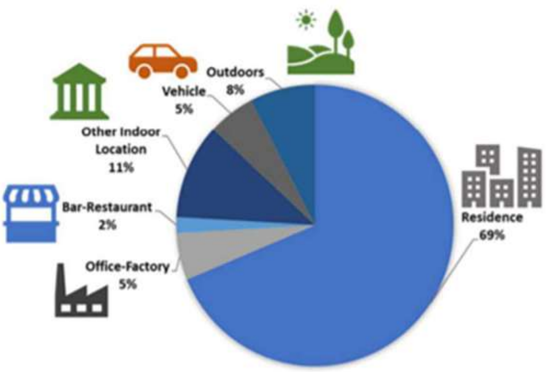


Figure 2 Pattern of time spent indoors (source: Mannan and Al-Ghamdi 2021)

1.3 Background

When studying the Indoor Air Quality standards an overview of World Health Organization (WHO), 'WHO, Regional Office for Europe 2011: 23' guidelines for Indoor Air Quality (IAQ) is necessary to understand the importance of the indicators and the significance of clean air in health and well-being.

Using guidance standards for (IAQ) like DIN EN 16798-1 and ISO 16814 we can explore the methods of deriving design criteria for an acceptable indoor environment. Standard like ISO 16000-1 could aid in the planning of indoor pollution monitoring. Exploring and analyzing the Indoor Air Quality Standards (IAQ) could provide useful information to the interested parties.

Architects and engineers can have an overview of methods to plan and design a sufficient Indoor Air Quality (IAQ) building. This can also increase the understanding of the default parameters used in the standards documentation. Stakeholders could understand better ways to protect and optimize their investment. Last but not least, this could increase the awareness on the matter of indoor air quality (IAQ) for the ones that make the biggest difference, the users. The interaction of the users with various buildings, for example, the number of times windows are opened, or how often filters are replaced, can determine how successful a design is in terms of air quality.

This contribution aims to put under the scope Austrian and European indoor air quality standards to create an overview of the 'tools' handed to a designer for the element of indoor air quality. A significant part of this contribution would be the deeper understanding of default parameters, formulas, and databases relevant to design support.

2 APPROACH

The focus point of this Master thesis is to explore the current national (Austrian) and international (European mostly) standards, in terms of indoor air quality. The methodology used to conclude this master thesis is a comprehensive standard review, which could provide methods and target values.

An investigation of the literature for the different aspects of indoor air quality, like the effects of bad air quality indoors on human health, aims to collect information on how the indoor environment conditions could change positive or negative our health condition and eventually our everyday life.

Books, journals, and conference papers are going to be part of the scope for this contribution, to provide the needed information and help to create a kind of ‘handbook’ for indoor air quality based on current standards.

Basic knowledge of the topic could be gathered in one place. Answers to the following questions will be presented to this contribution:

-What are the effects of low indoor air quality on humans?

-Which are the indoor air pollutants?

-What are the causes of indoor air pollution?

-Which tools and approaches from the indoor air quality standards could a building designer use?

-How can I monitor the indoor air quality of a building?

3 INDOOR AIR QUALITY, THE EFFECTS ON HUMAN HEALTH

In the last two decades, increased interest is shown towards indoor air quality (IAQ) due to the effects that it may have on human health. Currently, indoor air pollution is ranked by Environmental Protection Agency (EPA) as one of the top five environmental risks to public health. According to WHO, indoor exposure to air pollutants causes severe damage to human health at a global level and especially in developing countries. It is responsible for the deaths of 3.8 million people annually (WHO 2020). By understanding, controlling, and trying to reduce common indoor pollutants during the design or modernization of constructions, an architect or an engineer can contribute to decreasing the risk of indoor health concerns.

Over the years as various symptoms and illnesses have been linked to poor indoor air quality different categorization tools have been developed. We could categorize building-associated illnesses into categories based on the time the health impact may be experienced, into immediate and long-term effects. In this contribution, the categorization model in use will be the sick building syndrome (SBS) and the building-related illness (BRI). Their associated symptoms are shown in Table 1.

Table 1 Sick building syndromes and illnesses (source: Van Tran et al. 2020)

Sick Building Syndrome (SBS)	**Building-Related Illness (BRI)**
- Mucous membrane irritation: eye, nose, and throat irritation. - Neurotoxic effects: headaches, mental fatigue, reduced memory, nausea, tiredness, dizziness, and irritability. -Asthma and asthma-like symptoms: chest tightness and wheezing. -Skin dryness and irritation, gastrointestinal complaints, and others	- Flu: fever, chills, chest tightness, muscle aches, and cough. - ‘Legionnaires’ disease, hypersensitivity pneumonitis, humidifier fever. - Lung and respiratory problems.

3.1 Sick Building Syndrome (SBS)

The term "sick building syndrome" (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified (EPA 1991). World Health Organization (WHO) in 1983 represented the concept of sick building syndrome (SBS) as certain medical symptoms occurred by occupants in buildings with indoor environment problems. The first studies on the matter started among office buildings where the office workers experienced symptoms such as eyes and throat irritations, headache, and tiredness. Studies carried out in different indoor environments like schools and various symptoms and illnesses are correlated to SBS over the last years. Various factors contribute to the increase of SBS in a building such as the dependence on mechanical ventilation systems for air supply, increased use of synthetic materials for the construction of the building, inconsistent operating procedures, and poor maintenance. Indicators of signs and symptoms related to SBS could be the constant complaints of symptoms (as listed in Table 1) from the building occupants, feeling of relief soon after leaving the building, especially if the cause of a symptom is not known.

3.2 Building-Related Illness (BRI)

Building-related illness (BRI) is used as a term when symptoms of diagnosable illness are identified and can be attributed directly to airborne building contaminants (EPA 1991). In other words, it has to be a proven connection between a building-related exposure and the resultant's health disorders. The occupants continue to suffer from the disease even after leaving the building. This class of illnesses frequently involves the skin and respiratory tract because of the ease with which indoor environmental contaminants come in contact with these issues. Agents that cause building-related illnesses generally via one of four major mechanisms: (a) immunologic, (b) infectious, (c) toxic, or (d) irritant (Seltzer 1994). Psychologic mechanisms are often not paid significant attention but are demonstrably likely to increase the overall morbidity of building-related diseases as well (Gerardi 2010). Indicators of signs and symptoms related to SBS could be the constant complaints of symptoms (as listed in Table 1) from the building occupants, the symptoms can be defined and correlate clear with causes, complainants could require longer recovery time after exiting the building (EPA 1991).

Some of the most significant building-related illnesses and syndromes are hypersensitivity pneumonitis, humidifier fever, 'Legionnaires' disease, allergic rhinitis, conjunctivitis, and asthma.

3.3 Hypersensitivity pneumonitis (HP)

Hypersensitivity pneumonitis (HP) is also called extrinsic allergic alveolitis. It is an immune system disorder, which affects the lungs after inhaling specific substances, which exist in the environment. The exposure causes inflammation of the lungs (Pneumonitis 2021). The lungs function improperly, and, in some cases, this results in permanent damage. Substances include as causes could be: (a) bacteria and mycobacteria, (b) (bird-) proteins, (c) chemicals, (d) fungi and molds. Patients experience symptoms from the difficulty of breathing and cough (sometimes more gradually) in some cases exhibit fever and joint pains. Unfortunately, the disease is difficult to be defined from a diagnosis because the symptoms are alike to common diseases (Pneumonitis 2021a), Figure 3. Treatment, after diagnosis, is to avoid exposure to a variety of antigens. In addition, corticosteroids medicines could reduce inflammation (Costabel 2020).

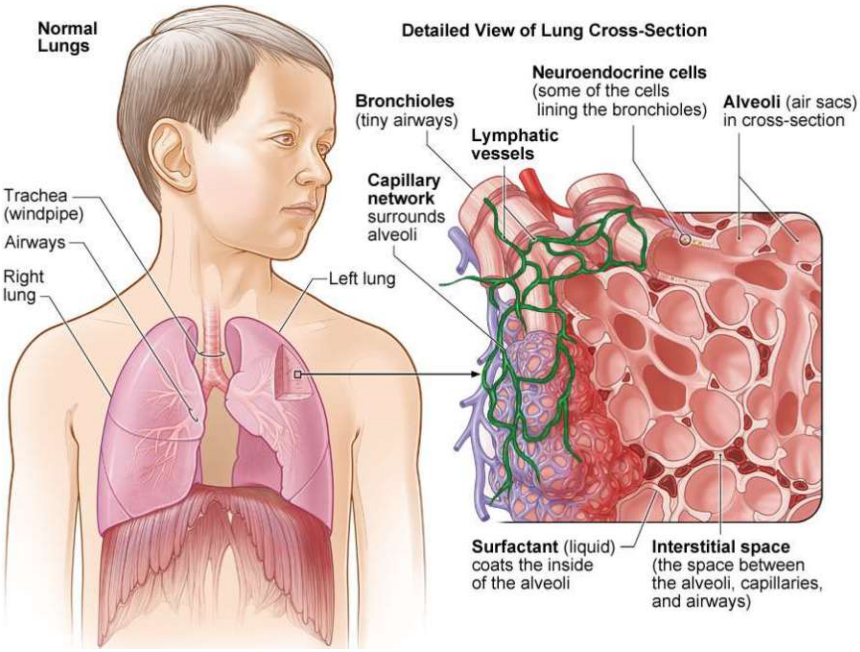


Figure 3 Lungs damage (source: Pneumonitis 2021a)

3.4 'Legionnaires' disease

'Legionnaires' disease, also known as Legionellosis, is a severe form of pneumonia — lung inflammation caused by the Legionella bacteria. The usually harmless bacteria can be found in water and soil, but cause health problems to humans if it grows to part of a building's equipment such as water or ventilation systems (OSHA 2021). The disease was first defined in 1977 after an outbreak during the summer of 1976 in a veteran convention of the American

Legion in Philadelphia, the U.S.A. where 25 people died (Legionellosis 2018). In 2018 only in the U.S.A. 10.000 cases of 'Legionnaires' disease was reported by the health departments (Diseases U.S. 2016). According to the center for disease control and prevention (CDC), 1 out of 10 people who get sick from Legionellosis will die (Legionellosis 2013). Symptoms of the disease include: (a) cough, (b) shortness of breath, (c) chest pain, (d) fever, (e) muscle aches, and (f) headaches (NHS 2020). A vaccine for 'Legionnaires' disease is not currently available (Legionellosis 2018), so after the diagnosis, the treatment requires mostly antibiotics but in some cases because of breathing difficulties, a breathing machine with oxygen through a face mask is needed.

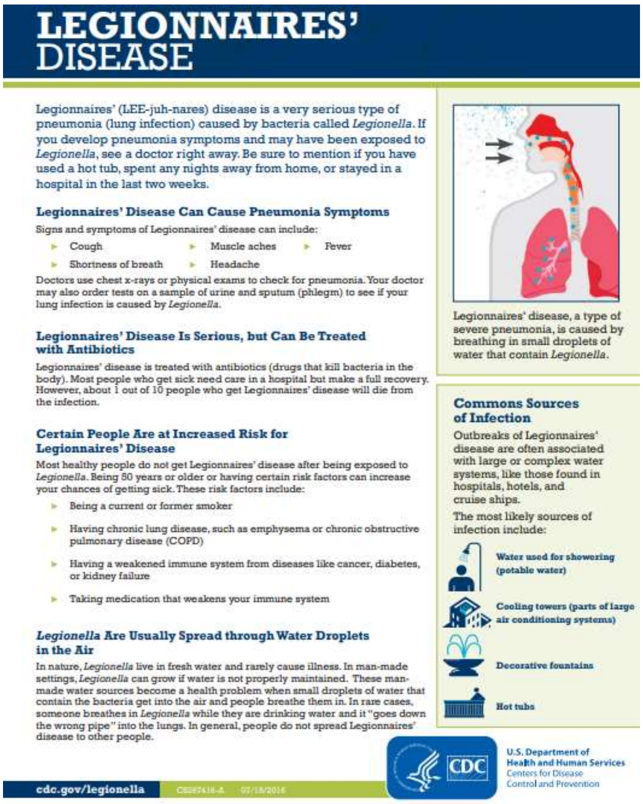


Figure 4 Diseases (source: CDC 2017)

3.5 Humidifier fever (HF)

Humidifier fever (HF) has been related to indoor air contamination substances and is an influenza-like illness. The disease could potentially spread in buildings where regulation of temperature, humidity, and ventilation seems necessary to maintain a quality of comfort. Different agents such as amoebas, bacteria, and fungi may develop in the moist environment of a humidifier and spread through the air. The main symptoms are pyrexia and malaise. Humidifier fever is often referred to as `Monday sickness' because occurs after the return in `contaminated` space after an absence (first day at work after the weekend). In many cases, the symptoms retreat after a day or two, and the disease does not let any permanent damage (Edwards et al. 1977).

3.6 Allergic rhinitis and conjunctivitis

Allergic rhinitis and allergic conjunctivitis are common conditions that recently been recognized as to have a big impact on human health (O'Hehir et al. 2016). Upper airway allergy appears through symptoms like sneezing, rhinorrhea, recurring scratchy throat, eye tearing, cough, ear pain, etc. (Mehta 2021). The best treatment for this condition is prevention, to stay away from the allergens causing the symptoms. For an indoor environment, a high-efficiency particulate air filter (HEPA), usage of ventilation to keep the window operation to a minimum could be very beneficial. Treatment from a medical aspect could be: (a) nasal sprays and washes, (b) oral medicines, and (c) allergen immunotherapy (Allergies 2020).

'Microscopic particles(allergens) are inhaled into the nose and bind to allergic antibodies that are attached to the surface of mast cells. Mast cells contain histamine, which, when released into the nasal tissue, causes the characteristic symptoms of allergic rhinitis.' (Colorado 2016)

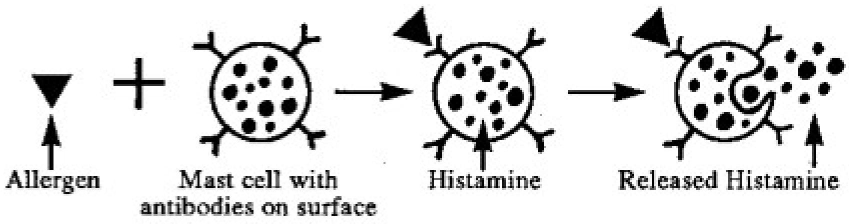


Figure 5 Allergen (source: Colorado 2016)

3.7 Asthma

Asthma is a condition, in which the airways are long-term inflamed. The airways to the lungs swell up, get narrowed and as a result, the individual has breathing difficulties (Asthma 2021), (Figure 6). Asthma is a chronic disease that sometimes could be also lethal. According to EPA 24 million Americans, among them 6 million children suffer from asthma (EPA 2021). The symptoms of asthma vary in each case to the intensity with the most common of them being: (a) shortness of breath, (b) wheezing, (c) chest tightness, and (d) coughing (Asthma 2021). We can categorize in terms of what triggers it in two categories: (a) allergic and (b) non-allergic asthma. Through physical and consulting examinations of the patient, doctors can define the disease and come to a diagnosis (Asthma 2021). For asthma, a condition for which there is no cure and treatment is tailored to the symptoms and the triggers for each patient. It is a disease that the patient has to learn to live with and take care of to smooth the outcome (EPA 2021). Some of the routines a patient has to implement in his everyday life are: (a) physical exercise, (b) quit or avoid smoking and smoky indoor environments, (c) be taught breathing techniques, and (d) monitoring yourself as a tool to record the symptoms and have an overview of the overall condition. Following Table 2 with major factors for asthma, more details will be provided in chapter 3, in indoor environments.

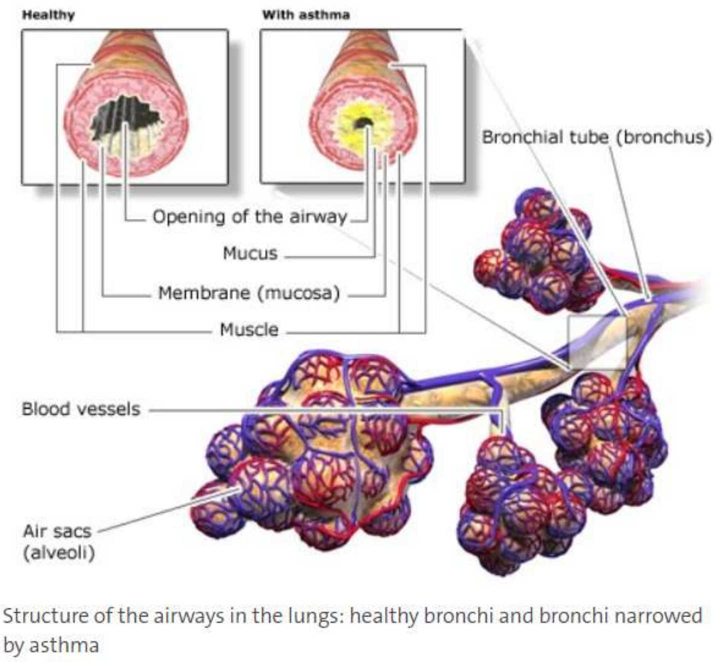


Figure 6 Factors of asthma (source: Asthma 2021)

Table 2 Major factors of asthma (source: Seltzer 1994)

Contaminant	Sources	
Volatile organic compounds	Perfumes Hairsprays Furniture polish Cleaning solvents Hobby and craft supplies Pesticides Carpel dyes and fibers Glues, adhesives, sealants	Paints, stains, varnishes, strippers Wood preservatives Dry cleaned cloths, moth repellants Air fresheners Stored fuels and automotive products Contaminated water Plastics
Formaldehyde	Particleboard , interior grade plywood Cabinetry, furniture	Urea formaldehyde foam insulation Carpet, fabrics
Pesticides	Insecticides (including termicides) Rodenticides	Fungicides, disinfectants
Nitrogen dioxide	Improperly operating gas or oil furnace/hot water heater, fireplace, wood store	Unvented gas heater/kerosene heater Tobacco products, gas cookstove Vehicle exhaust

Table 2 Continued

Sulfur dioxide	Combustion of sulfur-containing fuels (primarily, kerosene healers)	
Respiracle particulates	Fireplace, woodstove Unvented has heater	Tobacco products Unvented kerosene heater
Environmental tobacco smoke	Tobacco products	
Biological contaminants	Carpets Plants, animals, birds, human beings Pillows, bedding, house dust Wet or damp materials	Bacteria, fungi, protozoa Standing water Humidifiers, evaporative coolers

4 INDOOR AIR QUALITY, SELECTED POLLUTANTS

Public health is a major topic of discussion between individuals, nowadays mostly focused on the worldwide health crisis caused by the virus SARS-CoV. Also before, during, and hopefully, after the worldwide pandemic comes to an end, the awareness for public health will keep raising on a variety of issues, one of them being air pollution. As part of human nature, people most of the time have a sense of security if they are in an indoor environment. In the case of indoor air pollution, sometimes this sense of security can be proven false. Taking into consideration that for example, Americans spend on average approximately 90% (EPA 1989) of their time indoors, is crucial to communicate how essential indoor environmental quality is. In Figure 7 we can see the percentage of country contributions on indoor air quality to the total amount in Europe for the period 2000 to 2020. Indoor environmental quality is defined by several indoor conditions like (a) lighting, (b) air quality, (c) thermal conditions (relative humidity, airflow, temperature), etc. (CDC 2021).

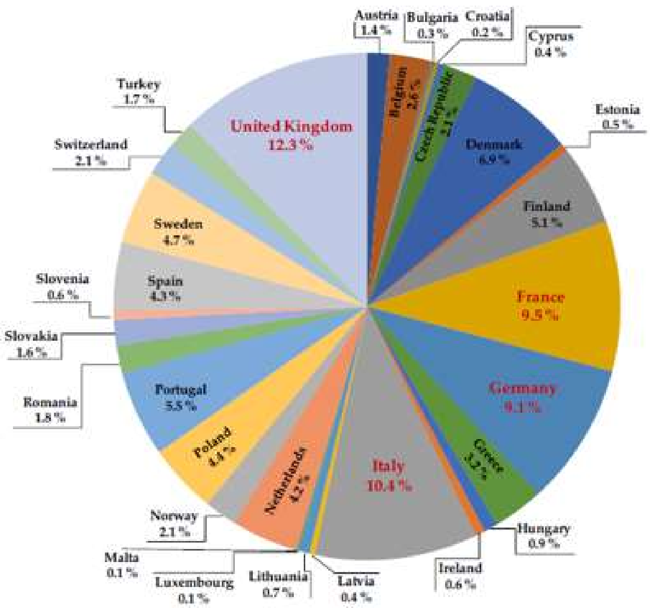


Figure 7 Percentage of country contributions on indoor air quality to the total amount in Europe for the period 2000 to 2020 (source: Settimo et al. 2020)

The purpose of this contribution's chapter is to focus on pollutants that decrease indoor air quality (IAQ). To require further information on the topic, an overview of indoor pollutants is essential and helps the reader to deepen his information pool regarding indoor air pollutants. A general classification of indoor air pollutants is organic, inorganic, biological, and even radioactive (Leung 2015). The pollutants could be produced in the indoor environment, originate from the outside environment or be present in both indoor and outdoor environments. A presentation of the pollutants will follow having as 'guideline' the Table 3 and adding some pollutants listed from WHO and EPA in their guidelines for the most common indoor pollutants.

Table 3 A presentation of the pollutants (source: Slezakova et al. 2012)

Pollutant		**Emission source**
Inorganic chemical substances	Carbon dioxide	Combustion activity, metabolic activity
	Carbon monoxide	Fuel burning, tobacco smoke, stoves, gas heaters, motor vehicles in garages
	Nitrogen dioxide	Outdoor air, fuel burning, motor vehicles in garages
	Sulfur dioxide	Outdoor air, fuel reaction
	Ozone	Photochemical reaction
	Radon	Soil and bedrock under houses, building materials, ground water
Organic chemical substances	Formaldehyde	Insulation, furnishings
	Polycyclic aromatic hydrocarbons	Tobacco smoke, fuel combustions
	Polychlorinated biphebyls	Heat transfer fluids used in lamp ballasts and TV capacitors, stabilizers used in PVC wire insulation materials, additives in sealants, adhesives, paints, and floor finishes

Table 3 Continued

	Volatile organic compounds	Household products (paints, aerosol sprays, cleaning supplies), building materials and furnishings, office equipment (i.e., copiers and printers)
Biological pollutants	Allergens	Domestic animals, insects, house dusts
	Fungi	Internal surfaces, soils, plants, food
	Microorganisms	Occupants- people, animals, plants, air heating, ventilation, air-conditioning systems
	Pollens	Outdoor air, indoor vegetation
Other	Asbestos	Fire retardant material, insulation
	Particles	Tobacco smoke, combustions, resuspension
	Pesticides	Commercial and residential application of insecticides and herbicides

4.1 Carbon Dioxide (CO2)

Carbon dioxide is an odorless, colorless, non-flammable gas that occurs naturally in the atmosphere. It is produced indoors through human activities and respiration. According to the exposure guidelines for residential indoor air quality published in 1989, Health Canada an acceptable long-term exposure range (ALTER) for CO_2 in residential indoor air is smaller or equal to 3500ppm (Canada 1989). Indoor levels tend to be higher than outdoor levels. A typical level of CO_2 concentration in indoor occupied spaces with air exchange is between 350 and 2500 ppm (Erdmann and Apte 2004).

4.2 Carbon Monoxide (CO)

Carbon monoxide (CO) is a colorless, tasteless, odorless, non-irritant gas produced by incomplete combustion of carbonaceous material, like fuels such as wood, coal, petrol, natural gas, etc. (Bernstein et al. 2008). Carbon Monoxide is one of the major causes of poisoning in the United States (Weaver et al. 2002). The molecule weight of Carbon Monoxide is 18.01 g/mol. Its weight is very similar to the weight of air (approximately 29 g/mol), something that causes freely mixing of it with air at any proportion (WHO 2010). Part of CO detected in indoor spaces is coming from the outdoor environment (emissions of combustion engines, industry, etc.) (Pontiki 2019). Indoor sources of CO are combustion sources with the main of them being tobacco smoke, gas appliances, space heaters that use fossil fuels. Since CO is an undetectable pollutant by people either by smell, taste, or sight and the intensity of poisoning by CO depends on concentration and time exposure, it is very likely for the exposed individual to have to be hospitalized (Bernstein et al. 2008).

Currently, the exposure limit according to Occupational Safety and Health Administration (OSHA) is 50 parts of carbon monoxide per million parts of air (ppm) for an average of eight (8) hours (EPA 2021a).

Table 4 Condition and minimum respiratory protection (source: CDC 1978)

Condition	Minimum Respiratory Protection* Required Above 50 ppm
Gas Concentration 500 ppm or less	Any supplied-air respirator Any self -contained breathing apparatus
1500 ppm or less	Any supplied- air respirator with full facepiece, helmet, or hood Any self- contained breathing apparatus with a full facepiece A Type C supplied-air respirator operated in pressure- demand or other positive pressure or continuous-flow mode

Table 4 Continued

Greater than 1500 ppm or entry and escape from unknown concentrations	Self- contained breathing apparatus with full facepiece operated in pressure- demand or other pressure mode A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure of continuous- flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or other positive mode
Fire Fighting	Self- contained breathing apparatus with full facepiece operated in pressure-demand or other positive pressure mode
Escape	Any gas mask providing protection against carbon monoxide Any escape self- contained breathing apparatus
*Only NIOSH- approved or MSHA-approved equipment should be used.	

4.3 Nitrogen Oxides (NO and NO2)

In the ambient air there are seven oxides of nitrogen. Nitrogen dioxide (NO_2) and nitric oxide (NO) are two of them connected with combustion sources (WHO 2010). Typical indoor sources of nitrogen oxides are combustion appliances that use coal, wood, gas, oil as fuel, of course, we have outdoor sources that influence the indoor concentration levels also. According to studies if a combustion appliance is not used indoors there is a decrease of concentration levels almost in the half in comparison with outdoors concentration levels (Theodoratou 2014). Knowing that, it is easy to assume that the concentrations of nitrogen oxides indoors peak during the wintertime due to the extensive use of heating and lower ventilation rates.

4.4 Sulfur dioxide (SO2)

Sulfur dioxide has a strong pungent smell (smell of burnt matches), is colorless and non-flammable or explosive gas with lower concentrations indoors than outdoors (Slezakova et al.

2012). EPA has created ambient quality standards for the entire group of sulfur oxides (SO_x), but sulfur dioxide (SO_2) is the greatest concern among that group. The biggest source of it is the burning process of fossil fuels mostly by power plants or other industrial facilities. Natural sources are also volcanic eruptions. The significant indoor source of sulfur dioxide at least in the U.S. is the not very common unvented kerosene heaters (Sulfur 2021). Therefore, sulfur dioxide falls into the category of air pollutants that penetrate from outdoors. An acceptable long-term exposure range (ALTER) for SO_2 is equal to or smaller than 0,019ppm according to Canadian standards.

4.5 Ozone (O3)

Ozone is a colorless gas that exists naturally in the Earth's upper atmosphere, approximately 20 to 50 kilometers above the surface. Natural ozone forms a kind of shield around planet Earth and protects us from the ultraviolet rays of the sun. Nevertheless, when ozone reaches high concentrations on the ground level could occur to health problems. According to reports of Canada Health, an average annual outdoor concentration is around 0.015 ppm and indoors 0.02 ppm. With a concentration of ozone up until 0,3 ppm people start to 'feel' the presence of the gas through irritation of the respiratory system. In concentrations of ozone between 1 and 30 ppm people will feel dizziness and weariness and in concentrations of 90ppm for a short period could lead to grave danger (Pavlidis 2019).

4.6 Radon (Rn)

Radon is an odorless and colorless radioactive noble gas, a member of the uranium-238 decay series, specifically, it arises from the decay of radium-226. International Agency for Research on Cancer (IARC) classifies radon as a human carcinogen (IARC 1988). The Source of indoor radon is mainly the soil subjacent of a house. Through the decay of radium in soil and rocks enters the indoor environments of buildings (WHO 2010). Building materials could be an origin of radon indoors, but their contribution to radon concentration is much less noticeable than the soil. There are also cases in which radon is carried in water supply and it is released by the usage of water. The concentration of radon in the surface water is usually very low. Drinking water that contains radon counts also as an exposure pathway (IAEA 2015).

4.7 Formaldehyde (CH2O)

Formaldehyde is a colorless flammable gas with a strong-smelling and it is highly reactive at room temperature (WHO 2008). It is a gas that is very often used in the making of several building materials, a variety of household products, and combustion processes such as cooking and smoking (Formaldehyde 2021). The main source of formaldehyde is poor air exchange rate which make the exposure to it more likely indoors than outdoors (Salthammer et al. 2010). The pathways of exposure to formaldehyde differ, in a gas form can be inhaled. If it is in liquid form could be absorbed through the skin and exposure to small amounts could be experienced by drinking liquids or eating foods that contain formaldehyde. According to EPA, the average concentration of formaldehyde is good below 0.1 ppm in older households, and in new buildings which obtain big amounts of wood products (mainly pressed wood) levels can reach the zone of 0.3 ppm. The government of Canada and its health care department recommended concentration values to be classified into two categories: (a) short-term exposure and (b) long-term exposure. For category (a) accepted concentration value is 123 μg/m³ or 100 ppb based on an hourly exposure and for (b) 50 μg/m³ or 40 ppb based on at least 8-hour exposure. In the Table 5 below we can see the effects of formaldehyde in humans after short-term exposure.

Table 5 Effects of formaldehyde in humans after short-term exposure (source: E.C. 1990)

Effect	Formaldehyde concentration (in mg/m³)	
	Estimated median	Reported range
Odour detection threshold (including repeated exposure)	0.1	0.06-1.2
Eye irritation threshold	0.5	0.02-1.9
Throat irritation threshold	0.6	0.1-3.1
Biting sensation in nose, eye	3.1	2.5-3.7
Tolerable for 30 minutes (lachrymation)	5.6	5-6.2
Strong lachrymation, lasting for 1 hour	17.8	12-25
Danger to life, oedema, inflammation, pneumonia	37.5	37-60
Death	125	60-125

4.8 Polycyclic aromatic hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) are the most common subclass of polycyclic organic matter (POM), they belong in a big group of organic compounds that have two or more fused aromatic rings (WHO 2008). Polycyclic aromatic hydrocarbons (PAHs) are listed as one of the highly health-relevant air pollutants and 16 of them have been classified by European

Commission and EPA (the United States Environmental Protection Agency) as priority pollutants (Wang et al. 2021). They are emitted from natural and anthropogenic sources into the environment, and they are carcinogenic. Sources of PAHs from human activity, relate to the combustion of fossil fuels like coal, gas, wood, oil, etc. These processes apply to residential heating systems, to the industry, and mobile sources for the release in an outdoor environment. The most important natural sources are forests fires and volcanic activity (Canada 2021). For indoor environments cooking, smoking and furniture are some of the sources of PAHs. In the United States, approximately 16% of the annual total PAH release comes from residential heating with the mobile sources accounting as the biggest source of air PAHs with approximately 36% of the annual total (Ohura et al. 2003).

Naphthalene is one of the most known polycyclic aromatic hydrocarbons. This chemical occurs in solid form (white crystalline powder) and has a very characteristic smell. The most common use of it is as insect repellent or deodorant (Vardoulakis et al. 2020).

4.9 Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are classified as persistent organic pollutants (POPs). They are manmade organic chemical mixtures of more than 209 individual chlorinated compounds (Polychlorinated Biphenyls 2021). Those very stable mixtures have no taste or smell and range in consistency from oil (liquid) with colors between colorless to light yellow and black waxy solids (Polychlorinated Biphenyls 2021a). PCBs were produced from 1929 for approximately 50 years until they got banned from the United States because of evidence that causes harmful health effects by building up in the environment. Their properties such as nonflammability, high boiling point, stability, and electrical insulating attributes made them useful in many industrial and commercial applications for example hydraulic equipment, heat transfer, rubber products, etc. (Nriagu 2011). PCBs can enter the human body in a variety of ways, most common nowadays because as mentioned they are banned products is eating or drinking contaminated food. If an organism encounters PCBs that do not have a direct meaning, it will get sick or have health issues. Getting sick from PCBs depends on the amount entering the body, the period of exposure, and the sensitivity of the body. According to EPA and studies in humans there is evidence that PCBs are related to cancer (Wexler 2014).

4.10 Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) are a large group of chemicals that are present in indoor and outdoor air, with boiling points between less than 0°C to about 400°C, and are found in many households and building products (Wolkoff 1995). World Health Organization classified these based on compound volatility into four categories as present in Table 6.

Table 6 Classification of Volatile Organic Compounds (source: Wolkoff 1995)

Classification	Abbr.[a]	Boiling point range from °C to °C[a]		Vapor pressure[c] kPa[d]	Irritation thresholds[e] µg/m³	Odor thresholds[f] µg/m³
Very volatile organic compounds	VVOCs	<0	50–100			
Volatile organic compounds	VOCs	50–100	240–260[a,b]	$>10^{-2}$	$1–10^{6}$	$0.1–10^{5}$
Semi-volatile organic compounds	SVOCs	240–260	380–400	$10^{-2}–10^{-8}$		
Organic compounds associated with particulate (organic) matter	POM	>380				

a) According to WHO (1989a). b) Polar VOCs appear at the higher end of the range. c) Lewis, 1989. d) 10^{-2} KPa=0.08 mm Hg. e) Mucous membrane irritation based on the mouse bioassay, $RD_{50}\times 0.03$ (Schaper, 1993). f) Odor detection thresholds (Devos et al., 1990).

As presented in chapter 1, people with asthma or similar respiratory diseases, the elderly, young children, and people with high sensitivity to the chemical may experience effects like irritation and illness in short term exposure (hours to days) to VOCs. Long term exposures (years to a lifetime) can cause illnesses like cancer, liver and kidney damage, damage of the central nervous system (Table 7, Neurotoxic effects of VOC commonly found in indoor air). According to EPA, the levels of VOCs in an indoor environment are on average 2 to 5 times higher than outdoors. The levels of concentration after specific activities, for example, wall painting, may reach 1000 times more during and for several hours. As the emissions of VOCs during the use of some products is inevitable some ways to reduce the exposure are: (a) ventilation increase during usage of products that emit VOCs, (b) proper sealing and storage of the products when they are out of use, (c) always use VOCs emitting household product according to the manufacturer's directions and avoid mixing them unless is allowed on the label, (d) keep them away from children and pets and (e) throw them away safely according to the local government's regulation and no just throw them in a normal garbage can. From a user perspective as a general comment, could be added, that the user has to react as he manages toxic products and waste and take all necessary safety actions.

Table 7 Effects of chemical (source: Jantunen et al. 1997)

Chemical	**Effects**
Benzene	Central nervous system depression, vertigo, convulsions, spasm
N-Butylacetate	Central nervous system depression
2- BUTANONE (MEK)	Central nervous system depression, vertigo, vision loss
Cyclohexane	Tremors, reflex loss, neurosis
1.1 Dichloroethane	Anaesthesia, mental retardation, ataxia
Ethylbenzene	Fatigue, vertigo, irritability
Formaldehyde	Excitation, insomnia, tremor, weakness, impaired vision, paresthesias
N-Hexane	Central nervous system depression, motor dysfunction, peripheral neuropathy
Toluete	Memory loss, visual disturbances, decreased reaction time, tremors, impaired balance
p-Xylene	Central nervous system depression, vertigo, convulsions, spasm

4.11 Allergens

Allergens which are classified as biological pollutants are substances responsible for allergic reactions or even asthma triggering in some people (Karol 1991). The most common causes of allergic reactions indoors are (a) house dust mites, (b) plants, (c) insects, (d) pets, (e) molds, and (f) chemical agents (Carrer et al. 2001). Allergens vary in size and their size is measured in micrometers. These particles are travelling in the air and settle on floor and furniture surfaces. Bigger particles settle faster out of the air, for example, pollen or dust mites will settle out of the air faster than animal allergens.

Indoor control of allergens is possible to improve the air quality and reduce or smooth some allergy symptoms. EPA suggests three strategies to improve the air quality and reduce allergens. The first is to control any contact with indoor airborne allergens. The user of an indoor environment must define and eliminate sources that trigger allergic reactions reduce their emissions. The second strategy is to ventilate well the indoor areas. The third strategy is the usage of air cleaners (EPA 2021b).

A worth mentioning allergen is pollen. Pollen is one of the most common allergens that trigger seasonal allergies. Seasonal depending on the type of the plant, plants release tiny pollen grains to fertilize. Most of the pollen that causes allergic reactions comes from trees. The plants produce tiny, light, and dry pollen grains that are transported in the air as a result they can penetrate a building. To reduce the penetration of pollen is suggested to keep the window closed during the problematic periods (Pollen 2022).

4.12 Fungi

Fungi are ubiquitous in the distribution in indoor environments which is why they are a serious threat to public health (Khan and Karuppayil 2012). They grow indoors when sufficient moisture exists and can grow almost on any type of material, natural or synthetic. Indoor pollution from fungi is classified as microbial pollution and inhalation or ingestion is the main route of exposure to fungal propagules. The ways fungi infiltrate a building is by transport on the surface of materials or clothing and ventilation. Based on their water requirements, fungi that grow indoors can be divided into three categories: (a) the primary colonizers, (b) secondary colonizers, and (c) tertiary colonizers (WHO 2010a). The most common symptoms from fungi exposure are (a) eye, nose, and throat irritation, (b) cough, (c) aggravation of asthma. To prevent potential contamination, the two strategies to follow are first to define the source and eliminate the problem, and second is to keep the relative humidity indoors between 30% and 50% with means like dehumidifiers (CCOHS 2022).

4.13 Asbestos

Asbestos designates a collection of silicate minerals that occurs in rock and soil. This material has a high fiber strength, conducts heat poorly, and is resistant to chemical attack. These characteristics of asbestos were the reason for usage in many products throughout the 20th century. Asbestos appliances are found in numerous building materials like roofing shingles, ceiling, and floor tiles, heat-resistant fabrics, etc. (Asbestos 2021). The health effects of asbestos exposure varied. Three main health risks by inhaling high levels of asbestos fibers are (a) lung cancer, (b) mesothelioma (type of cancer), and (c) asbestosis (lungs scarred with fibrous tissue). As the number of inhaled fibers rises, the risk of these issues raises also. Fibers per cubic centimeter of air are the measurement for the exposure levels (NCEH 2022).

Figure 8 Asbestos pipe wrap (joint partially removed) (source: Asbestos 2021)

4.14 Lead (Pb)

Lead is a toxic naturally occurring heavy metal element. In opposition with other pollutants lead does not vanish over time and does not exist a safe level of exposure. This material was in the past very commonly used in household products and gasoline, which is why it is classified as an outdoor and indoor air pollutant. The main exposure in lead was through old paint (1978 lead-based paint was banned by Consumer Product Safety Commission- CPSC) and the emissions of gasoline combustion engines. The concentration of lead in the air naturally is less than 0.1 microgram per cubic meter (DAWE 2022). This heavy metal is classified as a health hazard because can store in the bones and teeth and once it is inside the human body it circulates in the blood (Lead 2022). According to the American Lung Association children are more vulnerable than adults to lead pollution because their nervous systems are in development and as a result, they could be harmed for life. Poisoning of lead could have effects like (a) seizures, (b) anemia, (c) vomiting, (d) paralysis, and even (e) death among others. Through a lead blood test, exposure to lead can be detected. In the tables below we see the sum of lowest-observed-adverse-effect levels (LOAELs) for hematological and neurological effects in adults and children.

Table 8 Summary of LOAELs for lead-induced health effects in adults and children (source: WHO 2000)

Summary of LOAELs for lead-induced health effects in adults

LOAEL at given blood lead level (µg/l)	Haem synthesis, haematological and other effects	Effects on the nervous system
1000–1200		Encephalopathic signs and symptoms
800	Frank anaemia	
500	Reduced haemoglobin production	Overt subencephalopathic neurological symptoms, cognition impairment
400	Increased urinary ALA and elevated coproporphyrin	
300		Peripherial nerve dys- function (slowed nerve conduction velocities)
200–300	FEP elevation in males	
150–200	FEP elevation in females	

Summary of LOAELs for lead-induced health effects in children

LOAEL at given Blood lead level (µg/l)	Haem synthesis, haematological and other effects	Effects on the nervous system
800–1000		Encephalopathic signs and symptoms
700	Frank anaemia	
400	Increased urinary ALA and elevated coproporphyrin	
250–300	Reduced haemoglobin synthesis	
150–200	FEP elevation	
100–150	Vitamin D3 reduction	Cognitive impairment
100	ALAD inhibition	Hearing impairment

4.15 Benzene

Benzene is colorless with a sweet odor and highly flammable at room temperature liquid (density of 874 kg/m^3 at 25 °C). Benzene is classified as a volatile organic compound (VOC). It is widely used by the chemical industry, and it is found in vehicle emissions and tobacco smoke. It is a proven carcinogen, and the exposure levels indoors are higher than outdoors (Sekar et al. 2019). Benzene concentrations in indoor air are affected by outdoor air through the exchange of air due to natural or forced ventilation. Indoor sources can be building materials, attached garages, heating systems, cooking systems, human activities, etc. The most common pathway to exposure 95-99% to benzene is inhalation. Except for inhalation, consuming foods or drinking beverages containing benzene is also a way to be exposed. Humans after breathing high levels of benzene can experience symptoms like drowsiness, dizziness, headaches, tremors, and even death in very high levels. Intake of benzene via consumables can cause symptoms like vomiting, sleepiness, dizziness, irritation of the stomach, etc. (CDC 2021a). According to WHO indoor levels of benzene measured in the United States are similar to those measured in Australia and Europe, in a range of 2.6 to 5.8 µg/m^3.

5 SOURCES OF INDOOR AIR POLLUTANTS

To improve Indoor Air Quality (IAQ) is necessary to define the sources of indoor air pollutants. The sources can be categorized in (a) building materials and furnishings, (b) household products, (c) Heating, Ventilation, and Air Conditioning systems (HVAC), (d) occupants and their activities (Fernandes et al. 2008). In Figure 9 below, we can see a visualization of indoor air pollutant sources in example spaces of a residential house.

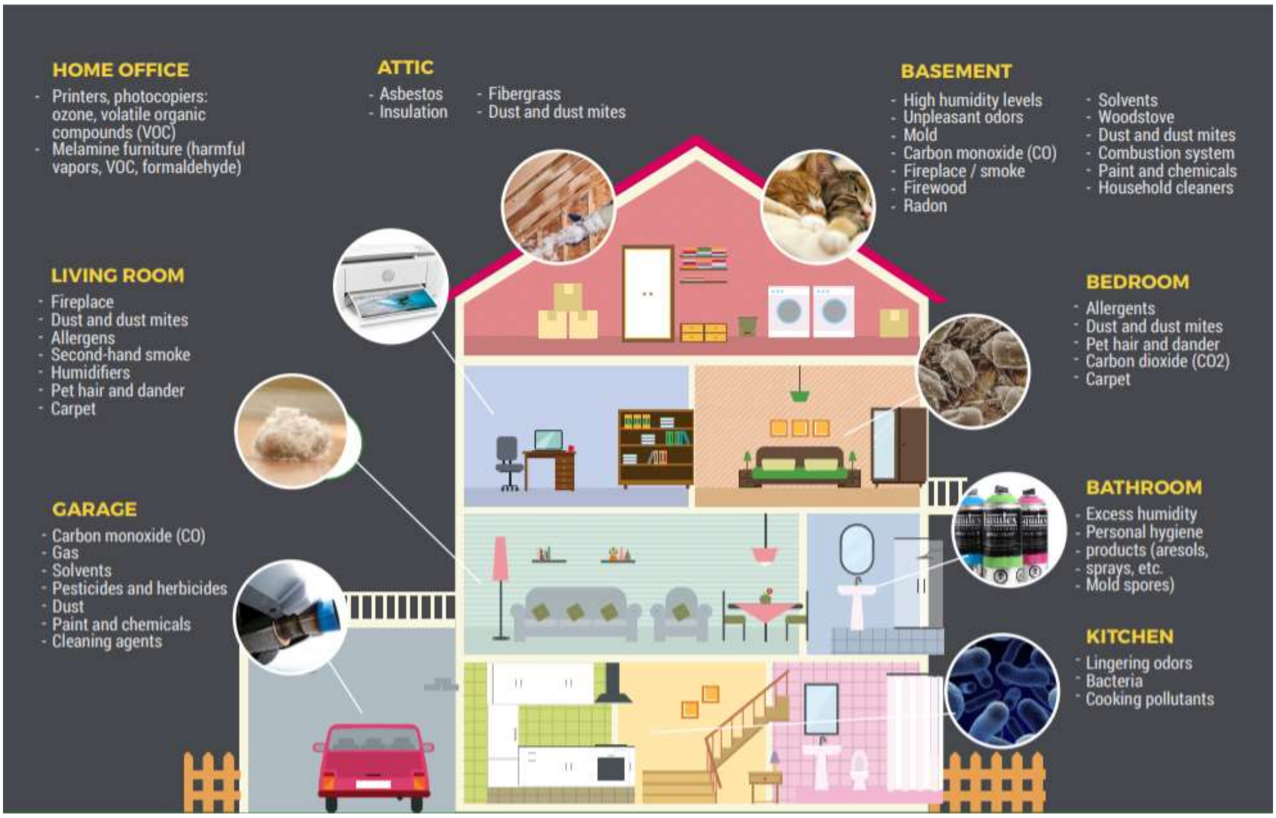


Figure 9 Visualization of indoor air pollutant sources in example spaces of a residential house (source: Yellowblue 2020)

5.1 Building materials and furnishing

The building materials and furnishing are a source of indoor air pollutants that influence the Indoor Air Quality (IAQ) and contribute to emissions of mostly volatile organic compounds (VOCs) and Formaldehyde (Zhuo 2018). In everyday life we experience a high concentration of VOCs in the indoor air with the comment ‘smells like new’ when we enter a new building or a car. In the case of building materials and furnishing, we can classify the emissions into two categories (a) the primary ones and (b) the secondary ones. A primary emission can be defined as a release of compounds which is already present in a material. Secondary emissions are those which are released as a product of chemical reactions between materials or in general the indoor environment (Uhde et al. 2007). The primary emissions are at their highest-level right after manufacture, and they reduce approximately 60 to 70% during half-year time (Šeduikyte et al. 2005). The large ratio surface-to-volume is a characteristic of building materials that can become a major factor of indoor air quality through several mechanisms, such as sorption and oxidate reactions (Rivas et al. 2019). Another important characteristic of the building materials and furnishing is that they emit pollutants themselves, but they can also operate like storage areas of different particles and gases pollutants from other sources (Šeduikyte et al. 2005). Figure 10 describes the generation of primary and secondary emissions from building products.

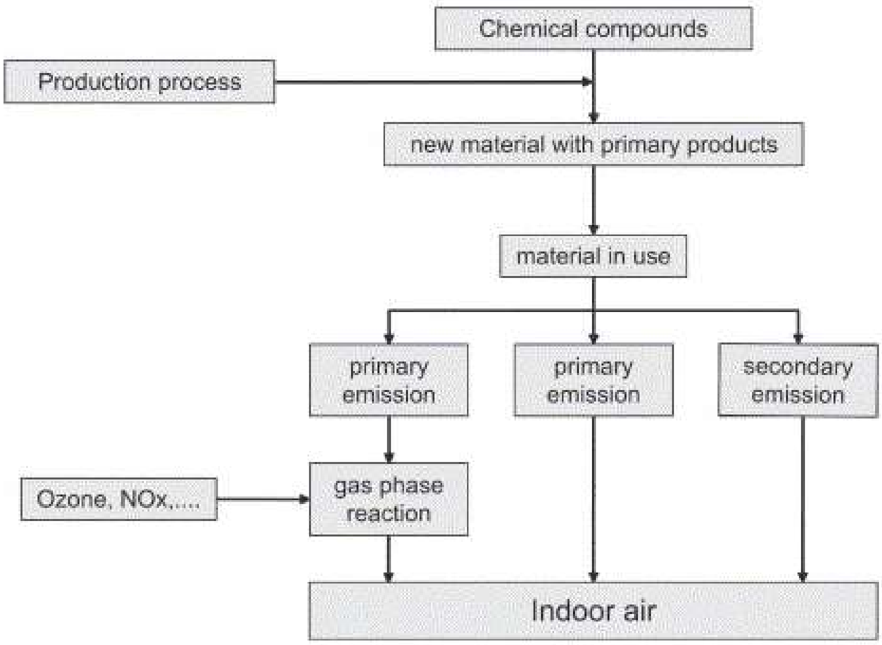


Figure 10 The generation of primary and secondary emissions from building products (source: Uhde et. al 2007)

According to EPA, the following building materials categories should be carefully considered to achieve good indoor air quality in a building:

(a) Flooring. Most common are carpets and resilient floors.
(b) Wall and Ceiling Materials. For example, wall panels, suspended ceiling tiles, surface mounted varieties of them.
(c) Paints and Coatings. Recently available "Zero-VOC" or "low-VOC" paints which reduce some of the indoor air pollution load.
(d) Adhesives and Sealants. For example, bonding agents, caulking, grouts.

(e) Engineered Wood Products. Numerous applications of pressed wood products like plywood, particleboard, and medium-density fiberboard (MDF).

Table 9 Indoor air pollutants from building material sources and their effects on human health (source: Wagdi 2015)

Pollutant	Health Effect	Building Material Sources
1. Volatile Organic Compounds (VOC)	ENT irritations and respiratory tract lesions, some types are carcinogenic	Rubber flooring, adhesives, particleboard and plywood, paints and coatings
2. Formaldehyde HCHO	Nausea, fatigue ENT and skin irritations, carcinogen	Plywood, particleboard, insulation materials, paints
3. Radon	Lung Cancer	Soil and building materials (marble, granite, bricks, ceramic tiles)
4. Ammonia NH_3	ENT irritation; aggravation of chronic respiratory diseases	Concrete and Floor Structures
5. PM 2.5 6. PM 10	Cancer Allergic Symptoms	Carpeting Gypsum board & concrete

5.2 Household and consumer products

Many household and consumer products may produce chemical compounds emissions or particles which can be absorbed by the human body mainly through inhalation (Europe 2022). To identify those products that could work as indoor air pollution sources, the chemical composition emitted should be examined (Kwon et al. 2008). Household products can be characterized as intense VOCs emitting indoor sources (Harb et al. 2020). Similarly, as described in the previous paragraph, household products have primary and secondary emissions. The secondary emissions are the product of interaction with other reactive species like ozone (Eichler et al. 2020).

Some characteristic examples of VOC-emitting consumer products that are to be found in many households, are (McDonald et al. 2018):

- Shampoo
- Hairspray
- Deodorant
- Perfume
- Air fresheners
- Cleaning sprays

- Laundry detergent
- Disinfectant wipes
- Hand sanitizer
- Glue
- Pesticides (EPA 2021)
- Newspaper and journals (Fernandes et al. 2008)
- Electronic devices (Fernandes et al. 2008)

5.3 Heating, ventilation, and air conditioning systems (HVAC)

Besides indoor air pollution other potential sources are the heating, ventilation, and air conditioning systems ventilation systems. Studies have shown that in an HVAC system (Figure 11) could be a variety of sources that reduce the indoor air quality (Wargocki 2004). Sources could include biological growth and bioaerosol production because of moisture, supplied by air washers and water recirculating systems, badly designed humidifying systems that lack control of humidity, and poorly maintained cooling coils and drip pans (Batterman and Burge 1995). According to a study by Fanger, who collected data from 15 office buildings in 1988, the perceived pollution from ventilation systems can potentially produce up to 40% of the total pollution loads in indoor spaces (Fanger et al. 1988).

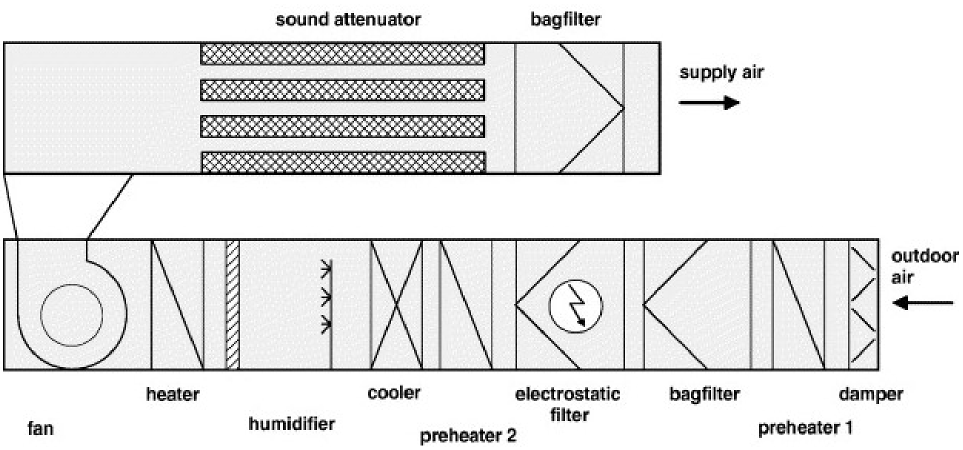


Figure 11. Central air-handling unit (source: Bitter and Fitzner 2002)

It is proven that components of an HVAC system contribute to the pollution of the passing air (Bluyssen et al. 2003). The filters, humidifiers, and rotary heat have the highest contribution to pollution (Bitter and Fitzner 2002).

The components of an HVAC system that work as integrated pollution sources can be:

- Low-quality outdoor air which is ventilated indoors.

- Contaminated ducts.

- Badly or poorly maintained dehumidifiers and humidifiers

- Rotary heat exchanges

- Poorly maintained filters

The type of construction, the use, and the maintenance of an HVAC system are the parameters that have an impact when defining the sources and reasons of pollution in an HVAC (Bluyssen et al. 2003).

5.4 Occupants and their activities

Human occupancy can contribute to indoor air quality, even if the occupants are not performing a high emitting activity (Rivas et al. 2019). Indoor air contaminants are generated also during various human activities like tobacco smoking, cooking, and emissions from a wide range of appliances (Nandan et al. 2021). We can safely conclude that the lifestyle, the routines, the usage of space, and in general the behavior of the occupants play a significant role to reduce or control emissions of pollutant sources indoors.

The occupants of a building interact with it in many ways, so it is only natural to contribute in various cases to the emissions of pollutants or the reduction of them. As an example, we can refer to the habit of tobacco smoking which contributes negatively to indoor air quality.

Is difficult to compare the relative importance of human activities in correlation with other sources of indoor air pollution. This is happening because in some cases the concentration of a pollutant shows for example high ratings during only the use of a product or a certain activity (Fernandes et al. 2008). Some activities, habits, or lifestyle decisions of occupants serve as indoor pollution sources and will be presented as follows.

- Cooking. During the activity of cooking, emissions could produce from two factors, the first is the cooking itself (ingredients and type of cuisine) and the second is the appliance we use to prepare the food (Kim et al. 2011). During cooking airborne particulate matter (PM) is produced from the fat, oil, or cooked food while frying, roasting, baking, etc. (Canada 2022). The type of appliance used is a strong determinant of the emissions. For example, a gas stove emits combustion by-products like carbon monoxide (CO) and nitrogen dioxide (NO_2) (CDC 2017). Excessive water vapor during cooking can lead to mold growth by increasing the amount of moisture in the air (Mold 2021).

- Cleaning. The usage of cleaning products acts as an emitting source of chemical pollutants mainly VOCs (Dimitroulopoulou et al. 2015). The act of vacuuming contributes also to the increase of indoor particle concentration (Corsi et al. 2008).

- Heating. Different heating systems influence the quality of indoor air in comparison with the fuel they use (combustion by-products). As a general comment, we can add that in residential houses with coal-burning or open fireplaces the concentration of carbon monoxide is high (Moriske 1996).

- Smoking. This source of emissions applies not only to tobacco smoking products but also to the nowadays widely used electronic cigarettes (e-cigarettes). A wide range of studies have indicated that smoke contains a wide range of compounds that transform into harmful pollutants during the act of smoking (Masjedi et al. 2019). Pollutants like particulate matter (PM10, PM2.5), volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NOx), etc.

- Plants and animals. Although studies have shown that indoor plants can reduce some types of air pollution in an urban environment (Han et al. 2020), according to the CDC they can be sources of indoor biologic pollutants. Pet animals could be also a source of indoor air pollution mostly allergens as the American lung association informs.

- Human themselves. The human body can serve as a source of chemicals and gas emissions. The most notable of them is the emission of CO_2, which follows water vapor and biological agents (Tsakas 2011). Human occupancy contributes also to indoor air quality. Studies have shown that occupancy rates are correlated with an increase of CO_2 and airborne bacteria (Ponsoni et al. 2010).

- Office equipment. Computers, printers and photocopiers are source of VOCs, particles, ozone etc. (Destaillats et al. 2008).

As a general comment, the houses and the workplace (or school) maybe be the most frequent indoor environments where we pass our everyday time. Apart from them, exist also other establishments which we visit for relatively shorter periods such as restaurants, hair salons, fitness centers, etc. Those environments potentially contribute also to exposure of humans to air pollutants in high concentrations.

6 DESIGN PARAMETERS AND METHODS FOR INDOOR AIR QUALITY

Indoor air quality (IAQ) should be assessed for public health concerns as it relates to matters like performance and productivity in workplaces, thinking well in a school environment, and feeling well in residential status.

This chapter will present an overview of national (Austrian) and international standards, guidelines, and technical requirements for indoor air quality and give best practice recommendations for the architects and engineers on heating and ventilation in case of new build projects and cases of renovations or upgrades in already existing buildings.

In the previous chapters, we presented information regarding the possible health risks from low indoor air quality, the pollutants, and their sources. In this chapter we will bring to the spotlight strategies that can be used to create and maintaining good indoor air quality. Those strategies follow three dependent points: (a) efficient ventilation and supply of clean fresh air, (b) selection of building materials with low pollutant emissions (mainly VOCs), and (c) usage of entry/exit air filters to control the dust and dirt infiltration into a building.

For the base structure of chapter 4, the Austrian Norm: ÖNORM 16798-1:2019 was used. Using the national (Austrian) standards for indoor air quality as a ‘case study’ helps to build a steady knowledge pool to explore further international guidelines and standards.

Annex 1. Factors taken into account in different methods of expressing IAQ. Table 1.1.

6.1 Efficient ventilation and supply of clean fresh air

Ventilation in a building could be provided through mechanical or natural means. The target of ventilation is to supply sufficient clean air to occupants for breathing (Shu et al. 2021). For the ventilation of a building, an architect or an engineer has to choose between three main design strategies.

-Natural ventilation concept

-Mechanical ventilation concept

-Hybrid ventilation concept. A mix of natural and mechanical ventilation.

According to ÖNORM EN 16798-1:2019, the ventilation flow rates should be used for the specification of any type of the three above-mentioned ventilation concepts. The design parameters for indoor air quality can be defined using one or even more from the following methods:

-1: Based on perceived air quality.

-2: Using limit values for substance concentration.

-3: Based on predefined ventilated airflow rates.

In the Austrian standard ÖNORM EN 16798-1:2019, the default input values are given for different categories of indoor air quality. The four categories presented in Table 10 are related to the level of expectations the occupants may have. A typical value would be category II – Medium, with a higher category to be selected for specific groups like children or the elderly.

Table 10. Categories of indoor environment quality Source EN 16798-1:2019

Category	Level of expectation
IEQI	High
IEQII	Medium
IEQIII	Moderate
IEQIV	Low
NOTE: In the tables only the category numbers are used without the IEQx symbols.	

6.2 Method 1 Based on perceived air quality

Using method 1 the total ventilation rate for the breathing zone is the result of the following equation, Formula (1), that combines the ventilation rate for occupancy per person and the ventilation rate for building emissions. The ventilation is the sum of these two components.

$$q_{tot} = n \cdot q_p + A_R \cdot q_B$$

Where:

q_{tot} = total ventilation rate for the breathing zone, l/s

n = design value for the number of persons in room

q_p = ventilation rate for occupancy per person, l/(s person)

A_R = floor area, m^2

q_B = ventilation rate for emissions from building, i/(s· m^2)

According to the standard ÖNORM EN 16798-1: 2019. '*The perceived air quality levels are defined by default for non-adapted persons in non-residential buildings and adapted persons in residential buildings. In non-residential buildings, assuming adapted persons shall be justified*'.

As Formula (1) indicates the design ventilation rate of method 1 has two components. The first one is the ventilation needed to remove pollution from the occupants and the second is the ventilation needed to remove pollution from the building.

The first component, value q_p can be extracted from Table 11 below.

Table 11 Design ventilation rates for sedentary, adults, non-adapted persons for diluting emissions (bio effluents) from people for different categories (source: EN 16798-1:2019)

Category	**Expected Percentage Dissatisfied**	**Airflow per non-adapted person l (s per person)**
I	15	10
II	20	7
III	30	4
IV	40	2.5

The second component, value q_B can be extracted from Table 12 below.

Table 12 Design ventilation rates for diluting emissions from different type of buildings (source EN 16798-1:2019)

Category	**Very low polluting building, LPB-1 l/ (sm^2)**	**Very low polluting building, LPB-2 l/ (sm^2)**	**Very low polluting building, LPB-2 l/ (sm^2)**
I	0.5	1.0	2.0
II	0.35	0.7	1.4
III	0.2	0.4	0.8
IV	0.15	0.3	0.6

To use Table 12 above the category of the building needs to be defined. The definition of a building of low or very low polluting, depends on the interior materials in use. Low and very low emitting materials are for example glass, ceramics, and stone. The standard requires a minimum of 4 l/s person for total ventilation (q_{tot}).

EU-project on ventilation and health In Table 13 below illustrate the criteria for different building types. *'R-value includes the pollutants with limit values that have been identified'.*

Table 13 Criteria for the different building types (source EN 16798-1:2019)

Source	**Low emitting products for low polluted buildings**	**Very low emitting products for very low polluted buildings**
Total VOCs TVOC (as in EN 16516)	< 1000 µg/m^3	< 300 µg/m^3
Formaldehyde	< 100 µg/m^3	< 30 µg/m^3
Any C1A or C1B classified carcinogenic VOC	< 5 µg/m^3	< 5 µg/m^3
R value (as EN 16516)	< 1.0	< 1.0

The standards recognize compliance if a test report from an EN ISO/IEC 17025 accredited laboratory is presented.

Follows example of default design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (non-adapted person), Table 14.

Table 14 default design ventilation air flow rates for a single-person office of 10 m^2 in a low polluting building (non-adapted person) (source: ISO/TR 17772-2:2018)

Category	**Low polluting building l / (s m2)**	**Airflow per non-adapted l / (s per person)**	**Total design ventilation air flow rate for the room expressed in different ways**		
			l/s	**L / (s per person)**	**L / (s m2)**
I	1.0	10	20	20	2
II	0.7	7	14	14	1.4
III	0.4	4	8	8	0.8
IV	0.3	2.5	5.5	5.5	0.55

In Annex 2 we present some examples of total ventilation rates for non-residential and non-industrial buildings. The default occupancy densities are categorized for non-adapted (Table 2.1) and for adapted persons (Table 2.2).

Using Tables 2.1 and 2.2 is possible to calculate values of q_B (l/s) for a specific room, for example a classroom of 50 m^2. The default value is 2 m^2 of floor area per person, that means we calculate 25 persons for the classroom.

Using the area (50 m^2) of a classroom with for example Table 2.1 for non-adaptive persons we receive values of q_B in l/s. The liters per second could be expressed in cubic meters per hour (m^3/h) by multiply them with 3.6.

1 l/s = 3.6 m^3/h.

The calculation for a low polluted building gives the following results illustrated in Table 15.

Table 15 Calculation of low polluted building (source: ISO/TR 17772-2:2018)

	q_B for a classroom of 50 m^2	
	Low polluted building	
Category	**l/s**	**m^3 / h**
I	50	180
II	35	126
III	20	72
IV	15	54

The calculation continues with finding the q_p value for both non-adapted and adapted persons using Tables 2.1 and 2.2. This time we multiply the 25 persons value with the default values of the two tables mentioned to come to results as illustrated in Table 16 below. Person component of ventilation air flow rate for adapted and non-adapted persons and different categories of buildings (Table 16).

Table 16 Person component of ventilation air flow rate for adapted and non-adapted persons and different categories of buildings (source: ISO/TR 17772-2:2018)

	q_p for 25 persons in a classroom			
	Non adapted		Adapted	
Category	l/s	m^3/h	l/s	m^3/h
I	250	900	87.5	315
II	175	630	62.5	225
III	100	360	37.5	135
IV	62.5	225	25	90

As next step, the airflow has to be summed with the airflow for building surface. Results for characterized low polluted buildings are illustrated in Table 17, total ventilation air flow rate for a classroom of a low polluted building.

Table 17 Results of characterized low polluted buildings (source: ISO/TR 17772-2:2018)

q_{tot} (q_p + q_B) for all students and classroom surface							
Category	q_B	Non adapted			Adapted		
	m^3/h	q_p m^3/h	q_{tot} m^3/h	l/s per person	q_p m^3/h	q_{tot} m^3/h	l/s per person
I	180	900	1080	12	315	495	5.5
II	126	630	756	8.4	225	351	3.9
III	72	360	432	4.8	135	207	2.3
IV	54	225	279	3.1	90	144	1.6
Values l/s per person which are under 4 l/s person have to be increased in minimum value							

Performing the above calculations and steps an overview of method 1 is achieved.

6.3 Method 2 Using criteria for individual substances

In this method, the requirements of the ventilation rate to dilute an individual substance are presented from the following equation, Formula (2).

$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon_V}$$

Where:

Q_h is the ventilation rate required for dilution, in m^3/s;

G_h is the generation rate of the substance, in µg/s;

$C_{h,i}$ is the guideline value of the substance, in µg/m^3;

$C_{h,o}$ is the concentration of the substance of the supply air, in µg/m^3;

ε_v is the ventilation effectiveness.

The default values of $C_{h,i}$ for CO_2 are as follow in Table 18 and for other substances Table 19, according to WHO.

$C_{h,i}$ and $C_{h,o}$ can be also expressed in ppm*10^6 (vol/vol), if this is the case then G_h should be in l/s.

The ventilation effectiveness can be either calculated according to ÖNORM EN 16798-3: 2017 by the equation, Formula (3), or its default value of 1 (for assumption of complete mixing) can be used.

'The ventilation effectiveness depends on individual design aspects and might change depending on temperature, air volume flow, air distribution and thermal loads.'

Table 18 Default design CO2 concentrations above outdoor concentration assuming a standard CO2 emission of 20 L/ (h per person) (source: EN 16798-1:2019)

Category	**Corresponding CO_2 concentration above outdoors in PPM for non-adapted persons**
I	550 (10)
II	800 (7)
III	1350 (4)
IV	1350 (4)

Table 19 Pollutants according to WHO Indoor Air Quality guidelines 2010 and WHO Air Quality guidelines 2005 (source: WHO 2010)

Pollutant	WHO Indoor Air Quality guidelines 2010	WHO Air Quality guidelines 2005
Benzene	No safe level can be determined	-
Carbon monoxide	15 min mcan: 100 mg/m^3 1 h mean:35 mg/m^3 8h mean: 10 mg/m^3 24h mean: 7 mg/m^3	-
Formaldehyde	30 min mean: 100 µg/m^3	-
Naphthalene	1 h mean: 200 µg/m^3	-
Nitrogen dioxide	1 h mean: 200 µg/m^3 Annual mean: 20 µg/m^3	-
Polyaromatic Hydrocarbons (c.g. Benzo Pyrene AB [a] P)	No safe level can be determined	-
Radon	100 Bq/m^3, (sometimes 300 µg/m^3 country specific)	-
Trichlorethylene	No safe level can be determined	-
Tetrachloroethylene	Annual mean: 250 µg/m^3	-
Sulfure dioxide	-	10 min mean: 500 µg/m3 24 h mean: 20 µg/m^3
Ozone	-	8 h mean: 100 µg/m^3
Particulate Matter PM 2.5	-	24 h mean: 25 µg/m^3 Annual mean: 10 µg/m^3

Table 19 Continued

Particulate Matter PM10	-	24 h mean: 50 µg/m^3 Annual mean: 20 µg/m^3

Ventilation effectiveness (Ɛv) can be calculated from the following equation, Formula (3)

$$\varepsilon_v = \frac{C_e - C_s}{C_i - C_s}$$

Where:

Ɛv is the ventilation effectiveness.

C_e is the pollutant concentration in extract air.

C_s is the pollutant concentration in supply air.

C_i is the pollutant concentration at breathing level

6.4 Method 3 Based on predefined ventilation airflow rates

This method uses predefined ventilation airflow rates, which are expressed from one or more of the following parameters:

-Total design ventilation for people and building components (q_{tot})

-Design ventilation per unit floor area (q_{m^2})

-Design ventilation per person (q_p)

-Design air changes rates (ach)

-Design air flow rates by room and building type (q_{room})

A way to express the design ventilation airflow rates is as a required rate per person (l/(s per person)) or as a required rate per m^2 floor area (l/(s m2). If both are given, the designer must choose the higher ventilation rate between them. Table 20 shows ventilation airflow rates for an office, for the category of non-adapted persons.

Table 20 Default predefined design ventilation air flow rates for an office (un-adapted person) (source: EN 16798-1:2019)

Category	**Total design ventilation air flow rate for the room (office)**	
	l / (s per person)	**l / (s m^2)**
I	20	2
II	14	1.4
III	8	0.8
IV	5.5	0.55

Ventilation air flow rate during un-occupied periods according to ÖNORM EN 16798-1:2019 has two default rates depending on the fact if the ventilation was completely shut down, then has a value of 1 volume within 2 hours, or if the ventilation was in un-occupied operation mode, then the total air flow rate for diluting emissions should be 0.15l/s m^2 of floor area in all rooms.

Default values of supply air flow rates for residential buildings (Table 21).

Table 21 Criteria based on pre-defined supply ventilation air flow rates: Total ventilation (1), supply air flow (2) and (3) (source: EN 16798-1: 2019)

Category	Total ventilation including air infiltration (1)		Supply air flow per. person* (2)	Supply air flow based on perceived IAQ for adapted persons (3)	
	l/s m²	ach	l/s (per person)	q_p l/s (per person)	q_B l/ s m²
I	0.49	0.7	10	3.5	0.25
II	0.42	0.6	7	2.5	0.15
III	0.35	0.5	4	1.5	0.1
IV	0.23	0.4			
*Supply air flow for method 3 is based on Formula (1)					

Criteria of default values of extract air flow rates for residential buildings (Table 22, Table 23) by room q_{room}.

Table 22 Design air flow rates by room and building type (qroom) (source: EN 16798-1: 2019)

Number of main rooms in the dwelling	Design extract air flow rates l/s				
	Kitchen	Bathrooms	Other wet room	Toilets	
				Single in dwelling	Multiple (2 or more) in dwelling
1	20	10	10	10	10
2	25	10	10	10	10
3	30	15	10	10	10
4	25	15	10	15	10
5 and more	40	15	10	15	10

By define the category of a building we could proceed further to calculation. The values of Table 22 have to be multiplied accordingly with values of Table 23.

Table 23 Airflow rates (source: EN 16798-1: 2019)

Category	**Airflow rated defined in Table 22 multiplies by**
I	1.4
II	1
III	0.7
IV	0.5

Design opening areas for natural ventilation is also a criterion to predefined air flow rates of a residential building. Detailed procedure is part of ÖNORM EN 16798-7:2017. In this contribution is decided the details of the topic to stay out of scope. Briefly we mention that exist according to the 16798-7 standards two methods to calculate the air flows rates entering and leaving a building's envelope including the infiltration.

-Method 1. Estimate the air flow rates by taken into consideration detailed building's characteristics.

-Method 2. Defines rules which have to apply to a statistical approach. This could be based on calculations with method 1 or on measurements to extract the data.

In the Table 24 below we see an illustration of default parameters for extract and supply rooms of a residential building.

Table 24 Default parameters for extract and supply rooms of a residential building (source: EN 16798-1: 2019)

	Extract kitchen, bathroom and toilet (cm^2)	**Supply bedroom and living room (cm^2)**
Default design opening area	100 per room	60 per room

The standards of indoor air quality define design criteria for the levels of humidification and dehumidification. Commonly, the control of humidity is in use only for buildings of special usability like museums. The process of dehumidification is a highly energy consuming procedure, especially if we refer to buildings located in humid climates and are in need of a certain humidity setpoint (ASHRAE 2018).

Table 25 bellow shows some example values of recommended design criteria in percentage of relative humidity for occupied spaces, in case of de- or humidification systems are installed.

Table 25: Values of design criteria (source EN 16798-1: 2019)

Type of building/space	Category	Design relative humidity for dehumidification, %	Design relative humidity for humidification, %
Spaces where humidity criteria are set by human occupancy.	I	50	30
	II	60	25
	III	70	20
Special spaces like museums, churches, etc. may require other limits.			

Noticeable is that for some of the recommended air flow rates mentioned in this chapter, it is possible to increase the chance of 'too' dry air in very cold climates. This is the reason that humidity recovery is recommended for buildings of category I and II. More information and guidance are provided to the standard FprCEN/TR 16798-2.

6.5 Selection of building materials with low pollutant emissions

The choice of building materials can affect indoor air quality, in terms of source emissions control. To help the designer choose the correct type of building material, a variety of labeling and certification schemes for low emissions building material products and databases have been developed. In order for a material to be characterized as a low or very low emissions product, it has to be tested in accordance with international testing standards like CEN/TS 16516 or ISO 16000-3, ISO 16000-6, ISO 16000-9, ISO 16000-11. In the EU and worldwide several indoor air quality schemes, eco-labels and databases are officially recognized and demonstrate compliance with national or international directives. In Table 26 below we see some EU-listed eco-labels, in Table 27 examples of international eco-labels and, in Table 28 sectoral labels.

Table 26 EU-listed eco-labels (source: Ecolabel 2022)

European Union – Eco Labels	
Nordic Swan – Nordic countries	http://www.nordic-ecolabel.org/
Blue Angel – Germany	https://www.blauer-engel.de/
RAL – Germany	http://www.ral-guetezeichen.de
Bra Miljöval – Sweden	http://www.naturskyddsforeningen.se/bra-miljoval/
Millieukeur – Netherlands	http://www.milieukeur.nl
Umweltzeichen – Austria	http://www.umweltzeichen.at/cms/de/home/content.html
NF Environnement – France	http://www.marque-nf.com
Környezetbarát Termék – Hungary	http://www.kornyezetbarat-termek.hu/
Prijatel Okoliša – Croatia	http://www.mzoip.hr/
Environmentálne vhodný produkt – Slovakia	http://www.sazp.sk/public/index/go.php?id=1571
Ekologicky šetrné výrobky – Czech Republic	http://www.ekoznacka.cz

Table 27 International -Eco labels (source: Ecolabel 2022)

International – Eco Labels	
Nature Plus	http://www.natureplus.org/
Ecologo	https://www.ul.com/resources/ecologo-certification-program
Екологічна сертифікація – Ukraine	http://www.ecolabel.org.ua/
Green Label Scheme – Hong Kong	https://www.greencouncil.org/hkgls
China Environmental United Certification Centre (CEC) – China	http://en.mepcec.com/
Good Environmental Choice Australia (GECA) – Australia	http://www.geca.org.au
Eco Mark – Japan	http://www.ecomark.jp/
Korea Eco-label	http://el.keiti.re.kr/enservice/enindex.do

Table 28 Sectoral- Eco Labels (source: Ecolabel 2022)

Sectoral – Eco Labels	
Energy Star – EU	http://www.eu-energystar.org/
Energy Star US	https://www.energystar.gov/
Österreichisches Institut für Baubiologie und Bauökologie IBO – Austria	http://www.ibo.at
ÖkoControl – Germany	http://www.oekocontrol.com
BFRC – Windows UK	http://www.bfrc.org/
Wers – Windows Australia	http://www.wers.net/
TCO Certified – A global sustainability certification for IT products in offices and data centres	https://tcocertified.com/

Table 28 Continued

OEKO-TEX – international Textiles Association	https://www.oeko-tex.com
Ok-power – Germany	http://www.ok-power.de

Examples of databases mentioned in ISO 16814:2008 that have been developed to extra data about products emission characteristics on Table 29 as follows.

Table 29 Examples of databases (source: ISO 16814:2008)

Databases examples
SOPHIE, (outcome of the European's Commission JOULE programme). The database includes, building materials, furnishing and ventilation system components.
BRE, https://www.bregroup.com/
Danish society of Indoor Climate database, https://www.danskindustri.dk/
VVT Technical Research Centre of Finland database
'Source Ranking Database' program developed by US Environment Protection Agency, Indoor Air Source Characterization Project, https://www.epa.gov/
MEDB-IAQ, developed by National Research Council Institute for Research in Construction, in Canada and is a material emission database, supported also by indoor air quality simulation program, https://nrc.canada.ca/en/research-development/research-collaboration/research-centres/construction-research-centre

Annex 3 additional European eco-labels tables provided.

6.6 Usage of entry/exit air filters to control the dust and dirt infiltration

According to EPA research shows that filtration of the air can be an effective addition to source control and ventilation. Filtration offers the removal of possible contamination from the supply air and protection of mechanical ventilation components from particulate damage (Butcher et al. 2015). The actual European standard for air filters EN779:2012 classifies air filters based on their lowest filtration efficiency, referred as minimum efficiency (ME).

According to ÖNORM EN 16798-1: 2019 the filters can influence the quality of indoor air by:

- reducing the penetration of airborne pollutants like pollens, dust, particles, etc. in a building from the outdoor air.

- filtering secondary air through a filter reduces the concentration of pollutants in indoor air

The basic idea is to pass air through a filter that keeps the pollutant and distribute the filtered air to the occupied from human spaces. A large variety of filters that perform this duty exist, with some of them retaining only specific types of matter and others being able to reduce gaseous pollutants like carbon filters. Essential for the performance of filters is the correct maintenance and replacement of them when necessary. The correct specification and frequent replace of filters contribute according to ISO 16814:2008 to the following sectors:

- contribute to the system to operate steady with designed airflow as planed because the system is maintained clean.

- maintain the efficiency of the equipment

- reduce the entry, storage and growth of micro-organisms

- reduce the concentration levels of microbiological pollutants, pollens etc. in indoor air

- reduce outdoor and indoor contaminants in the air stream

- make the air visually and from a feeling aspect cleaner

- reduce the need of cleaning indoor spaces

- reduce the deposit of dust near electronic devices and equipment

A wide selection of different types of filters is available on the market. In this contribution, we briefly present the classification of filters, in order to give the designers and engineers an overview of the variety of products accessible on offer.

Types of air cleaner are to find in Annex 4.

Table 30 Classification of air filters according to ISO 21220

Class	**Final pressure crop Pa**	**Average arrestance of synthetic dust A_m %**	**Average efficiency of 0.4 µm particles E_m %**
G1	250	$50 \leq A_m < 65$	
G2	250	$65 \leq A_m < 80$	
G3	250	$85 \leq A_m < 90$	
G4	250	$90 \leq A_m$	
F4			$20 \leq E_m < 40$
F5	450		40 ≤ Em < 60
F6	450		60 ≤ Em < 80
F7	450		80 ≤ Em < 90
F8	450		90 ≤ Em < 95
F9	450		95 ≤ Em

The categories we witness in Table 30 above are classified are in correlation with the performance of a filter to maintain, to trap certain sizes of particles.

G1 until G4 filter can be characterized as gross ones. With average arrestance A_m between 50 and 65%.

Filters classified F5 and F6 are in recent standards referred to as M5 and M6, medium average efficiency E_m filters. F4 is a new category that could be characterized as medium class.

Filters F7 to F9 are fine filters of high efficiency.

Table 31 below corresponds to the classification according to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). In the US the standard has more subcategories something that provides flexibility of choice to the designer and larger practice pool.

Table 31 Classification of filters according to ASHRAE 52.2:2000

Group Member	**MERV**	**Average efficiency in size range %**			**Arrestance* %**	**Final pressure Pa**
		0.30μm to 1.0 μm	1.0μm to 3.0μm	3.0μm to 10μm		
1	1	-	-	$E_3 < 20$	$A_{avg} < 65$	75
	2	-	-	$E_3 < 20$	$65 \le A_{avg} < 70$	75
	3	-	-	$E_3 < 20$	$70 \le A_{avg} < 75$	75
	4	-	-	$E_3 < 20$	$75 \le A_{avg}$	75
2	5	-	-	$20 \le E_3 < 35$	-	150
	6	-	-	$35 \le E_3 < 50$	-	150
	7	-	-	$50 \le E_3 < 70$	-	150
	8	-	-	$70 \le E_3$	-	150
3	9	-	$E_2 < 50$	$85 \le E_3$	-	250
	10	-	$50 \le E_2 < 65$	$85 \le E_3$	-	250
	11	-	$65 \le E_2 < 80$	$85 \le E_3$	-	250
	12	-	$80 \le E_2$	$90 \le E_3$	-	250
4	13	$E_1 < 75$	$90 \le E_2$	$90 \le E_3$	-	350
	14	$75 \le E_1 < 85$	$90 \le E_2$	$90 \le E_3$	-	350
	15	$85 \le E_1 < 95$	$90 \le E_2$	$90 \le E_3$	-	350
	16	$90 \le E_1$	$90 \le E_2$	$90 \le E_3$	-	350
*Values are from ASHRAE 52.1: 1992						

If decided to use only one-step filter, then the minimum requirement is an F5 or MERV9. If the effectiveness of the removal needs to be higher because of the quality of outdoor air, for example in urban environments is very common the use of gas-phase filters, then these filters have to be protected from a fine filter of quality F6 or MERV11 as a minimum design choice.

Table 32 below shows the correspondence of filters with the desired level of practice.

Table 32: Correspondence of filters with the desired level of practice (source ÖNORM EN 16798-3: 2017 and ISO 16814:2008)

Level of practice	Protection of equipment	Increased IAQ
Very good	F7/MERV 13	F7/MERV 13 + F9/MERV 15
Good	F6/MERV 11	F5/MERV 9 + F8/MERV 14
Acceptable	G4/MERV 7	G4/MERV 11 + F7/MERV 13

Design guidelines on filtration are given in ÖNORM EN 16798-3: 2017 and ISO 16814:2008. Life cost analysis guidelines for calculation of the costs could be found in EUROVENT Rec 10-1999.

On Annex 5 are to find the test standards for different types of filters.

7 SAMPLING AND MONITORING OF INDOOR AIR QUALITY (IAQ)

After the application of an indoor air quality design in a building, the next step is to keep monitoring the quality levels of indoor air. A good design that offers high-quality indoor air is only successful if could provide this result constantly. Because a variety of research studies show that low air quality effects negative the users of an indoor environment, there is a growing demand for devices that measure and control indoor air quality (Kozicki and Nieslochowski 2020). According to WHO and European Commission during sampling outdoor or indoors some key pollutants as presented in Table 33 bellow have to be measured.

Table 33 Chemical, physical and comfort parameters, microbiological agents and allergens needs evaluation (source: Csobod et al. 2014)

Chemical parameters	**Physical and comfort parameters**	**Microbiological agents and allergens**
Formaldehyde	Temperature	Endotoxins
Benzene	Relative humidity	Fungal and bacteria DNA
Trichloroethylene	CO_2	Allergens
Tetrachloroethylene	Ventilation rate	
d-limonene, a-pinene		
Naphthalene		
NO_2		
$PM_{2.5}$, PM_{10}		
Ozone		
Benzopyrene		
CO		
Radon		

This chapter will briefly present the monitoring varieties of indoor air quality. Sensing techniques, variety of sensors, state of the art technologies, models, algorithms or guidelines like ISO 16000-1 that defines the way of installation of sampling equipment will not be analyzed. The target is to raise the reader's awareness of the monitoring types for indoor air quality. As mentioned previously, a good design in terms of high indoor air quality has to constantly supply 'fresh' and 'clean' air to the users of a building.

Parameters commonly analyzed for indoor air quality are PM2.5, PM10, CO, CO2, VOCs and NOx. Also, temperature and humidity are crucial parameters in terms of comfort. These parameters could be measured from a variety of sensors like laser, digital, and analog sensors (Saini et al. 2020). For long-term and continuous, real-time monitoring a promising alternative are also electronic gas sensors (Caron et al. 2016). In general, we could comment that the sector of a building automation is a huge technological application area which includes high diversity and great interaction with the users (Vázquez et al. 2013). Figure 12 shows a general architecture of a monitoring system of indoor air quality.

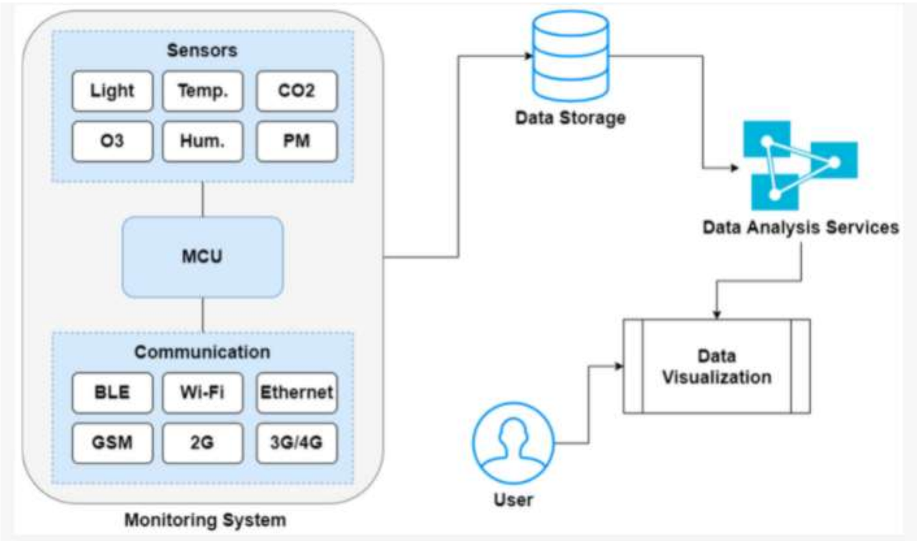


Figure 12 General architecture of IAQ monitoring system. Source: (Saini et al. 2020)

In Figure 12 above we present a monitoring system that includes a variety of IAQ sensors and microcontrollers (MCUs). The data collected are driven in data storages which could be online (cloud-based interface) or physical (hardware). The next step is to analyze the collected data and provide a visualization system for the user and the interest parties (Saini et al. 2020). With this process the maintenance of high indoor air quality, the optimization of users behavior and the general operation routines of a building can be improved. On Figure 13 we see a composition of multi-sensor device, which can provide data for different crucial indoor air quality parameters.

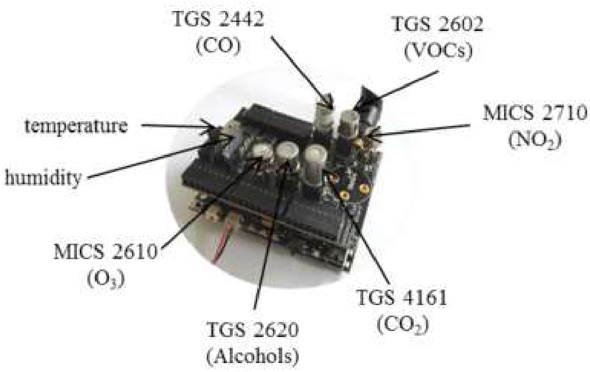


Figure 13 Composition of multi-sensor device (source: Caron et al. 2016)

According to EPA by placing sensors for monitoring the indoor air quality, as an engineer or an architect you have to consider the following parameters (EPA 2021).

-Location. Priority should be spaces that are most common used and populated.

-Access. This parameter refers mostly for sensors installed in public spaces. Sensors located in public spaces have to have restricted accessibility, in order to provide the needed data without interference. Access has to be provided for necessary maintenance.

-Power. Sensors have to be close to a power outlet and this outlet has to be pre-defined only for the supply of the sensor. Unwanted unplugging of the sensor may cause a loss of sampling data.

-Communications. Cellular communications, stable WiFi connection for some type of sensors has to be available, stable and secure.

-Security. Placing of sensors in visible mount positions, which could be helpful to recognize potential damage and avoiding tampering or theft.

-Placement. Near the breathing zone is the ideal position of IAQ sensors. Avoid placing near to air pollution sources like cooking areas. Placing near windows, doors, in areas with limited air circulation, with steep changes of humidity, sudden changes of temperature (ventilation duct) etc. should be avoided.

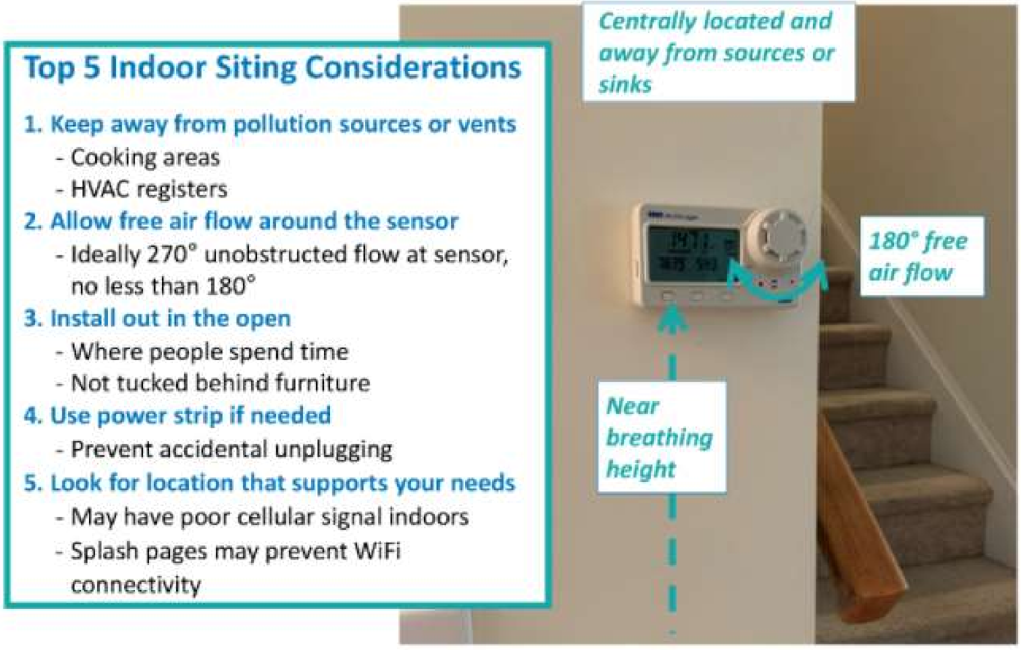


Figure 14 Top 5 indoor siting considerations of an IAQ sensor (source: Sensors 2021)

Apart from technological achievements via monitoring concepts in order to collect data of building's indoor air quality, another way to gather information, is to directly question the users and occupants of an indoor space through questionnaires. These questionnaires could be developed and specified according to the use of the building (school, office, etc.). The development of a questionnaires is out of the scope in this contribution, but an example of questionnaire's development for a school will follow for better understanding of this tool.

In presented example, the questionnaires where part of European Commission's project under SINPHONIE (Schools Indoor Pollution and Health Observatory Network in Europe), (Csobod et al. 2014). These questionnaires used as a base structure the standardized questionnaire of International Study of Asthma and Allergies in Childhood (ISSAC). The standardized ISSAC questionnaire is presented in Annex 6 (Asher et al. 1995).

The example is chosen since it puts into consideration the different user groups, that exist and work together direct or indirect in a school environment, the teachers, the children, and the parents. In our example five questionnaires were prepared, each for a target group and two additional for each monitored classroom and the whole school building.

-A questionnaire for the children, which was used to collect information like allergic symptoms or diseases they may experience and perceptions of indoor and outdoor quality.

-A questionnaire for parents, which was targeting the same information as the one for the children with additional questions for potential home risk factors, like for example smoking habits, heating appliances, pet keeping and familiarity with cases of allergic diseases. In the case of the questionnaire for the parents, the tool, worked like a self-administered document, that was developed to gather information for both life-long and recent symptoms by analyzing habits and lifestyles.

-A questionnaire for the teachers, that targets to gather information on allergic symptoms, diseases etc. and asked about their perceptions of air quality outside and inside of the school. Additional questions for the teachers were perceptions of influence on school performance related with the indoor air quality and also alike the one for the parents, questions for collection of information for home risk factors.

-A questionnaire about every monitored classroom was asked to be filled. This questionnaire focused also to a classification of building characteristic of each classroom, perceptions of indoor air quality, furnishing and cleaning procedures.

-A questionnaire about the school as a building system. Building characteristics, features of the ventilation system and equipment was asked to be completed by the school principal.

By analyzing this example, we can understand that a major amount of information data can be collected via questionnaires from different perspectives, because the users of a building spend their time indoors under different roles, which leads to different perceptions. The development of a questionnaire could focus on different target groups of users of a building for an overall overview of their opinion on the related topic.

More examples of questionnaires are to find in Annex 7.

8 DISCUSSION AND FUTURE RESEARCH

This contribution aimed to help the reader understand the importance of Indoor Air Quality (IAQ) and hopefully to raise their awareness to this important for the human health field. We started by introducing the pollutants and the sources of them in a building environment. We proceeded to explain the ways to counter the indoor air pollution and provide a healthier environment for the users with the guidance of Austrian and European standards. Finally, we described approaches to check the quality of the design and keep it in high levels through monitoring via sensors and questionnaires.

One of the differences noticed during exploring a variety of standards is that the US standard ASHRAE 10: 2016 integrates in the factors effecting the Indoor Air Quality perspectives like the illumination (Daylight and Electric) and acoustical environment. In the European standards they are part of Indoor Environmental Quality factors. ASHRAE investigates the lighting and acoustical aspects in terms of pollutants. For example, surfaces which get heated by direct solar penetration could increase the airborne distribution of organic contaminants of dust.

During the investigation of standards, we noticed that some standards mentioned some factors and provided default values that other standards did not took into consideration. As an example, the British standard BS 5925: 1991 which focused on ventilation principles and designing for natural ventilation introduces moisture generation rates. Default values are given in form of a table and moisture generation is categorized in three categories. These categories are: (a) moisture generation form household activities, (b) from heating fuels and, (c) from occupancy of the habitants (BSI 1991).

In general, the reading and understanding of the standards from a designer aspect is on one hand clear and well defined but on the other hand could be more user friendly. Of course, the standards need to be written in a clear and well-defined format but maybe a shorter or a more accessible version could help for some basic steps in terms of pre-calculations or during concept phase of a project. We could refer the green building certificates as a step to a visualization of the standards. The backbone of those certificates are national and international standards and during design phase could guide via a user-friendly environment the designer to choose accordingly his building characteristics and equipment.

This contribution aims to initiate discussion in terms of transparency, improvements in national/international building regulations standards. For example, we can mention that the government of Dubai has integrated several green building requirements as mandatory in its regulation for new residential and non-residential buildings (DCLD 2012). Future questions of interest on the matter could be:

-Are the minimum rates of Indoor Air Quality sufficient?

-Addition of more parameters into consideration?

-Should monitoring/sampling system of indoor air quality in buildings be obligatory?

-Expect the obvious advantages for the environment and occupants, what else can attract investors? Correlation between investment cost and productivity raise?

9 INDEX

9.1 List of Figures

9.2 List of Tables

LITERATURE

Allergies (2020)*: Allergic rhinitis and conjunctivitis: University of Iowa Hospitals & Clinics, [online] https://uihc.org/health-topics/allergic-rhinitis-and-conjunctivitis [abgerufen am 29.10.2021].*

*Asbestos (*2021): *Impact on Indoor Air Quality*: US EPA, [online] https://www.epa.gov/indoor-air-quality-iaq/asbestos-impact-indoor-air-quality [visited 02.01.2022].

Asher, M.I., U. Keil, U., Anderson, H.R., Beasley, R., Crane, J., Martinez, F., Mitchell, E.A., Pearce, N., Sibbald, B., A.W. Stewart, A.W., Strachan, D., Weiland, S.K. and Williams, H.C. (1995): *International study of asthma and allergies in childhood (ISAAC): rationale and methods*, in: European Respiratory Journal, Bd. 8, Nr. 3, S. 483–491, [online] doi:10.1183/09031936.95.08030483.

Asthma (2021): Asthma, informedhealth.org, [online] https://www.informedhealth.org/asthma.html [visited 01.11.2021].

Batterman, S. and Burge, H. (1995): *HVAC Systems As Emission Sources Affecting Indoor Air Quality*: A Critical Review, in: HVAC&R Research, Bd. 1, Nr. 1, S. 61–78, [online] doi:10.1080/10789669.1995.10391309.

Bernstein, J.A., Alexis, N., Bacchus, H., Bernstein, I.L., Fritz, P., Horner, E., Li, N., Mason, S., Nel, A., Oullette, J., Reijula, K., Reponen, T., Seltzer, J., Smith, A. and Tarlo, S.M. (2008): The health effects of nonindustrial indoor air pollution, in: Journal of Allergy and Clinical Immunology, Bd. 121, Nr. 3, S. 585–591, [online] doi:10.1016/j.jaci.2007.10.045.

BIS (1991): British Standard 5925:1991 Code of Practice for Ventilation Principles and Designing for Natural Ventilation, British Standards Institute, London, 1991.

Bitter, F., and Fitzner, K. (2002): *Odour emissions from an HVAC-system, in Energy and Buildings*, Bd. 34, Nr. 8, S. 809–816, [online] doi:10.1016/s0378-7788(02)00104-4.

Bluyssen, P.M., Cox, C., Seppänen, O., Fernandes, E., Clausen, G., Müller, B. and Roulet, C.A. (2003): *Why, when and how do HVAC-systems pollute the indoor environment and what to do about it? the European AIRLESS project*, in: Building and Environment, Bd. 38, Nr. 2, S. 209–225, [online] doi:10.1016/s0360-1323(02)00058-6.

Butcher, K. and Craig, B. (2015): *Environmental Design: CIBSE Guide A*, London, UK: Chartered Institution of Building Services Engineers.

Canada (1989): Federal-Provincial Advisory Committee on Environmental and Occupational Health (Canada)/Canada. Environmental Health Directorate/Federal-Provincial Advisory Committee on Environmental and Occupational Health (Canada)/Canada. *Environmental Health Directorate (1989): Exposure Guidelines for Residential Indoor Air Quality: A Report, Ottawa, Canada: Environmental Health Directorate*.

Canada (2021): Canada, Environment and Climate Change (o. D.): *Toxic substances list: PAHs - Canada.ca, official website of the Government of Canada*, [online] https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances/list-canadian-environmental-protection-act/polycyclic-aromatic-hydrocarbons.html [visited 08.12.2021].

Canada (2022): Health Canada (o. D.): Factsheet: *Cooking and indoor air quality* - Canada.ca, canada.ca, [online] https://www.canada.ca/en/health-canada/services/publications/healthy-living/factsheet-cooking-and-indoor-air-quality.html [visited 23.01.2022].

Caron, A., Redon, N., Thevenet, F., Hanoune, B. and Coddeville, P. (2016): *Performances and limitations of electronic gas sensors to investigate an indoor air quality event*, in: Building and Environment, Bd. 107, S. 19–28, [online] doi:10.1016/j.buildenv.2016.07.006.

Carrer, P., Maroni, M., Alcini, D. and Cavallo, D. (2001): *Allergens in indoor air: environmental assessment and health effects*, in: Science of The Total Environment, Bd. 270, Nr. 1–3, S. 33–42, [online] doi:10.1016/s0048-9697(00)00791-9.

CCOHS (2022): *Indoor Air Quality - Moulds and Fungi: OSH Answers (o. D.)*: Canadian Center of Occupational Health and Safety, [online]https://www.ccohs.ca/oshanswers/biol_hazards/iaq_mold.html [visited 01.01.2022].

CDC (1978): Occupational Health Guideline for Carbon Monoxide (o. D.): https://www.cdc.gov, [online] https://www.cdc.gov/niosh/docs/81-123/pdfs/0105.pdf [visited 18.04.2022].

CDC (2017): LEGIONNAIRES' DISEASE (o. D.): CDC, [online] https://www.cdc.gov/legionella/downloads/fs-legionnaires.pdf [visited 18.04.2022].

CDC (2021): *Indoor Environmental Quality | NIOSH | CDC (o. D.)*: Centers for Disease Control and Prevention, [online] https://www.cdc.gov/niosh/topics/indoorenv/default.html [visited 05.11.2021].

CDC (2021a): Facts About Benzene (o.D.): CDC, [online] https://emergency.cdc.gov/agent/benzene/basics/facts.asp [visited 04.01.2022].

Colorado (2016): *Colorado Allergy & Asthma Centers*, P.C., [online] https://coloradoallergy.com [visited 01.11.2021].

Corsi, R.L., Siegel, J.A. and Chiang, C. (2008): *Particle Resuspension During the Use of Vacuum Cleaners on Residential Carpet*, in: Journal of Occupational and Environmental Hygiene, Bd. 5, Nr. 4, S. 232–238, [online] doi:10.1080/15459620801901165.

Costabel, U. (2020): *Hypersensitivity pneumonitis*, Nature Reviews Disease Primers, [online] https://www.nature.com/articles/s41572-020-0191-z?error=cookies_not_supported&code=5c6abbaf-9611-4880-ba02-5f182c0bbcf1 [visited 29.10.2021].

Csobod, É. (2014): Schools *Indoor Pollution and Health: Observatory Network in Europe/Europäische Kommission* (2014): Final Report, Stuttgart, Deutschland: UTB.

DAWE (2022): Lead - DAWE (o. D.): https://www.awe.gov.au/, [online] https://www.awe.gov.au/environment/protection/chemicals-management/lead [visited 02.01.2022].

DCLD (2012): Government of Dubai. Manual of Green Building Materials, Products & Their Testing Facilities. Retrieved March 2021, from: ManualofGreenBuildingMaterialsproductsitstestignfacilities-updated_version.ashx (dewa.gov.ae)

Destaillats, H., Maddalena, R.L., Singer, B.C., Hodgson, A.T. and McKone, T.E. (2008): *Indoor pollutants emitted by office equipment: A review of reported data and information needs*, in: Atmospheric Environment, Bd. 42, Nr. 7, S. 1371–1388, [online] doi:10.1016/j.atmosenv.2007.10.080.

Dimitroulopoulou, C., Trantallidi, M., Carrer, P., Efthimiou, G.C. and Bartzis, J.G. (2015): *EPHECT II: Exposure assessment to household consumer products*, in: Science of The Total Environment, Bd. 536, S. 890–902, [online] doi:10.1016/j.scitotenv.2015.05.138.

Diseases U.S. (2016): TABLE 2h. *Reported cases of notifiable diseases, by region and reporting area - United States and U.S. territories*, (o. D.): https://wonder.cdc.gov, [online] https://wonder.cdc.gov/nndss/static/2016/annual/2016-table2h.html [visited 29.10.2021].

E.C. (1990): European Commission/Joint Research Centre: European Collaborative Action „Indoor Air Quality and Its Impact on Man“: Report No. 7 *Indoor Air Pollution by Formaldehyde in European Countries, Brussels-Luxembourg, Belgium-Luxembourg: OPOCE*.

Ecolabel (2022): EU Ecolabel - Environment - European Commission (o. D.): ec.europa.eu, [online] https://ec.europa.eu/environment/ecolabel/ [visited 13.02.2022].

Edwards, J.H., Harbord, P., Skidmore, J.W., Mullins, J., Davies, B.H., Seaton, A. and Cotes, J.E. (1977): Report of a symposium held on 14 and 15 December 1976 at the Medical Research Council Pneumoconiosis Unit, Cardiff, sponsored by the Medical Research Council, UK. [online] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC470808/

Eichler, C.M.A., Cohen Hubal, E.A., Xu, Y., Cao, J., Bi, C., Weschler, C.J., Salthammer, T., Morrison, G.C., Koivisto, A.J., Zhang, Y., Mandin, C., Wei, W., Blondeau, P., Poppendieck, D., Liu, X., Delmaar, C.J.E., Fantke, P., Jolliet, O., Shin, HM., Diamond, M.L., Shiraiwa, M., Zuend, A., Hopke, P.K., Goetz, N., Kulmala, M. and Little, J.C. (2020): *Assessing Human Exposure to SVOCs in Materials, Products, and Articles: A Modular Mechanistic Framework*, in Environmental Science & Technology, Bd. 55, Nr. 1, S. 25–43, [online] doi:10.1021/acs.est.0c02329.

Emory (2022): Emory University Environmental Health & Safety Office (o. D.): https://www.ehso.emory.edu/, [online] https://www.ehso.emory.edu/ [visited 10.03.2022].

EPA (1989): U.S. Environmental Protection Agency (EPA). *Report to Congress on indoor air quality 1989*; Volume2: EPA/400/1-89/001C. Washington, DC

EPA (1991): United States. *Environmental Protection Agency. Office of Air and Radiation/United States. Environmental Protection Agency. Office of Air and Radiation* (1991): Indoor Air Facts, No. 4: Sick Building Syndrome, [online] https://www.gov/sites/default/files/2014-08/documents/sick_building_factsheet.pdf.

EPA (2021): *Controlling Pollutants and Sources: Indoor Air Quality Design Tools for Schools* (2021): US EPA, [online] https://www.epa.gov/iaq-schools/controlling-pollutants-and-sources-indoor-air-quality-design-tools-schools#Categories [visited 15.01.2022].

EPA (2021a): *Carbon Monoxide's Impact on Indoor Air Quality* (2021): US EPA, [online] https://www.epa.gov/indoor-air-quality-iaq/carbon-monoxides-impact-indoor-air-quality [visited 26.11.2021].

EPA (2021b): *Improving Indoor Air Quality* (2021): US EPA, [online] https://www.epa.gov/indoor-air-quality-iaq/improving-indoor-air-quality [visited 01.01.2022].

Erdmann, C., A. and Apte, M.G. (2004): *Mucous membrane and lower respiratory building-related symptoms in relation to indoor carbon dioxide concentrations in the 100-building BASE dataset, in Indoor Air*, Bd. 14, Nr. s8, S. 127–134, [online] doi:10.1111/j.1600-0668.2004.00298.x.

Europe (2022): *Indoor Air Quality: 7. What household chemicals and products can pollute indoor air? (o. D.)*: ec.Europa.eu, [online] https://ec.europa.eu/health/scientific_committees/opinions_layman/en/indoor-air-pollution/l-2/7-household-sources.htm [abgerufen am 16.01.2022].

Fanger, P.O., Lauridsen, J., Bluyssen, P. and Clausen, G. (1988): *Air pollution sources in offices and assembly halls, quantified by the olf unit, in: Energy and Buildings*, Bd. 12, Nr. 1, S. 7–19, [online] doi:10.1016/0378-7788(88)90052-7.

Fernandes, E., Gustafsson, H., Seppanen, O., Crump, D. and Ventura Silva, G. (2008). ENVIE Co-ordination action on indoor air quality and health effects; WP3 Final report – Characterisation of spaces and source. November 2017, 1–49. https://doi.org/10.13140/RG.2.2.26022.42567

Formaldehyde (2021): American Cancer Society, [online] https://www.cancer.org/cancer/cancer-causes/formaldehyde.html [visited 08.12.2021].

GBC (2022): USGBC homepage | U.S. Green Building Council (o. D.): https://www.usgbc.org/, [online] https://www.usgbc.org/ [abgerufen am 18.04.2022].

Gerardi D. (2010): *Building-related illness*. Clin. Pulm. Med. 2010; 17:276–281. doi:10.1097/CPM.0b013e3181fa1448.

Haleem Khan, A.A. and Karuppayil, S.M. (2012): *Fungal pollution of indoor environments and its management*, in: Saudi Journal of Biological Sciences, Bd. 19, Nr. 4, S. 405–426, [online] doi:10.1016/j.sjbs.2012.06.002.

Han, K.T. and Li-Wen, R. (2020): *Effects of indoor plants on air quality: a systematic review*, in: Environmental Science and Pollution Research, Bd. 27, Nr. 14, S. 16019–16051, [online] doi:10.1007/s11356-020-08174-9.

Harb, P., Locoge, N. and Thevenet, F. (2020): *Treatment of household product emissions in indoor air: Real scale assessment of the removal processes*, in: Chemical Engineering Journal, Bd. 380, S. 122525, [online] doi:10.1016/j.cej.2019.122525.

IAEA (2015): International Atomic Energy Agency/International Atomic Energy Agency: *Protection of the Public Against Exposure Indoors Due to Radon and Other Natural Resources of Radiation*: Specific Safety Guide, Vienna, Austria: International Atomic Energy Agency.

IARC (1988): The International Agency for Research on: *Man-Made Mineral Fibres and Radon. Vol 43 (Iarc Monographs on the Evaluation of the Carcinogenic Risks to Humans*, Band 43), Lyon, France: WORLD HEALTH ORGN.

Jantunen, M., Jaakkola, J. and Krzyzanowski, M. (1997): World Health Organization. Regional Office for Europe: *Assessment of Exposure to Indoor Air Pollutants*, Copenhagen, Denmark: World Health Organization, Regional Office for Europe.

Karol, M.H. (1991): *Allergic reactions to indoor air pollutants.*, in Environmental Health Perspectives, Bd. 95, S. 45–51, [online] doi:10.1289/ehp.919545.

Kim, KH., Pandey, S.K., Kabir, E., Susaya, J./Richard J.C. Brown (2011): *The modern paradox of unregulated cooking activities and indoor air quality*, in: Journal of Hazardous Materials, Bd. 195, S. 1–10, [online] doi:10.1016/j.jhazmat.2011.08.037.

Kozicki, M. and Nieslochowski, A. (2020): *Materials Contamination and Indoor Air Pollution Caused by Tar Products and Fungicidal Impregnations*: Intervention Research in 2014–2019, in: Sensors, Bd. 20, Nr. 15, S. 4099, [online] doi:10.3390/s20154099.

Kwon, KD., Jo, WK., Lim, HJ. and Jeong, WS. (2008): *Volatile pollutants emitted from selected liquid household products*, in: Environmental Science and Pollution Research, Bd. 15, Nr. 6, S. 521–526, [online] doi:10.1007/s11356-008-0028-x.

Lead (2022): *Air Pollution from Lead (o. D.): Texas Commission on Environmental Quality*, [online] https://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-lead [visited 02.01.2022].

Legionellosis (2013): *Active Bacterial Core Surveillance for Legionellosis — United States*, 2011–2013 (o. D.): https://www.cdc.gov, [online] https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6442a2.htm [visited 29.10.2021].

Legionellosis (2018): https://www.who.int, [online] https://www.who.int/news-room/fact-sheets/detail/legionellosis [visited 29.10.2021].

Leung, D. (2015): *Outdoor-indoor air pollution in urban environment: challenges and opportunity,* Frontiers, [online] https://www.frontiersin.org/articles/10.3389/fenvs.2014.00069/full [visited 14.11.2021].

Mahdavi, A., Berger, C., Bochukova, V., Bourikas, L., T.Hellwig, R., Jin, Q., Pisello, A.L. and Schweiker, M. (2020): *Necessary Conditions for Multi-Domain Indoor Environmental Quality Standards.* Published October 13, 2020. https://doi.org/10.3390/su12208439

Mannan, M. and Al-Ghamdi, S.G. (2021): *Indoor Air Quality in Buildings: A Comprehensive Review on the Factors Influencing Air Pollution in Residential and Commercial Structure,* in: International Journal of Environmental Research and Public Health, Bd. 18, Nr. 6, S. 3276, [online] doi:10.3390/ijerph18063276.

Masjedi, M.R., Taghizadeh, F., Hamzehali, S., Ghaffari, S., Fazlzadeh, M., Jonidi Jafari, A., Niazi, S., Abouee Mehrizi, E., Moradi, M., Pasalari, H. and Arfaeinia, H. (2019): *Air pollutants associated with smoking in indoor/outdoor of waterpipe cafés in Tehran, Iran: Concentrations, affecting factors and health risk assessment*, in: Scientific Reports, Bd. 9, Nr. 1, S. 1–11, [online] doi:10.1038/s41598-019-39684-3.

Mason, S., Nel, A., Oullette, J., Reijula, K., Reponen, T., Selzer, J., Smith, A. and Tarlo, S.M. (2008): The health effects of nonindustrial indoor air pollution, [online] doi:10.1016/j.jaci.2007.10.045.

McDonald, B.C., De Gouw, J.A., Gilman, J.B., Jathar, S.H., Akherati, A., Cappa, C.D., Jimenez, J.L., Lee-Taylor, J., Hayes, P.L., McKeen, S.A., Cui, YY., Kim, SW., Gentner, D.R., Isaacman-VanWertz, G., Goldstein, A.H., Harley, R.A., Frost, G.J., Roberts, J.M., Ryerson, T.B. and Trainer, M. (2018): *Volatile chemical products emerging as largest petrochemical source of urban organic emissions,* in: Science, Bd. 359, Nr. 6377, S. 760–764, [online] doi:10.1126/science.aaq0524.

Mehta, R. (2021): *Allergy and Asthma: Allergic Rhinitis and Allergic Conjunctivitis*, PubMed, [online] https://pubmed.ncbi.nlm.nih.gov/30152668/ [visited 29.10.2021].

Mold (2021): Mold Course Chapter 2: (2021): US EPA, [online] https://www.epa.gov/mold/mold-course-chapter-2 [visited 23.01.2022].

Moriske, H. (1996): *Indoor air pollution by different heating systems: coal burning, open fireplace and central heating,* in: Toxicology Letters, Bd. 88, Nr. 1–3, S. 349–354, [online] doi:10.1016/0378-4274(96)03760-5.

Nandan, A., Siddiqui, N.A., Singh, C. and Aeri, A. (2021): *Occupational and environmental impacts of indoor air pollutant for different occupancy: a review,* in: Toxicology and Environmental Health Sciences, Bd. 13, Nr. 4, S. 303–322, [online] doi:10.1007/s13530-021-00102-9.

NCBI (2020): Indoor Air Pollution, Related Human Diseases, and Recent Trends in the Control and Improvement of Indoor Air Quality (2020): PubMed Central (PMC), [online] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7215772/#B2-ijerph-17-02927 [visited 27.10.2021].

NCEH (2022): Chapter 5: I*ndoor Air Pollutants and Toxic Materials | Healthy Housing Reference Manual | NCEH (o. D.)*: Centers of Disease Control and Prevention, [online] https://www.cdc.gov/nceh/publications/books/housing/cha05.htm [visited 02.01.2022].

NHS (2020): website: Legionnaires' disease, nhs.uk, [online] https://www.nhs.uk/conditions/legionnaires-disease/ [visited 29.10.2021].

Nriagu, J. (2011): Encyclopedia of Environmental Health, Michigan, USA: Elsevier Science & Technology.

O'Hehir, R., Holgate, S. and Sheikh, A. (2016): *Middleton's Allergy Essentials,* 1 Har/Psc, [online] doi:10.1016/B978-0-323-37579-5.00008-8.

Ohura, T., Amagai, T., Fusaya, M. and Matsushita, H. (2003): *Polycyclic Aromatic Hydrocarbons in Indoor and Outdoor Environments and Factors Affecting Their Concentrations*, in: Environmental Science & Technology, Bd. 38, Nr. 1, S. 77–83, [online] doi:10.1021/es030512o.

OSHA (2021): 'Legionnaires' Disease and Pontiac Fever - Overview | Occupational Safety and Health Administration (o. D.): https://www.osha.gov, [online] https://www.osha.gov/legionnaires-disease#ftn1 [visited 29.10.2021].

Pavlidis, G. (2019): *Indoor air quality, study case of school environment*, MSc, [online] https://apothesis.eap.gr/bitstream/repo/41086/1/122962_PAVLIDIS_GEORGIOS.pdf.pdf

Perniu, D. and Manciulea, I. (2007): *Indoor pollution. Learning toxicology through open educational.* Program TOXOER. Available at: http://moodle.toxoer.com/pluginfile.php/4624/mod_page/content/1/4.1.U3.%20Indoor%20pollution.pdf

Pillai, J., Desai, R. and Ten, A., 2018. *Dehumidification strategies and their applicability based on climate and building typology.* In: 2018 Building Performance Analysis Conference and SimBuild. pp. 759-766.

Pneumonitis (2021): *Learn About Hypersensitivity Pneumonitis (o. D.)*: https://www.lung.org/, [online] https://www.lung.org/lung-health-diseases/lung-disease-lookup/hypersensitivity-pneumonitis/learn-about-hypersensitivity [visited 29.10.2021].

Pneumonitis (2021a): *Hypersensitivity Pneumonitis* | NHLBI, NIH (o. D.): https://www.nhlbi.nih.gov/, [online] https://www.nhlbi.nih.gov/health-topics/hypersensitivity-pneumonitis [visited 29.10.2021].

Pollen (2022): Pollen Allergies | AAFA.org (o. D.): aafa, [online] https://www.aafa.org/pollen-allergy/ [visited 01.01.2022].

Polychlorinated Biphenyls (2021): *Learn about Polychlorinated Biphenyls (PCBs)*: US EPA, [online] https://www.epa.gov/pcbs/learn-about-polychlorinated-biphenyls-pcbs [visited 28.12.2021].

Polychlorinated Biphenyls (2021a): *(PCBs) (o. D.)*: Illinois Department of Public Health, [online] http://www.idph.state.il.us/envhealth/factsheets/polychlorinatedbiphenyls.htm [visited 28.12.2021].

Ponsoni, K. and Raddi, M.S.G. (2010): *Indoor Air quality related to occupancy at an air-conditioned public building*, in: Brazilian Archives of Biology and Technology, Bd. 53, Nr. 1, S. 99–103, [online] doi:10.1590/s1516-89132010000100013.

Pontiki, M. (2019): *Sick Building Syndrome: a danger for domestic environment: Sources, measures for prevention and confrontation*, Master Thesis.

QUT (2021): [online] https://www.qut.edu.au/ [visited 10.03.2022].

Rivas, L., Fussell, J.C., Kelly, F.J., and Querol, X. (2019): *Indoor Sources of Air Pollutants,* in: Issues in Environmental Science and Technology, S. 1–34, [online] doi:10.1039/9781788016179-00001.

Saini, J., Dutta, M. and Marques, G. (2020): *Indoor Air Quality Monitoring Systems Based on Internet of Things: A Systematic Review*, in: International Journal of Environmental Research and Public Health, Bd. 17, Nr. 14, S. 4942, [online] doi:10.3390/ijerph17144942.

Salthammer, T., Mentese, S. and Marutzky, R. (2010): *Formaldehyde in the Indoor Environment, in Chemical Reviews,* Bd. 110, Nr. 4, S. 2536–2572, [online] doi:10.1021/cr800399g.

Šeduikyte, L. and Bliūdžius, R. (2005): *Pollutants emission from building materials and their influence on indoor air quality and people performance in offices,* in: Journal of Civil Engineering and Management, Bd. 11, Nr. 2, S. 137–144, [online] doi:10.1080/13923730.2005.9636343.

Sekar, A., Varghese, G.K. and Ravi Varma, M.K. (2019): *Analysis of benzene air quality standards, monitoring methods and concentrations in indoor and outdoor environment,* in: Heliyon, Bd. 5, Nr. 11, S. e02918, [online] doi:10.1016/j.heliyon.2019.e02918.

Seltzer, J.M. (1994): *Journal of allergy and clinical immunology*, [online] doi:10.1053/ai.1994.v94.a57114.

Sensors (2021): *'A Guide to Siting and Installing Air Sensors* (2021)': US EPA, [online] https://www.epa.gov/air-sensor-toolbox/guide-siting-and-installing-air-sensors [visited 06.03.2022].

Settimo, G., Manigrasso, M. and Avino. P. (2020): *Indoor Air Quality: A Focus on the European Legislation and State-of-the-Art Research in Italy*, in: Atmosphere, Bd. 11, Nr. 4, S. 370, [online] doi:10.3390/atmos11040370.

Shu, L., Bivolarova, M.P. and Melikov, A.K. (2021): *Localized Ventilation Method for Providing Clean Air to Hospitalized Patients,* in: J. Kurnitski/M. Thalfeldt (Hrsg.), E3S Web of Conferences, Bd. 246, S. 02003, [online] doi:10.1051/e3sconf/202124602003.

Slezakova, K., Morais, S. and Pereira, M.D.C. (2012): *Indoor Air Pollutants: Relevant Aspects and Health Impacts*, in: Environmental Health - Emerging Issues and Practice, S. 126–145, [online] doi:10.5772/30364.

Sulfur (2021): *Sulfur Dioxide & Health | California Air Resources Board (o. D.)*: California air resources board, [online] https://ww2.arb.ca.gov/resources/sulfur-dioxide-and-health [visited 04.12.2021].

Theodoratou, A. (2014): *Degradation of indoor air quality. Presence of people and heating systems*, MSc, [online] https://pergamos.lib.uoa.gr/uoa/dl/frontend/file/lib/default/data/1311154/theFile.

Tsakas, M. (2011): *Indoor Air Pollutants and the Impact on Human Health*, IntechOpen, [online] https://www.intechopen.com/chapters/16335 [visited 27.10.2021].

Uhde, E., and Salthammer, T., (2007): *Impact of reaction products from building materials and furnishings on indoor air quality—A review of recent advances in indoor chemistry*, in: Atmospheric Environment, Bd. 41, Nr. 15, S. 3111–3128, [online] doi:10.1016/j.atmosenv.2006.05.082.

Vardoulakis, S., Giagloglou, E., Steinle, S., Davis, A., Sleeuwenhoek, A., Galea, K., Dixon, K. and Crawford, J. (2020): I*ndoor Exposure to Selected Air Pollutants in the Home Environment: A Systematic Review,* in: International Journal of Environmental Research and Public Health, Bd. 17, Nr. 23, S. 8972, [online] doi:10.3390/ijerph17238972.

Vázquez, F., Kastner, W. and Kofler, M. (2013): *Holistic smart homes for air quality and thermal comfort,* in: Maglogiannis, I., Iliadis, L. and Papadopoulos, H., Intelligent Decision Technologies, Bd. 7, Nr. 1, S. 23–43, [online] doi:10.3233/idt-120149.

Wagdi, D. (2015): *Effect of Building Materials on Indoor Air Quality in Residential Building in Egypt: A Pre Occupancy Assessment*. May 2015, 10–147.

Wang, M., Jia, S. Lee, S.H., Chow, A. and Fang, M. (2021): *Polycyclic aromatic hydrocarbons (PAHs) in indoor environments are still imposing carcinogenic risk*, in: Journal of Hazardous Materials, Bd. 409, S. 124531, [online] doi:10.1016/j.jhazmat.2020.124531.

Wargocki, P. (2004): *Sensory pollution sources in buildings,* in: Indoor Air, Bd. 14, Nr. s7, S. 82–91, [online] doi:10.1111/j.1600-0668.2004.00277.x.

Weaver, L.K., Hopkin, R.O., Chan, K.J., Churchill, S., Elliott, C.G., Clemmer, T.P., et al. Hyperbaric oxygen for acute carbon monoxide poisoning (2002): [online] doi:10.1056/NEJMoa013121.

Wexler, P. (2014): Encyclopedia of Toxicology (English Edition), 3. Aufl., Bethesda, USA: Academic Press.

WHO (1989a): *Indoor Air Quality: Organic Pollutants.* EURO Reports and Studies No. 111, World Health Organization, Copenhagen, pp. 1- 70.

WHO (2000): Regional Office for Europe/World Health Organization. Regional Office for Europe: *Air Quality Guidelines for Europe, Copenhagen, Denmark*: World Health Organization, Regional Office for Europe.

WHO (2008): *Children's Health and the Environment*: www.who.int, [online] https://www.who.int/ceh/capacity/Indoor_Air_Pollution.pdf [visited 14.11.2021].

WHO (2010): WHO *Guidelines for Indoor Air Quality*: Selected Pollutants, Copenhagen, Denmark: WHO.

WHO (2010a): [(WHO Guidelines for Indoor Air Quality: Dampness and Mould)] [By (author) World Health Organization] published on (March 2010), Copenhagen, Denmark: WHO Regional Office for Europe.

WHO (2011): Who Regional Office for Europe: *WHO Guidelines for Indoor Air Quality: Selected Pollutants*, Illustrated, Copenhagen, Denmark: WORLD HEALTH ORGN.

WHO (2020): '*Household Air Pollution and Health*'. [(accessed on 28 January 2020)]; Available online: https://www.who.int/en/news-room/fact-sheets/detail/household-air-pollution-and-health.

Wolkoff, P. (1995): *Volatile Organic Compounds Sources, Measurements, Emissions, and the Impact on Indoor Air Quality*, in: Indoor Air, Bd. 5, Nr. S3, S. 5–73, [online] doi:10.1111/j.1600-0668.1995.tb00017.x.

Yellowblue (2020): Yellowblue - *Multi-layer Insulation, Solar Fans & Energy Saving Products, yellowblue,* [online] https://yellowbluetech.com/ [visited 15.01.2022].

Zhuo, J. (2018): *Research on Prevention of Indoor Air Environment Pollution by Building Decoration Materials, in IOP Conference Series*: Earth and Environmental Science, Bd. 208, S. 012107, [online] doi:10.1088/1755-1315/208/1/012107.

ANNEX 1

Table 1.1. Factors taken into account in different methods of expressing IAQ as listed in ISO 16814:2008

Table 1.1: ÖNORM EN 16798-1:2019

Factors taken into account			Basis of standard/guidance																			
			Ventilation rate								Target concentration								Health risk			
			Health				Comfort (PAQ)				Health				Comfort (PAQ)							
			AS 1668.2	ASHRAE 62.1	EN 13779	CR 1752	EN 13779	CR 1752	ASHRAE 62.1	AS 1668.2	ASHRAE 62.1	EN 13779	CR 1752	AS 1668.2	EN 13779 [a]	ASHRAE 62.1	CR 1752	AS 1668.2	AS 1668 [b]			
Approach to multiple pollutants	Independent/none		X				X			X	X	X	X	X	X	X	X	X	X			
	Partial addition						X															
	Add			X		X		X	X													
Comfort assumption	Adapted								X	X								X				
	Unadapted						X	X		X					X			X				
Health basis	Short-term (< 1 day)		X								X			X								
	Long-term (> 1 day)		X								X			X					X			
Population	Children		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
	Working-age adult		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	Elderly		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
	People with health-related sensitivity (e.g. asthma)																					
Emission sources	People	per square metre	X	X			X	X	X	X				X	X			X				
		number	X	X			X	X	X	X				X				X	X			
	Smoking						X	X		X								X	X			
	Materials/equipment		X	X	X	X	X	X	X	X				X				X				
	Effect of temperature/ RH/air flow									X								X				

Table 1.1 (Continued)

Factors taken into account		Basis of standard/guidance																			
		Ventilation rate								Target concentration								Health risk			
		Health				Comfort (PAQ)				Health				Comfort (PAQ)							
		AS 1668.2	ASHRAE 62.1	EN 13779	CR 1752	EN 13779	CR 1752	ASHRAE 62.1	AS 1668.2	ASHRAE 62.1	EN 13779	CR 1752	AS 1668.2	EN 13779[a]	ASHRAE 62.1	CR 1752	AS 1668.2	AS 1668[b]			
Ventilation	Rate	X	X	X	X	X	X	X	X				X	X			X	X			
	Recirculation	X	X	X	X	X	X	X	X				X	X			X	X			
	Effectiveness	X	X	X	X	X	X	X	X				X	X			X	X			
	Air movement between zones	X						X	X				X				X				
Modifying mechanism	Air cleaning	X						X	X	X			X		X		X	X			
	Sink effects													X							
Outdoor air	Concentrations	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Zone	Multi-zone	X	X			X	X	X	X				X	X			X				
	By zone	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Variation	Complete day	X	X			X	X	X	X				X				X	X			
	Shorter periods	X	X					X	X				X				X				
	Occupancy	X	X					X	X				X				X	X			
Output (ventilation requirement)	Default table	X	X	X	X	X	X	X	X				X				X				
	Calculation for each case	X							X	X	X	X	X	X	X	X	X	X			
	More than one target level					X	X		X					X			X	X			

[a] For CO_2.

[b] For the environmental tobacco smoke harm index (ETSHI).

ANNEX 2

Table 2.1. Non-adapted persons. Examples of recommended ventilation rates for non-residential buildings with default occupancy density for three categories of pollution from the building itself.

Table 2.1 Source: ISO/TR 17772-2:2018

Type of building or space	Category	Floor area m²/ person	q_p Minimum ventilation rate	q_p	q_B	q_{tot}		q_B	q_{tot}		q_B	q_{tot}	
			l/(s m²)	l/s pers.	l/s, m²	l/s, m²	l/s.pers	l/s, m²	l/s, m²	l/s.pers	l/s, m²	l/s, m²	l/s.pers
			For occupancy only		For very low-polluted building			For low-polluted building			For non-low polluted building		
Conference room	I	2	5	10	0,5	5,5	11	1	6,0	12,0	2	7,0	14
	II	2	3,5	7	0,35	3,9	8	0,7	4,2	8,4	1,4	4,9	10
	III	2	2	4	0,2	2,2	4	0,4	2,4	4,8	0,8	2,8	6
	IV	2	1,25	2,5	0,15	*(1,4) 1,8*	*(3) 4*	0,3	*(1,6) 2*	*(3,1) 4*	0,6	1,9	4
Auditorium	I	0,75	13,3	10	0,5	13,8	10	1	14,3	10,8	2	15,3	12
	II	0,75	9,3	7	0,35	9,7	7	0,7	10,0	7,5	1,4	10,7	8
	III	0,75	5,3	4	0,2	5,5	4	0,4	5,7	4,3	0,8	6,1	5
	IV	0,75	3,3	2,5	0,15	*(3,5) 4,7*	*(3) 4*	0,3	*(3,6) 5,3*	*(2,7) 4*	0,6	*(3,9) 4,7*	*(3) 4*
Restaurant	I	1,5	6,7	10	0,5	7,2	11	1	7,7	11,5	2	8,7	13
	II	1,5	4,7	7	0,35	5,0	8	0,7	5,4	8,1	1,4	6,1	9
	III	1,5	2,7	4	0,2	2,9	4	0,4	3,1	4,6	0,8	3,5	5
	IV	1,5	1,7	2,5	0,15	*(1,8) 2,4*	*(3) 4*	0,3	*(2,0) 2,7*	*(3,0) 4*	0,6	*(2,3) 2,4*	*(3) 4*
Classroom	I	2	5	10	0,5	5,5	11	1	6,0	12,0	2	7,0	14
	II	2	3,5	7	0,35	3,9	8	0,7	4,2	8,4	1,4	4,9	10
	III	2	2	4	0,2	2,2	4	0,4	2,4	4,8	0,8	2,8	6
	IV	2	1,25	2,5	0,15	*(1,4) 1,8*	*(3) 4*	0,3	*(1,6) 2*	*(3,1) 4*	0,6	1,9	4
Kindergarten	I	2	5	10	0,5	5,5	11	1	6,0	12,0	2	7,0	14
	II	2	3,5	7	0,35	3,9	8	0,7	4,2	8,4	1,4	4,9	10
	III	2	2	4	0,2	2,2	4	0,4	2,4	4,8	0,8	2,8	6
	IV	2	1,25	2,5	0,15	*(1,4) 1,8*	*(3) 4*	0,3	*(1,6) 2*	*(3,1) 4*	0,6	1,9	4
Department store	I	7	1,4	10	1	2,4	17	2	3,4	24	3	4,4	31
	II	7	1,0	7	0,7	1,7	12	1,4	2,4	16,8	2,1	3,1	22
	III	7	0,6	4	0,4	1,0	5	0,8	1,4	9,6	1,2	1,8	12
	IV	7	0,4	2,5	0,3	0,7	7	0,6	10	6,7	0,9	1,3	9

NOTE Italics is for situations where the calculated ventilation rate is lower than 4 l/s per person required for health.

Table 2.1 (Continued)

Type of building or space	Category	Floor area m²/ person	q_p Minimum ventilation rate l/(s m²)	q_p l/s pers.	q_B l/s. m²	q_{tot} l/s. m²	q_{tot} l/s.pers	q_B l/s. m²	q_{tot} l/s. m²	q_{tot} l/s.pers	q_B l/s. m²	q_{tot} l/s. m²	q_{tot} l/s.pers
			For occupancy only		For very low-polluted building			For low-polluted building			For non-low polluted building		
Single office	I	10	1	10	0.5	1.5	15	1	2.0	20.0	2	3.0	30
	II	10	0.7	7	0.35	1.1	11	0.7	1.4	14.0	1.4	2.1	21
	III	10	0.4	4	0.2	0.6	6	0.4	0.8	8.0	0.8	1.2	12
	IV	10	0.25	2.5	0.15	0.4	4	0.3	0.6	5.5	0.6	0.9	9
Landscaped office	I	15	0.7	10	0.5	1.2	18	1	1.7	25.0	2	2.7	40
	II	15	0.5	7	0.35	0.8	12	0.7	1.2	17.5	1.4	1.9	28
	III	15	0.3	4	0.2	0.5	7	0.4	0.7	10.0	0.8	1.1	16
	IV	15	0.2	2.5	0.15	0.3	5	0.3	0.5	7.0	0.6	0.8	12
NOTE Italics is for situations where the calculated ventilation rate is lower than 4 l/s per person required for health.													

Table 2.2. Adapted persons. Examples of recommended ventilation rates for non-residential buildings with default occupant density for three categories of pollution form building itself.

Table 2.2 Source: ISO/TR 17772-2:2018

Type of building or space	Category	Floor area m²/ person	q_p *Adapted q_p* according to Table B l/s. m²	q_p l/s. person	q_B l/s.m²	q_{tot} l/s.m²	q_{tot} l/s. person	q_B l/s.m²	q_{tot} l/s.m²	q_{tot} l/s. person	q_B l/s.m²	q_{tot} l/s.m²	q_{tot} l/s. person
			For occupancy		For very low-polluted building			For low-polluted building			For non-low polluted building		
Conference room	I	2	1.75	3.5	0.5	2.25	4.5	1	2.75	5.5	2	3.75	7.5
	II	2	1.25	2.5	0.35	*1,60*	*(3,2)4*	0.7	*1,95*	*(3,9)4*	1.4	2.65	5.3
	III	2	0.75	1.5	0.3	*1,05*	*(2,1)4*	0.4	*1,15*	*(2,3)4*	0.8	*1,55*	*(3,1)4*
	IV	2	0.50	1	0.25	*0,75*	*(1,5)4*	0.3	*0,80*	*(1,6)4*	0.6	*1,10*	*(2,2)4*
NOTE Values in italics indicate situations where the calculated ventilation rate is lower than the minimum value of 4l/s per person required for health. The values are expressed per m² floor area even if the emitting surfaces can be floor, wall, etc.													

Table 2.2 (Continued)

Type of building or space	Cate-gory	Floor area m²/ per-son	q_p		q_B	q_{tot}		q_B	q_{tot}		q_B	q_{tot}	
			Adapted q_p according to Table B										
			l/s, m²	l/s, person	l/s,m²	l/s,m²	l/s, person	l/s,m²	l/s,m²	l/s, person	l/s,m²	l/s,m²	l/s, person
			For occu-pancy		For very low-polluted building			For low-polluted building			For non-low polluted building		
Auditori-um	I	0,75	4,67	3,5	0,5	*5,17*	*(3,9)4*	1	5,67	4,3	2	6,67	5,0
	II	0,75	3,33	2,5	0,35	*3,68*	*(2,8)4*	0,7	*4,03*	*(3,0)4*	1,4	*4,73*	*(3,6)4*
	III	0,75	2,00	1,5	0,3	*2,30*	*(1,7)4*	0,4	*2,40*	*(1,8)4*	0,8	*2,80*	*(2,1)4*
	IV	0,75	1,33	1	0,25	*1,58*	*(1,2)4*	0,3	*1,63*	*(1,2)4*	0,6	*1,93*	*(1,5)4*
Classroom	I	2	1,75	3,5	0,5	2,25	4,5	1	2,75	5,5	2	3,75	7,5
	II	2	1,25	2,5	0,35	*1,60*	*(3,2)4*	0,7	*1,95*	*(3,9)4*	1,4	2,65	5,3
	III	2	0,75	1,5	0,3	*1,05*	*(2,1)4*	0,4	*1,15*	*(2,3)4*	0,8	*1,55*	*(3,1)4*
	IV	2	0,50	1	0,25	*0,75*	*(1,5)4*	0,3	*0,80*	*(1,6)4*	0,6	*1,10*	*(2,2)4*

NOTE Values in italics indicate situations where the calculated ventilation rate is lower than the minimum value of 4l/s per person required for health.

The values are expressed per m² floor area even if the emitting surfaces can be floor, wall, etc.

ANNEX 3

Table 3.1 European labeling schemes as listed in ISO 16814:2008

European labelling schemes for low-emission flooring products

Labelling schemes	Classification requirements/Description
Danish voluntary labelling scheme	Requires evaluation of the VOC emission rates and odour and irritation thresholds of the flooring materials in an environmental chamber or cell, with results scaled to a 17 m^3 modelled room.
Finnish M1 label for finishing materials http://www.rts.fi/	Requires measurements of TVOC (< 200 $\mu g \cdot m^{-2} \cdot h^{-1}$), carcinogens (< 5 $\mu g \cdot m^{-2} \cdot h^{-1}$), formaldehyde (< 50 $\mu g \cdot m^{-2} \cdot h^{-1}$), ammonia (< 30 $\mu g \cdot m^{-2} \cdot h^{-1}$) and odour dissatisfaction (15 %) after 28 days of exposure in an environmental chamber.
GuT, Environmental Quality Mark for Carpets http://www.gut-ev.org/	Regulates emissions of CFCs, pesticides, carcinogens (recognized, proven or suspected, e.g. benzene, butadiene, vinylchloride, vinylacetate and formaldehyde), which shall not be detected in product; and limits emission of toluene (50 $\mu g \cdot m^{-3}$), styrene (5 $\mu g \cdot m^{-3}$), 4-vinylcyclohexene (2 $\mu g \cdot m^{-3}$), 4-phenylcyclohexene (20 $\mu g \cdot m^{-3}$), TVOC (30 $\mu g \cdot m^{-3}$), total aromatic hydrocarbons (150 $\mu g \cdot m^{-3}$), and odours, tested in a standard environmental chamber. Dyes or auxiliary substances shall not contain heavy metals, such as lead, cadmium, mercury or chromium(VI).
GEV EMICODE Labelling System for adhesives, primers and smoothing compounds http://www.emicode.com/	The product is analysed for carcinogenic compounds after 24 h of exposure in an environmental chamber. The substances are classified as a recognized (C1), a proven (C2) or a suspected (C3) carcinogen according to European Directives or German legislation. The following carcinogenic compounds are currently restricted: C1: acrylamide, acrylonitrile, benzene, 1,4-dioxane; C2: acetaldehyde and formaldehyde; C3: vinylacetate. EMICODE sets the following limits: C1 substances: < 2 $\mu g \cdot m^{-3}$, C2 substances: < 10 $\mu g \cdot m^{-3}$; C3 substances: < 50 $\mu g \cdot m^{-3}$. TVOC and the principal VOCs (above 20 $\mu g \cdot m^{-3}$) are also quantified, after 10 days of exposure. The following three categories of product are used, based on TVOC emission rates.

Product	TVOC emission rates by product category $\mu g \cdot m^{-3}$		
	EC 1	EC 2	EC 3
Primers	< 100	100 to 300	> 300
Levelling compounds	< 200	200 to 600	> 600
Flooring adhesives	< 500	500 to 1 500	> 1 500

(continued)

Labelling schemes	Classification requirements/Description
Swedish standard for floorings GBR/SP Trade standards GBR 1992.	Requires measurement and declaration of TVOC emission rates after 4 weeks and 26 weeks of exposure of the flooring materials in an emission cell, and the 10 principal individual VOCs.
Nordic Swan Ecolabelling Programme	The scheme prohibits the presence in the product of carcinogens, halogenated VOCs, organic tin compounds, phthalates, polybrominated diphenyl ethers and also substances that are mutagenic or harmful to the human reproductive system. Heavy metals are also not allowed. Emission of formaldehyde from the finished product shall be less than 0,1 $mg \cdot m^{-3}$ in the chamber air. The procedures used in the Danish and Finnish schemes also apply in the Nordic Swan Ecolabelling Programme. Both the environmental chamber and emission cell tests can be used.
German Blue Angel Ecolabelling Scheme RAL-UZ 38 RAL-UZ 76 RAL-UZ 430	This labelling scheme covers flooring materials, furniture and wall panels. Auxiliary materials, such as adhesives and coating materials, are also included in the scheme. The scheme provides labelling to cover the whole life-cycle of the products. The scheme controls emissions of formaldehyde, TVOC, halogenated organic compounds and toxic substances that are carcinogenic, mutagenic and/or teratogenic. Standard environmental chamber tests are required for the certification of VOC emissions from the products. The following are the emission requirements for large surface products used in building.

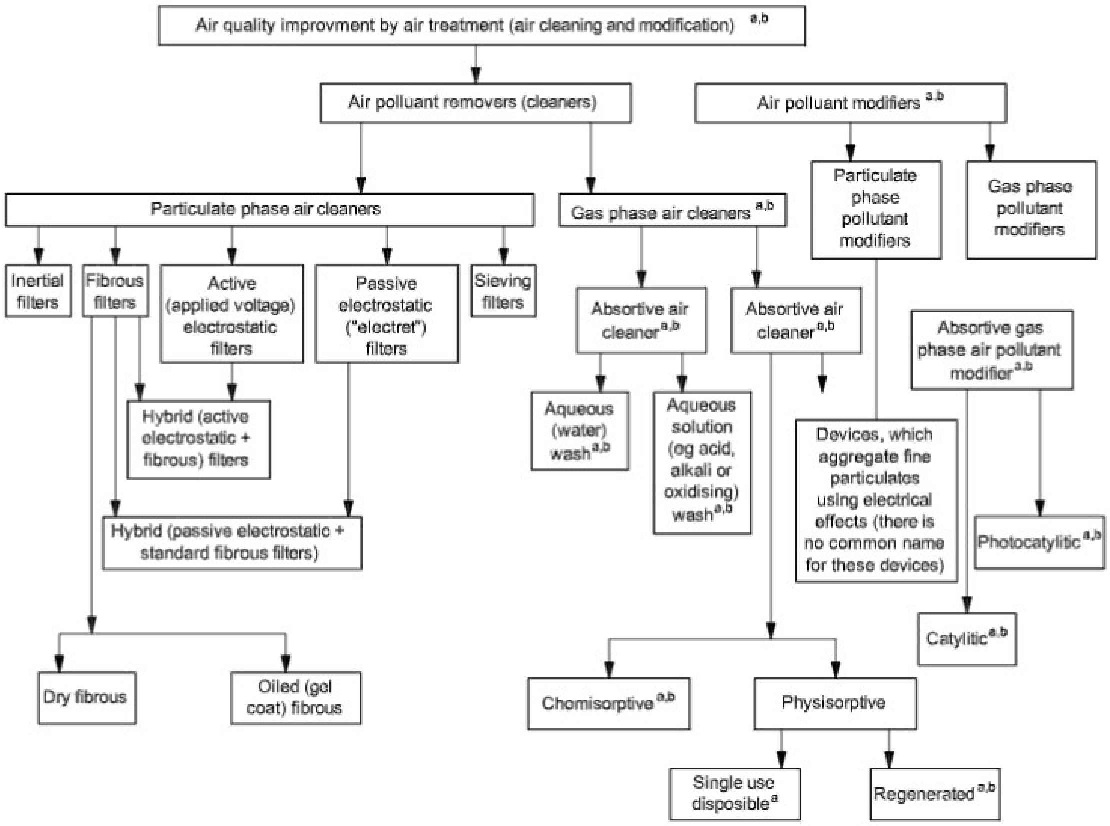
Compound	Emission requirements $\mu g \cdot m^{-3}$	
	1 day	28 day
Formaldehyde	—	62
TVOC (50 °C to 250 °C)	—	300
Total VOCs (> 250 °C)	—	100
Toxic substances	< 1	1

European labelling schemes for control of VOC emissions from coatings

Labelling schemes	Requirements/Description
Danish voluntary labelling scheme	See Table D.1 for requirements.
Finnish M1 label for finishing materials http://www.rts.fi/	See Table D.1 for requirements.
EU Ecolabel Scheme http://www.ecosite.co.uk/ B & Q and British Coating Federation Scheme	Provides criteria for paints, varnishes and cleaning products for indoor uses. The quantity of VOCs and volatile aromatic hydrocarbons (VAHs) are included in restrictions. The limits for Class I and Class II paints and varnishes are similar to those required by B & Q and the British Coatings Federation schemes. The "Ecolabel" criteria limit the use of paints and varnishes that contain toxic, highly toxic, carcinogenic, mutagenic or teratogenic substances classified under the European Directives 79/831/EEC and 83/4367/EEC, and also substances that are mandated a warning label by Directives 88/379/EEC. The VOCs included in this restriction are benzene, methanol, acetonitrile, 1,1,1-trichloroethane, xylenes, toluene, turpentine, ethylbenzene, butanol, 2-ethoxyethylacetate and formaldehyde. a) Paint category 1 (for walls and ceiling): — The VOC content shall not be greater than 30 $g \cdot l^{-1}$ (and in warm and dry climate $\leqslant$ 60 $g \cdot l^{-1}$). — The VAHs shall not be greater than 0,5 % of the product mass. b) Paint category 1 (for use on other surfaces): — The VOC content shall be less than or equal to 250 $g \cdot l^{-1}$. — The VAHs shall be less than or equal to 5 % of the product mass.
German Federal Environment Agency, Blue Angel Scheme	This scheme requires that the paints and varnishes not contain mutagenic or carcinogenic substances. The maximum allowed levels are as follows: — VOC content 10 % by mass for water-soluble paints and 15 % by mass for oil-based paints; — toxic VOC content $\leqslant$ 0,5 % by mass for water-soluble paints and $\leqslant$ 5 % by mass for oil-based paints. The product should not contain any heavy metals, such as lead, cadmium or chromium. Chamber tests of low-emission paints that had qualified for the Blue Angel Label showed that, after 48 h of paint application, the emission of the solvent VOCs was reduced to below the detection range of the analysis. The scheme also has restrictions on the production and uses of dyes that contain more than 1 % 2-naphthylamine, 1 % 4-nitrodiphenyl and $\leqslant$ 1 % chlorinated solvents, such as carbon tetrachloride, tetrachloroethanes and pentachloroethanes.
The Danish Technological Institute "Paint favourable to IAQ"	The factors included for consideration are IAQ and working environment, paint application characteristics, and coating performance. Emission rates of VOCs and odour are the properties to be assessed as well as drying time, adhesion and paint mass application. Three categories of paints are provided. This classification scheme is supported by a Nordic group of industries and institutes. Products are characterized as follows: — "Amongst the very best paints": paints that produce a VOC concentration less than 5 $\mu g \cdot m^{-3}$ within 2 weeks to 4 weeks after paint application; — "Acceptable": paints that do not emit any substances that are carcinogenic or have a toxic effect or cause mucous membrane irritation to the eye or the respiratory system; — "Poor-quality paints": paints that do not meet the criteria for acceptable paints.

ANNEX 4

Table 4.1 Types of air cleaners as presented in ISO 16814:2008



a May humidify.
b May dehumidify.

ANNEX 5

Table 5.1 Different air filter test methods that exist according to the type of filter as presented in ISO 16814:2008

Type of filter	Test method reference
Particulate – coarse filter	EN 779:2002 or ASHRAE 52.1:1992 or ASHRAE 52.2: 2000
Particulate – fine filter	EN 779:2002 or ASHRAE 52.2: 2000
In situ test	EUROVENT 4/10
Portable air cleaner	ANSI-AHAM AC-1:2006
Gas-phase air cleaning	Different methods are currently being developed

ANNEX 6

Table 6.1 Standardized questionnaire of International Study of Asthma and Allergies in Childhood (ISSAC)

Core questionnaire wheezing module for 13–14 year olds

1. Have you <u>ever</u> had wheezing or whistling in the chest at any time in the past?
   Yes [ ]   No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. Have you had wheezing or whistling in the chest <u>in the last 12 months</u>?
   Yes [ ]   No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. How many attacks of wheezing have you had <u>in the last 12 months</u>?
   None [ ]   1 to 3 [ ]   4 to 12 [ ]   More than 12 [ ]

4. <u>In the last 12 months</u>, how often, on average, has your sleep been disturbed due to wheezing?
   Never woken with wheezing [ ]
   Less than one night per week [ ]   One or more nights per week [ ]

5. <u>In the last 12 months</u>, has wheezing ever been severe enough to limit your speech to only one or two words at a time between breaths?   Yes [ ]   No [ ]

6. Have you <u>ever</u> had asthma?   Yes [ ]   No [ ]

7. <u>In the last 12 months</u>, has your chest sounded wheezy during or after exercise?
   Yes [ ]   No [ ]

8. <u>In the last 12 months</u>, have you had a dry cough at night, apart from a cough associated with a cold or a chest infection?   Yes [ ]   No [ ]

Core questionnaire rhinitis module for 13–14 year olds

All questions are about problems which occur when you DO NOT have a cold or the flu.

1. Have you <u>ever</u> had a problem with sneezing, or a runny, or a blocked nose when you DID NOT have a cold or the flu?
   Yes [ ]   No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. <u>In the past 12 months</u>, have you had a problem with sneezing, or a runny, or a blocked nose when you DID NOT have a cold or the flu?   Yes [ ]   No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. <u>In the past 12 months</u>, has this nose problem been accompanied by itchy-watery eyes?   Yes [ ]   No [ ]

4. In which of the <u>past 12 months</u> did this nose problem occur? (please tick any which apply)
   January [ ]   February [ ]   March [ ]   April [ ]   May [ ]   June [ ]
   July [ ]   August [ ]   September [ ]   October [ ]   November [ ]   December [ ]

5. <u>In the past 12 months</u>, how much did this nose problem interfere with your daily activities?   Not at all [ ]   A little [ ]
   A moderate amount [ ]   A lot [ ]

6. Have you <u>ever</u> had hay fever?   Yes [ ]   No [ ]

Core questionnaire eczema module for 13–14 year olds

1. Have you ever had an itchy rash which was coming and going for at least 6 months?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. Have you had this itchy rash at any time in the last 12 months? Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. Has this itchy rash at any time affected any of the following places: the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears or eyes? Yes [ ] No [ ]

4. Has this rash cleared completely at any time during the last 12 months?
   Yes [ ] No [ ]

5. In the last 12 months, how often, on average, have you been kept awake at night by this itchy rash? Never in the last 12 months [ ]
   Less than one night per week [ ] One or more nights per week [ ]

6. Have you ever had eczema? Yes [ ] No [ ]

Core questionnaire wheezing module for 6–7 year olds

1. Has your child ever had wheezing or whistling in the chest at any time in the past?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. Has your child had wheezing or whistling in the chest in the last 12 months?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. How many attacks of wheezing has your child had in the last 12 months?
   None [ ] 1 to 3 [ ] 4 to 12 [ ] More than 12 [ ]

4. In the last 12 months, how often, on average, has your child's sleep been disturbed due to wheezing? Never woken with wheezing [ ]
   Less than one night per week [ ] One or more nights per week [ ]

5. In the last 12 months, has wheezing ever been severe enough to limit your child's speech to only one or two words at a time between breaths? Yes [ ] No [ ]

6. Has your child ever had asthma? Yes [ ] No [ ]

7. In the last 12 months, has your child's chest sounded wheezy during or after exercise?
   Yes [ ] No [ ]

8. In the last 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or a chest infection? Yes [ ] No [ ]

Core questionnaire rhinitis module for 6–7 year olds

1. Has you child ever had a problem with sneezing, or a runny, or a blocked nose when he/she DID NOT have a cold or the flu? Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

2. In the past 12 months, has your child had a problem with sneezing, or a runny, or a blocked nose when he/she DID NOT have a cold or the flu?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 6

3. In the past 12 months, has this nose problem been accompanied by itchy-watery eyes? Yes [ ] No [ ]

4. In which of the past 12 months did this nose problem occur? (please tick any which apply)
   January [ ] February [ ] March [ ] April [ ] May [ ] June [ ]
   July [ ] August [ ] September [ ] October [ ] November [ ] December [ ]

5. In the past 12 months, how much did this nose problem interfere with your child's daily activities?
   Not at all [ ] A little [ ] A moderate amount [ ] A lot [ ]

6. Has your child ever had hay fever? Yes [ ] No [ ]

Core questionnaire eczema module for 6–7 year olds

1. Has your child ever had an itchy rash which was coming and going for at least 6 months?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 7

2. Has your child had this itchy rash at any time in the last 12 months?
   Yes [ ] No [ ]

   IF YOU ANSWERED "NO" PLEASE SKIP TO QUESTION 7

3. Has this itchy rash at any time affected any of the following places: the folds of the elbows, behind the knees, in front of the ankles, under the buttocks, or around the neck, ears or eyes?
   Yes [ ] No [ ]

4. At what age did this itchy rash first occur? Under 2 years [ ]
   Age 2–4 [ ] Age 5 or more [ ]

5. Has this rash cleared completely at any time during the last 12 months?
   Yes [ ] No [ ]

6. In the last 12 months, how often, on average, has your child been kept awake at night by this itchy rash? Never in the last 12 months [ ]
   Less than one night per week [ ] One or more nights per week [ ]

7. Has you child ever had eczema? Yes [ ] No [ ]

ANNEX 7

Examples of IAQ questionnaires.

Example 1. (Source: QUT 2021)

CONFIDENTIAL **Household**

Indoor Air

Housing Questionnaire

Field Officer: ______________________________

Date: ______________________________
day – month – year

Part A. Property Information

1. Type of Property:

☐A. Single Storey ☐B. Multi storey ☐C. Queenslander ☐D. Townhouse

☐E. Apartment (you are in ______ floor) ☐F. Other ________________________

2. Age of the property? ___________ (estimate if not known)

3. Function of the property? ☐Residential ☐Commercial

4. Number of separate bedrooms or office spaces (as applicable)_______________________

5. Type of road on which the property is located:

☐A. Major road ☐B. Minor road ☐C. Residential street

☐D. Other ________________________

6. Surface of road on which the property is located

☐A. Sealed, with gutters ☐B. Sealed, no gutters ☐C. Unsealed

7. Negative-grade towards structure

☐A. Yes ☐B. No

If yes, describe:

___

8. Gutters and downpipes intact and appear free draining away from structure?

☐A. Yes ☐B. No

If no, describe:

___

9. French drains, perforated pipe, etc.

☐A. Yes ☐B. No

If yes, describe:

---

10. Estimated distance to the nearest major road __________ metres

11. Dominant vegetation in the street in which the property is located

☐A. Mainly native ☐B. Native and exotic ☐C. Mainly exotic ☐D. Not sure

☐E. Other___________

12. Types of vegetation are present in the garden (if present)

☐A. Native ☐B. Exotics ☐C. Tropical

☐D. Other _________________________

13. Density of the vegetation (if present)

☐A. Sparse ☐B. Medium density ☐C. High density

14. Condition of the garden (if present)

☐A. Recently mown/maintained ☐B. Maintained, but not recently

☐C. Overgrown

15. Floor Material:

☐A. Timber ☐B. Concrete ☐C. Tile ☐D. Carpet

☐E. Vinyl ☐F. Other_________________________

16 Ground Floor (if applicable) floor material:

☐A. Timber ☐B. Concrete ☐C. Tile ☐D. Carpet

☐E. Vinyl ☐F. Other_________________________

17. Wall Material:

☐A. Timber ☐B. Concrete ☐C. Plasterboard ☐D. Wallpaper

☐E. Brick ☐F. Other________________________

18 Ground Floor (if applicable) wall material:

☐A. Timber ☐B. Concrete ☐C. Plaster ☐D. Wallpaper

☐E. Brick ☐F. Other________________________

19. Ceiling Material:

☐A. Timber ☐B. Plaster ☐C. Wallpaper ☐D. Brick

☐E. Other________________________

20. Roof Material:

☐A. Tile ☐B. Metal ☐C. Fibro ☐D.Other

____

21. Roof construction:

☐A. Flat ☐B. Pitched ☐D.Other______________________

22. Roof ventilation:

☐A. None ☐B. Whirly Birds (#) ☐C. Soffit Vents

☐D.Other______________________

23 Ceiling Insulation:

☐A. Yes ☐B. No _____________________

24 If yes, ceiling Insulation type:

☐A. Fibreglass Blown-In ☐B. Fibreglass bats ☐C. Cellulose fibre _

☐D. Other________________________

25. Type of stove/oven:

☐A. Electric ☐B. Gas ☐C. Wood/Coal

☐D. Other________________________

26. Is there extraction fan over the stove/oven? ☐Yes ☐ No

27. Does the property have ceiling fans? ☐Yes ☐ No

28. Do bathrooms/or toilets have exhaust fans? ☐Yes ☐ No

29. Do above exhaust to be exterior of the structure? ☐Yes ☐No

30. What type of hot water system does the property have?

☐A. Electric ☐B. Gas ☐C. Solar

☐D. Other________________________

31. Does the property have a garage? ☐Yes ☐ No

If yes: ☐Single or ☐Double

☐Used for car storage or other storage

Where it is located? ☐Connected to property

☐Separated from property

32. What type of heating does the property use in winter?

☐A. Air-con ☐B. Electric ☐C. Gas ☐D. Wood/Coal

☐E. Other________________________ ☐F. No heating

Please estimate the number of days in a year that you use heating

_____________ and for how long each day ______________

days hours/minutes

33. What type of cooling does the property use in summer?

☐A. Air-con ☐B. Ceiling/wall fan ☐C. Portable fan ☐E. Natural ventilation

☐F. Other_______________________

Please estimate the number of days in a year that you use air conditioning

_____________ and for how long each day ______________

days hours/minutes

34. Window frame construction

☐A. Aluminum ☐B. Wood ☐B. Plastic ____________________

35. Has condensation been observed on window interiors?

☐A. Yes ☐B. No

If yes:

☐A. Affected rooms/areas _______________________________________

36. Has mould been observed on window frames?

☐A. Yes ☐B. No

If yes:

☐A. Affected rooms/areas _______________________________________

37. Any observed water intrusion into structure in the past (prior to 2011 flood)?

☐A. Yes ☐B. No ______________________

If yes:

☐A. Roof leak ☐B. Plumbing Leak ☐C. Spillage _

☐D. Wind driven rain__☐E. Wind driven rain__☐D. Other______________________________

38. Water intrusion into structure during 2011 floods?

☐A. Yes ☐B. No ______________________

If yes:

☐A. Height of water intrusion with respect to structure__________________________________

☐B. Remediation actions taken and approxiumate dates

Action____Date______________
_

Action____Date______________
_

Action____Date______________
_

Action____Date______________
_

39. Were disinfectants/antimicrobials used during remediation?

☐A. Yes ☐B. No ______________________

If yes:

☐A. Type of dinsnfectant/antimicrobial__________________________________

Part B. Living Information

40. How many adults/children live/work in the property? ______ / ______

41. How long do they usually stay in day/night? ______ / ______hr/day

42. How many cars usually park in the ambit of property? ______ cars

43. Are there any pets in the property? ☐Yes ☐ No

If yes: how many indoors __________

how many outdoors __________

44. Are indoor plants in the structure? ☐Yes ☐ No

If yes: how many indoors __________

45. Are there smokers residing at the property? ☐Yes ☐ No

If yes, how many? __________

46 Do they smoke inside the property? ☐Yes ☐ No

47. Do you use an air cleaning device? ☐Yes ☐ No

If yes: what type device? __________

48. Do you often open windows for ventilation? ☐Yes ☐ No

49. Do you wear outdoor shoes inside the property? ☐Yes ☐ No

50. Are there any areas inside the house where mould appears frequently? ☐Yes ☐ No

If yes: which areas ____

Which materials are typically affected (leather, cotton, synthetics, gyprock, paper, books, etc.)

____

51. Which of the following are regularly done in the property?

☐A. Mopping/Vacuuming ☐B. Wash bed linen at high temperature

☐C. Use of protective mattresses or pillow covers

☐D. Use chemicals to kill dust mite ☐E. Dry clean furnishings

☐F. Wash/Dry clean curtain

52. How often do you mop/vacuum the floor? __________ per week

53. When did you last mop/vacuum the floor? __________ days ago

54. Has the property had pest control within the last 12 months? ☐Yes ☐ No

Part C. Flooding Information

55. Has your property been flooded? ☐Yes ☐
No

If yes, go to Question 56 to 61, otherwise go to the end.

56. For how many days was it flooded? ________________________

57. What was the height of flood water in the property?

☐A. Under ground floor ☐B. Above ground floor

☐C. Up to ground floor ceiling ☐D. Above 1st floor

☐E. Up to 1st floor ceiling ☐F. Higher (_____ floor)

58. Has the property been cleaned? ☐Yes ☐
No

If yes, how has it been cleaned?

Floor: ☐A. Water ☐B. Detergent ☐C.
Other________________

Wall: ☐A. Water ☐B. Detergent ☐C.
Other________________

Ceiling: ☐A. Water ☐B. Detergent ☐C.
Other________________

Furniture: ☐A. Water ☐B. Detergent ☐C.
Other________________

When was it cleaned? _____________

59. Do you have any of the following complaints concerning indoor air quality after the property was flooded?

☐A. Stuffy air ☐B. Mouldy (musty) odours ☐C. Dusty

☐D. Too humid ☐E. Other odours (please describe) ________________________

60. Have you experienced any negative health impacts following the flood?

☐Yes ☐

No

If Yes: Please indicate below (next page) what physical health symptoms you have experienced after the property was flooded and whether these been diagnosed by a GP/specialist?

Symptom	✓ if yes Your feeling	✓ if yes GP/Specialist diagnosed
Difficulty in concentrating		
Dry or sore throat		
Aching joints		
Asthma		
Emphysema		
Dizziness		
Skin irritation		
Itching		
Heartburn		
Nausea		
Noticeable odours		
Sinus congestion		
Frequent coughing		
Allergic Rhinitis		
Chest tightness		
Eye irritation		
Fainting		
Hyperventilation, shortness of breath		
Headache		
Fatigue / drowsiness		
Other (please specify)		

61. Do you continue to experience the symptoms 1-2 hrs after leaving the flooded property?

☐Yes ☐

No

Example 2. (Source: Emory 2022)

EMORY UNIVERSITY | Environmental Health and Safety Office
Research Administration

1762 Clifton Road NE, Suite 1200
Atlanta, GA 30322
(404) 727-5922
FAX: (404) 727-9778

INDOOR AIR QUALITY QUESTIONNAIRE

Instructions:

- Answer all questions
- Complete this form electronically and press the "SUBMIT" button on the top right corner
  - Use the mouse, tab, or scroll (*page up/down arrows will not work)*
- If you are a MAC user submit the electronic document, with any applicable supporting documentation, to EHSO @ **indhyg@emory.edu**

---

1. **Indicate if you frequently have any of the following complaints concerning the indoor air quality at this building** *(check all that apply)*

☐ Temperature too cold	☐ Dusty
☐ Temperature too hot	☐ Noisy
☐ Stuffy air	☐ Too dry
☐ Moldy odors	☐ Too humid
☐ Other odors (please describe)	☐Drafty
Crowded work area	
☐ Poor lighting	☐ Vibration
☐ Other	☐ No Complaints

2. **Indicate if any of the following apply to you.** *(check all that apply)*

☐ Wear contact lenses
☐ Operate video display terminals at least one hour/average
☐ day Use any chemical substance such as cleaners, white
☐ out, etc.
☐ Use carbonless copy paper
☐ Smoke tobacco products
None of the above

3. **Since you have worked in this building, have you ever been diagnosed with any of the following?** *(check all that apply)*

☐ Allergic Rhinitis Emphysema ☐
☐ Asthma Laryngitis ☐
☐ Allergies Bronchitis ☐
☐ Conjunctivitis Other chest conditions ☐ Sinusitis None
☐ ☐

4. **During the last year while working in the building, have you experienced any of the following symptoms?** *(check all that apply)*

Frequent cough Nasal congestion ☐
☐ Wheezing (except colds) Sinus ☐ infections
☐ Multiple colds (more than four) Sore ☐ throat
☐ Shortness of breath Hoarse voice ☐
☐ Migraines Headaches (at least ☐ 2/month)
☐ Burning or irritated eyes Sneezing ☐ attacks

☐None of the above ☐Other (please specify) __________

5. **Please check all medications you are currently taking on a daily or weekly basis:**

☐ Pain relievers (aspirin, Tylenol, etc.) ☐ Antidepressants
☐ Decongestant Antihistamines None ☐ Other (please specify)
☐ __________ ☐

6. **How would you rate the indoor air quality at this building?**

☐Good ☐Average ☐Poor

7. **If you feel that there is an indoor air quality problem, does the problem occur more frequently during specific seasons of the year?**

☐Yes ☐No ☐Don't Know ☐Not Applicable

8. **If you answered yes to #7, rank each season from one to four as follows:**

1 – season least likely to be associated with indoor air quality problems and
4 – season most likely to be associated with indoor air quality problems

☐ **Winter** (Dec.–Feb) ☐ **Spring** (Mar–May) **Summer** (June–Aug) ☐ **Fall** (Sept – Nov)

9. **If you answered yes to #7, when do indoor air quality problems seem to be most notable?**

☐Morning ☐Afternoon ☐All day ☐Not applicable

10. **Which of the following symptoms have you experienced that you feel may be related to your work environment?** *(check all that apply)*

☐ Headache ☐ Sinus congestion Sinus ☐ infection
☐ Eye irritation ☐ Sore throat ☐ Hoarseness
☐ Runny nose ☐ Dizziness Sneezing ☐
☐ Fever (>100.5 ☐ °F) ☐ Fatigue/Drowsiness
☐ Eyes red/watery ☐ ☐
☐ ☐ ☐

Cough Wheezing Shortness of breath Skin problems Muscle aches
Other ____________________

11. Do most of the symptoms checked above go away within 1 hour after leaving work?

☐ Yes ☐ No ☐ Not applicable

12. If no, do they go away by the morning?

☐ Yes ☐ No ☐ Not applicable

13. If no, do they go away when you are on vacation?

Yes ☐ No ☐ Not applicable

14. Which of the following symptoms have you experienced within the <u>last week</u> and feel are related to your work place? *(check all that apply)*

☐ Headache ☐ Sinus congestion Sinus ☐ infection
☐ Eye irritation ☐ Sore throat ☐ Hoarseness
☐ Runny nose ☐ Dizziness Sneezing ☐
☐ Fever (>100.5 ☐ °F) ☐ Fatigue/Drowsiness
☐ Eyes red/watery ☐ ☐
☐ Cough ☐ Wheezing Shortness ☐ of breath
Skin problems Muscle aches Other ____________________

15. Do you have any health problems or allergies that might account for the abovesymptoms?

☐ Yes ☐ No ☐ Not applicable

16. What percentage of your work day do you typically spend in your building?

☐ 0 – 25% ☐ 26% – 50% ☐ 51% – 75% ☐ 76% – 100%

17. What percentage of your work day do you typically spend in your office/cubicle?

☐ 0 – 25% ☐ 26% – 50% 51% – 75% ☐ 76% – 100%

18. Are any of the following items located within your workroom or area? (check all that apply)

☐ Photo copier ☐ Laser printer ☐ Windows ☐ Plants

19. Please rank the lighting at your work area?

☐ Too bright ☐ Little too bright ☐ Just right ☐ Little too dim ☐ Too dim

20. Has there been any renovation/demolition related activities occurring in or near your work environment? (i.e., new carpet, painting, new office furniture HVAC work, etc.)

☐ No ☐ Yes – specify: ____________________

21. Has there been any evidence of water leaks or visible signs of moisture in andaround your area? ☐ Yes ☐No

____

☐ ☐

____

22. If yes, please describe:

23. Is your office near a laboratory? Yes No

24.If yes, list the known chemicals used.

Your Name *(Optional)*: ______________________________

Telephone Number (Optional):______________________________

☐ Male ☐ Female

Age *(Optional)*: under 30 ☐ 30-40 ☐41-50 ☐ over 50

____

Name of building: ______________________________

Suite #: ______________________________

Gender:

Job Title: