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Indoor Air Pollutants and the Future Perspectives for Living Space Design

Igor Cretescu, Dorina Nicolina Isopescu, Doina Lutic and Gabriela Soreanu

Abstract

This study presents an overview on the indoor air pollutants and their implications in the living space design-related strategy implementation. Not only the buildings but also the cabins of diverse traveling vehicles (busses, trains, cars, spacecrafts, submarines, etc.) are envisaged in this regard. Overall, in the smart eco-efficient built environment, such indoor spaces should ensure an adequate indoor air quality (IAQ), along with accomplishing the performance for other key components such as durability, energy saving, aesthetical architecture, etc. General aspects on indoor air quality and indoor air pollution, IAQ monitoring, and remediation strategies, as well as the main types of indoor pollutants and their effects upon human health, are highlighted.

Keywords: monitoring methodology, indoor air composition, human health, indoor air quality, smart building, vehicle cabins, spacecrafts

1. Introduction

The issues of indoor air pollutants present in living spaces determine the consideration of indoor air quality (IAQ) as a priority within the environmental programs. On the other hand, the assessment of the IAQ is a complex task, taking into consideration that there are hundreds of pollutants generated by many different sources that are detected in indoor environments, depending on the particularity of each indoor space [1].

In this study, the indoor space is defined as the space for leaving, working, traveling, or other activity of people inside the buildings as well as the space inside the cabin of a traveling vehicle as trains, busses, air and spacecrafts, submarines, etc. The inhabitants in buildings or temporary users of indoor spaces are looking for a healthy indoor environment in terms of health state and well-being, based on comfort (usually ensured by the temperature and humidity control in the indoor space). However, from the point of view of the one responsible in health and environment quality, the chemical content of the indoor air, even in terms of ppm levels for some kinds of compounds, should be precisely measured and well-known. The indoor air should be free of several contaminants and odors (or limit admissible levels should be defined), including the exhaust respiratory gases, such as carbon dioxide (CO₂)

and even nitrogen oxides. Also, the particle content, in terms of PM_{2.5} and PM₁₀, should be strictly monitored, because of their physiological complex and often dangerous effects.

Particularly, urban people spend most of the time indoors, which can suggest a direct relationship between IAQ and public health [1]. Moreover, IAQ applies also to other specific environments such as spacecraft cabins, which are sealed environments where the astronauts spend 100% of time during the period of their mission. Carbon dioxide can reach 7000 ppm in such environments [2]. In addition, the following compounds can be detected in spacecraft cabins (e.g., as based on NASA-Mir Program and International Space Station's atmosphere) as traces (usually from fraction to few ppm level): alcohols, siloxanes, halocarbons, aldehydes, ketones, esters, aromatics, carbon monoxide (CO), ammonia, hydrogen sulfide, sulfur dioxide, and nitrogen dioxide (NO₂) [2–6].

Overall, the indoor environment involves complex interactions between a high number of factors, being in a quite dynamic, continuous, and complex changing.

In this chapter, the only factors considered for defining the IAQ are the chemical composition and PM content, while other factors related less evidently to the air quality issues but still very important to the well-being of the inhabitants/users will be ignored (levels of lighting and sound, appropriate ergonomic conditions, work satisfaction, happiness, etc.).

When the conditions for a healthy indoor environment are not fulfilled, health problems of different seriousness levels will occur, and the most important will be presented here. Therefore, the information in this respect is equally important to be known by the specialists in the environment and health and by the large public.

2. General aspects about the indoor air pollution

The indoor air quality depends on many constantly changing parameters, requiring an interdisciplinary approach due to their complexity. These parameters are related to environment, industrial hygiene, mechanical and chemical engineering, architecture and design, and constructions, including practical advices for a better understanding of the IAQ issues.

The industrial hygiene provides information that colligates health symptoms to indoor air contaminants, serving to the identification of their sources. The main contaminant sources in this case are the architectural components of the buildings; therefore, the building process is a critical component to pursue a complete investigation and to generate a comprehensive remediation design.

Heating, Ventilation and Air Conditioning (HVAC) systems could also be sources of contaminants and may eventually distribute the pollutants from the sources to the populated parts of the buildings. The study of the HVAC is a task for the mechanical engineering discipline, contributing to design the necessary system modifications for diminishing or, ideally, eliminating the contaminating pollutants. In some cases, the HVAC system may have a beneficial role in controlling and decreasing the indoor contaminants, being the most cost-effective way to solve this problem by simply changing the ventilation track and/or air distribution [7].

In conclusion, straightforward IAQ problems can be identified and solved by knowledgeable practitioners in any of these disciplines. The more complicated situations are best addressed by an investigation comprising all these disciplines. An approach based on a specific methodology will generate a coordinated and comprehensive investigative effort. This book chapter addresses mainly to architects, mechanical engineers, building managers, and others but not to industrial hygienists.

Lately, sick building syndrome (SBS) is a popular term very often met in a specialty literature. SBS has been defined as the situation when at least 20% of the building occupants of a construction display illness symptoms for more than 2 weeks, but the source of the illness cannot be positively identified [7]. Another term associated with indoor-generating disorders is the building-related illness (BRI), when the cause of the symptoms is known. BRI can be related to a specific building source and is characterized by a distinguishable set of symptoms. Based on these concepts related to the health of the building users, a significant issue itself, in a forthcoming step, the economic aspects should be also considered, due to the high costs of medical treatment involved as a consequence of IAQ problems. Therefore, the “sick” buildings are costly due to the decrease of productivity and high absenteeism rates. According to the Environmental Protection Agency (EPA) reports, the annual loss due to a low productivity brought by poor IAQ was \$60 billion [8]. Many people continue to work/live in inappropriate conditions even while experiencing symptoms related to poor IAQ, and many do not connect the illness symptoms with the air quality of the work/living places. The productivity loss is only a fraction of the cost of sick buildings. The legal implications are an ever-increasing cause for concern. Building owners and managers are the primary defendants in the rising number of lawsuits related to IAQ, but many other professions are affected: building’s architects; mechanical contractors; manufacturers, sellers, installers, and consulting engineers of building air-conditioning and heating equipment; and manufacturers, distributors, sellers, and installers of carpeting, floor tiles, adhesives, and chemical products used in office machinery manufacturers, distributors, and sellers [7].

A building could be considered as a product. Anyone in the chain comprising the leasing, design, and construction of the building chain would be liable for injuries suffered by the plaintiffs. Many governmental agencies are involved in IAQ policy-making efforts, considering building design guidelines, indoor emission standard, and product labeling requirements. For example, the EPA and the World Health Organization (WHO) have estimated that 20% of the buildings in the USA have serious IAQ problems, 40% have somewhat serious problems, and 40% have no serious problems [7].

The energy-efficient designs of the actual buildings resulted in tighter building envelopes with improved insulation and low-energy-consuming ventilation, without openable windows. Under these conditions, the indoor pollutants were not sufficiently diluted with fresh air. Here, multiple aspects as the HVAC system operations and their impact on IAQ should be taken into consideration. An increase of the indoor pollutant sources is due to the tight building design. New building materials, products, and furnishings emit significant amounts of potentially hazardous chemicals into the air [7]. Moreover, this aspect could be of a special interest for specific closed environments (spacecrafts, submarines, etc.) where polluting materials should be avoided at a larger extent.

The operations of modern office equipment, including its necessary periodic cleaning and service, are another group of products and activities being a source of indoor air contaminants. Daily current activities such as the use of cleaning/disinfecting agents and the episodic use of pesticides contribute as well to the increase of the indoor pollutants level.

Among the health problems generated by the above-mentioned chemical pollutants, headaches, burning and itching eyes, respiratory difficulties, skin irritation, nausea, and fatigue are some of the common complaints. These symptoms are often vague, but they generally become worse after a longer exposure time (a whole day) spent in the indoor spaces; they disappear when the occupant leaves this environment. A number of symptoms may occur together, without a specific identifiable reason [7].

The human factor should be also taken into consideration as a contributor to the quality of the indoor environment. The presence of people, breathing and emitting body odors, affects IAQ. Human activities such as smoking significantly alter the indoor environment. Cosmetics and personal care products are sources of contaminants. The resulting situation is an increase in contaminants circulating through the indoor environment, with insufficient fresh outside air introduced through the HVAC system aiming to dilute the contaminants [7]. The risk of contaminant accumulation due to the use of different products is much higher in closed leaving environments and should be minimized as much as possible.

A detailed discussion of maintenance activities, building materials, and building operations, which affect a building's IAQ and human health, is presented in the technical-specific literature [7–11].

Another factor contributing to the IAQ issue is a change in the whole building or a certain space function, without proper modifications in the HVAC systems. In the latest decade, there have been strong increases in the commercial space renovation, for many reasons. The “modern” office building is easier to renovate than its predecessor; therefore, renovation is often a more cost-effective solution than a new edifice. When changes in the interior layout occur or when the new equipment requires additional ventilation, the technically possible changes in the HVAC systems often cannot keep up [7].

Certain other physical parameters can relate to building occupants' perception of indoor air quality. Glare from artificial lighting and visual stress from the use of visual display terminals (VDTs) can cause headaches and eye irritation. Vibration and noise may contribute to dizziness, nausea, and general irritability. Ergonomic stressors, such as chairs having wrong heights for the required task, may promote fatigue. Psychosocial factors, such as excessive workload and poor interpersonal relations, may cause headaches, irritability, and other symptoms, mistakenly attributed to poor IAQ. All these symptoms are similar to the ones associated with IAQ problems, further complicating the health effects assignments, blaming incorrectly the effects of the contaminated air. In reality, the physical, ergonomic, and psychosocial stressors can in fact increase dramatically the sensitivity of human beings to IAQ, generating a distorted sensation concerning the IAQ and a lower acceptability of reasonable IAQ. Therefore, these facts should be considered in the overall IAQ problem [7, 9].

3. Monitoring methodology and remediation of IAQ

Finding solutions to IAQ problems requires a methodical approach. A principle procedure for an efficient and practical investigation is presented in **Figure 1**.

Particularly, IAQ investigations for existing building could be required for two reasons [7, 8, 12]:

1. A building assessment is requested to evaluate the potential for IAQ issues. This action is generally connected to the purchase or lease of a building, when the buyer or the leaser requires an audit of the property. This may also occur as a good general practice by building owners or managers who apply the prudence in preventing problems. Most commonly, a building assessment is requested as a response to the specific complaints of the occupants.
2. The design of a new structure or renovation should be reviewed to avoid the IAQ issues with occupancy.

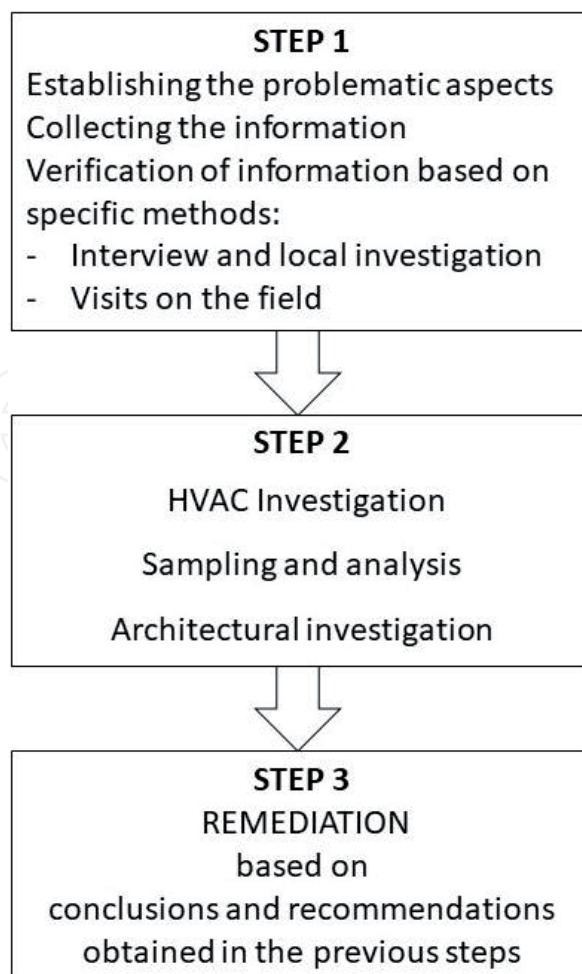


Figure 1.
Steps of monitoring and remediation of IAQ.

The building assessment is an investigative process, using three checklists [7, 12]:

1. A core checklist, with general information about the facility
2. An HVAC checklist, with information regarding the mechanical systems
3. An architectural component checklist, with information on architecture, construction, and operations

The information obtained from these checklists should allow the building investigator to reach certain conclusions about deficiencies or potential problems in the facility. These findings, along with recommendations, will make up the final report, and based on this, the remediation should be performed.

In the perspective of the remediation of a contaminated environment as described in **Figure 1**, four types of activities could be distinguished: anticipation, recognition, evaluation, and control of hazards.

Anticipating health safety problems before they really happen and acting to prevent them are the two actions which should be taken into consideration with priority by the practitioners. Foreseeing the hazardous events is possible based on previous data on the same topics, gathered from similar situations and, sometimes, statistically processed; this information could be considered historical data. The Occupational Safety and Health Administration (OSHA) considers that the

so-called historical data could be used, to a certain extent and in well-defined conditions, to predict the medical problems for population [7].

The terms hazard and risk, which are used in some situations as synonyms, have in this field quite different significance. A hazard is an object or a set of conditions which can affect the human health or safety and could be extended to plants and animals in the broader context of the environment. The risk is the manifestation of an imminent harmful occurrence, defined quantitatively by a statistical expression or qualitatively via the probability of occurrence. For example, the possibility of harm from many carcinogen hazard facts is low if the exposure to the hazardous substance happens at low intensity and short duration (i.e., the risk is low). In other words, a highly toxic chemical could be out of risk if an efficient barrier is built between the substance potential emission space and the human subject working in the area. In brief, the hazard is given by the intrinsic properties of the contaminant, while the risk is rather dependent on the exposure time and intensity [7].

In this light, IAQ is an important part of so-named smart building concept, along with other essential components, such as aesthetical architecture, durability, energy savings, etc. The accomplishment of the performance objectives related to these criteria by using environment-friendly and cost-effective tools contributes to the eco-efficient built environment [13]. More details about the different strategies (e.g., from marketing to technologies, algorithms, and big data) involved in the achievement of a smart eco-efficient built environment are described in [14].

Based on these aspects, the EPA in the USA published on its website a special program, Indoor airPLUS, in order to help the new home builders to improve the quality of indoor air, by defining construction practices and product specifications that minimize the exposure to airborne pollutants and contaminants [11].

4. Main types of pollutants in indoor air living spaces and involved interactions

The international legislation and local regulations aim to protect the inhabitants and workers from harmful exposures to hazardous substances, as well as the environment from indoor-generated pollutants.

A classification of the factors causing people discomfort or morbidity could be made by the nature of these factors like chemical, physical, and biological. The route by which the harmful agent enters the body is the key solution to protect people against their harmful action. The chemical and biological contaminants enter the human body usually through inhalation, skin contact, or ingestion. Physical agents (vibration, noise, pressure, temperature, various electromagnetic radiations, etc.) usually act to the whole body and can result in harmful biochemical reactions and in tissues and organ damage [7].

The correlation between occupational exposures and worker health is studied by the environmental and occupational medicine, with specialization in industrial hygiene (an interdisciplinary science based on chemical, mechanical, civil, or environmental engineering, chemistry, biology, physics) with tight connections with air pollution; analytical chemistry; engineering; heat, pressure, ergonomics, and other physical factors; ionizing and nonionizing radiation; noise and vibration; personal protective equipment; regulations, standards, and guidelines; sampling and instrumentation; and toxicology [7].

The main types of indoor pollutants are screened below, and methods for their detection were previously published by the authors in “Electrochemical Sensors for Monitoring of Indoor and Outdoor Air Pollution” [15].

5. Air contaminants and their effects upon human health

The prediction of hazards and risks generated by some building materials is based on a review of the individual chemical components of the whole material, taking into consideration how these components interact between them as well as with other factors like humidity, respiratory gases, etc. For this reason, the safety and health file contains information on each chemical compound from the material composition, the chemistry of the possible reactions which could occur, etc.

The specific behavior upon living creatures and different characterization of pollutants from air determined the literature definition thereof as particulate pollutants and gaseous pollutants. Many terms of science and engineering will be used in this section, without a definition if the words are used consistently with commonly accepted meanings in these fields, and, therefore, could be easily found in professional references. If, however, a term has a unique or different meaning, this will be defined in the text.

Airborne contaminants could be classified according to their nature, following the definitions according to the *Glossary of Fundamentals of Industrial Hygiene* [7]:

5.1 Dusts

This word is used to designate solid particles generated by diverse mechanical and/or thermal procedures applied during exploitation and/or processing of ores, rocks, wood, and coal. Dusts are the results of advanced fragmentation associated with the above-mentioned types of operations. Generally, dusts are made of particles with high densities; therefore, the particles settle rather easily by gravity and, in most situations, do not flocculate.

5.2 Fume

This name is given for the small particles formed in air by the evaporation of solid materials (the typical case is the metal fume formed during welding). These particles have sizes less than 1 micron and needle-like morphology.

5.3 Smoke

The particles from smoke are generally formed during the combustion or sublimation processes, associated with the local overheating; the particles from smoke are called soot. The smoke cannot be usually avoided when solid carbon-rich fuels are burned (coal, wood, solid waste). In smoke, the dry soot particles are often associated with liquids in complex droplets.

5.4 Vapors

The term vapors refers to the existence of small amounts of certain substances in gas phase, substances which are, in pure state, solid or liquid at ambient temperature and pressure. When increasing the pressure and/or decreasing the temperature, most vapors transform into solid or liquid state. The vapors spread fast and easy in the air, due to their high diffusion potential associated with the high degree of freedom of moving molecules in the gas phase. Most vapors from the indoor air belong to the volatile organic compound (VOC) class (typical examples are various solvents with low boiling points).

5.5 Aerosols

The term aerosol refers to particles of 0.01–100 μm (smaller than in smokes or fumes), in liquid or solid phase. The aerosols remain dispersed in air for quite long time and have a high diffusion capacity to the lung alveoli, even when breathing. Some aerosols are beneficial to health, when a medicine is conditioned as aerosol.

5.6 Mists

Mists are formed sometimes when proper conditions are reached to condense a compound from vapor state to liquid state. The size of the droplets formed is small enough not to be settled as liquid, but remains suspended as small particles. The mists are differentiated from aerosols by the bigger size of the droplets in the first case. Mists are also formed by atomization and splashing in different liquid manipulation technologies.

The effects of the particles on the human health strongly depend on their size and behavior when entering the human body. The fine particles persist in the atmosphere for a few days without sedimentation, so they can be transported over long distances. They can have harmful effects on human health and environment even thousands of kilometers away from the source. The respiratory system supports the strongest attack by small particles. The particles that reach the lungs are fixed on the lung alveoli, reducing the oxygen exchange surface of the lungs. Three types of fractions can be defined [7]:

- The inhalable fraction, which includes all the particles that can enter the nostrils and mouth
- The thoracic fraction, which includes particles that can pass through the larynx and enter the tracheobronchial region during inhalation
- The respirable fraction, which includes small particles that can reach the alveolar region

The risk of particles is due to deposits that occur throughout the respiratory system, from the nose to the alveoli, because the respiratory system is like a channel that branches from the point of inhalation (the nose or mouth) to the pulmonary alveoli with the constant diameter decreasing. As the particle containing air passes through the tracheobronchial tract to the alveoli, the largest particles are progressively stored, followed by smaller particles. The particles with sizes less than 10 μm (PM 10) are deposited on the tracheobronchial tract, and those around 2.5 μm and smaller (PM 2.5) are stored in the lungs. They can readily be absorbed into the blood, causing poisoning or worsening of chronic respiratory diseases [7].

5.7 Gas

Gas is a state of matter characterized by materials with very low density and viscosity, expanding or contracting upon temperature and pressure changes. The gases easily diffused are distributed uniformly in any container. The gases are characterized by weak interactions between the molecules and a strong extent of freedom in moving of the molecules contained. Some gas species from the lower atmosphere layers can diffuse to the upper layers (troposphere), where they can occur chemical reactions influencing the overall atmosphere quality.

Among the gaseous contaminants of the indoor air, the nitrogen and sulfur oxides, hydrogen sulfide, carbon monoxide, carbon dioxide, as well as a large number of Volatile Organic Compounds (VOCs) could be mentioned.

Due to their health-associated issues, such indoor air contaminants are regulated by several organizations in different countries [7, 13].

Sulfur dioxide is a colorless gas with a pungent, irritating odor that causes tearing, retards breathing, and generates discomfort. At long exposure at low concentrations, it was found that pollution from sulfur dioxide and sulfates may cause a higher incidence of colon and breast cancers. In the upper respiratory system, SO_2 can cause lung edema or even death. The main sources of sulfur compounds in the atmosphere are the volcanic eruptions, the bacterial reactions in swamps, the marine phytoplankton reactions, burning of fossil fuels, and sulfide burning to produce SO_2 in the production of sulfuric acid. Traces of SO_2 result from the fuel burning, especially in diesel engines. In wet air and in the presence of UV radiation from the sun, sulfur dioxide transforms into sulfuric acid, which has a remarkable ability to associate the soot particles, generating a very toxic and stable smoke named smog [16].

Hydrogen sulfide results mainly from the urban wastewater treatment and from the spontaneous decomposition of swamp vegetation. This gas has a very unpleasant odor (as rotten eggs) and a quite acidic character [16].

Nitrogen oxides. The main oxides of nitrogen from the air are nitrogen monoxide (NO) and nitrogen dioxide. Nitrogen monoxide is a colorless and odorless gas, while nitrogen dioxide is a brownish-red gas with a strong, sulfurous odor. In combination with airborne particles, NO_2 forms a brown-red mist that, in the presence of sunlight, forms photochemical oxidants. Nitrogen dioxide is a highly toxic gas for both humans and animals because of its oxidizing effect; the degree of toxicity of nitrogen dioxide is four times higher than that of nitrogen monoxide. Short-term exposure to these pollutants causes respiratory difficulties, respiratory irritation, and lung dysfunctions. Long-term exposure at a low concentration may destroy the lung tissue, resulting in pulmonary emphysema, and exposure to high concentrations may be fatal [16].

Carbon monoxide is a colorless, odorless, and insipid gas of natural or anthropogenic provenience. The anthropogenic activities responsible for CO generation are the different processes of incomplete combustion of fossil fuels, in both high-capacity thermoelectric power plants and small domestic heating plants, as well as the combustion of fuels in internal combustion engines and chemical processes occurring in the production of iron and steel and in oil refining. CO is a very toxic gas for humans and animals, being lethal at concentrations of about 100 mg/m^3 , by reducing the oxygen transport capacity in the blood. At relatively low concentrations, it affects the central nervous system, weakens the heart rate, decreases the volume of blood distributed in the body; reduces the visual acuity and physical capacity; generates acute fatigue, breathing difficulties, irritability, migraines, rapid breathing, lack of coordination, nausea, dizziness, and confusion; and reduces the ability to concentrate [17].

Carbon dioxide is the normal product of fuel combustion from the power plants, as well as from the respiratory processes of the living creatures. In ambient conditions, carbon dioxide is a colorless, odorless, slightly acidic, and non-flammable gas. Upon compression and temperature decrease, CO_2 transforms into a liquid or a solid (dry ice) [18].

Carbon dioxide is not what is called a toxic gas, but its concentration indoor is an indicator of a good, breathable healthy air. The normal outdoor CO_2 concentration is of 250–350 ppm, while indoor air of good quality can reach 1000 ppm. After this limit, the CO_2 levels begin to influence the health condition of humans: up to

2000 ppm, the sensation of poor air combines with sleepiness, between 2000 and 5000 ppm; the symptoms are drowsiness, headaches, loss of attention, and even nausea or increased heart rate. Over 5000 ppm, CO₂ could be considered a potential toxic gas, and the oxygen deprivation appears [19].

Particularly, space maximum allowable concentration of CO₂ is 10,000 ppm [2].

The VOCs are a numerous class of organic compounds, with small- or medium-sized molecules, present indoor especially from the construction and decorating materials, as paints, varnishes, and wax; hygiene; and beauty products for cleaning/disinfecting, degreasing, personal care, and hobby products. Commonly, the levels of the most usual VOCs are several times higher inside homes than outside, even for homes located in rural or in highly industrial areas. A characteristic of the VOCs indoor is the fact that the exposure to elevated concentrations can persist in the air long after the activity generating the chemicals had finished [20].

Among the most common VOCs, formaldehyde, aromatic and aliphatic hydrocarbons, carbonyl compounds, as well as chlorinated organic compounds are widely spread indoor [20].

Formaldehyde is one of the most common VOCs. It is a colorless gas with a sharp smell. The sources of formaldehyde indoor are lots of building and finishing materials: plywood, particleboard, glues, waterproof fabrics, foams, and fuel burning [21].

It should be noted that formaldehyde is one of the most toxic indoor air pollutants [13] and its high presence probability indoors due to the above-mentioned sources suggests the need of action in the direction of source-reduction measure implementation.

The main *aromatic, naphthenic, and aliphatic hydrocarbons* cited to be present in the indoor air, especially in the car interiors, are: benzene; toluene; ethylbenzene; xylenes; styrene; propyl-benzene; cumene; ethyl-methyl-benzenes; trimethyl-benzenes; naphthalene; methylcyclopentane; 1,2-dimethylcyclopentane; cyclohexane; dimethylcyclopentane cis- and trans-1,2-dimethylcyclopentane; methylcyclohexane; ethylcyclopentane; 1,4-dimethylcyclohexane; trimethylcyclohexanes; propylcyclohexane; methyl-propyl-cyclohexanes; hexane; 3,3-dimethylpentane; 2-methylhexane; 2,3-dimethylpentane; 3-methylhexane; 3-ethylpentane; heptane; dimethylhexanes; 2-methylheptane; octane; 2,5-dimethylheptane; 3-methyloctane; 2,6-dimethyloctane; 2-methylnonane; decane; undecane; dodecane; tridecane; tetradecane; and pentadecane.

Methylene chloride (dichloromethane), benzyl chloride, carbon tetrachloride, chloroform, trichloroethylene, tetrachloroethylene, p-dichlorobenzene, and 1,1,1-trichloroethane used together with polybrominated diphenyl ethers, hexabromocyclododecanes, tetrabromobisphenol A, and polybrominated biphenyls are some examples of *halogenated compounds* used in plastic materials to improve their technical performance or act as flame retardants [7, 10].

Radon is a radioactive, colorless, odorless, and tasteless gas [22] which occurs naturally as an intermediate step in the normal radioactive decay chains of thorium and uranium. These last elements are often found in the composition of construction materials (i.e., bricks, ceramic tiles, cement, etc.), and therefore the buildings made from these materials could accumulate in time (if the ventilation system is not appropriate) a huge amount of this radioactive gas with dangerous action for human health [23].

6. Conclusions

In order to better understand and control IAQ problems in living spaces, some general aspects related to chemical and particle content of air, with practical

advices, specific terminology including links to standards and regulations, were presented in this chapter.

Monitoring methodology and remediation of IAQ were also reviewed.

Main types of pollutants in indoor air living spaces and their effects upon human health were presented.

In order to point out the importance of IAQ for everyone's health but especially to those that have chronic respiratory problems, a governmental program, namely, Indoor airPLUS, was launched in the USA, on the EPA website, consisting in a voluntary partnership and labeling actions that helps new home builders to improve the quality of indoor air by requiring construction practices and product specifications that minimize exposure to airborne pollutants and contaminants.

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