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Review Article

Air Quality: A Paradox of Toxicity and Aesthetics

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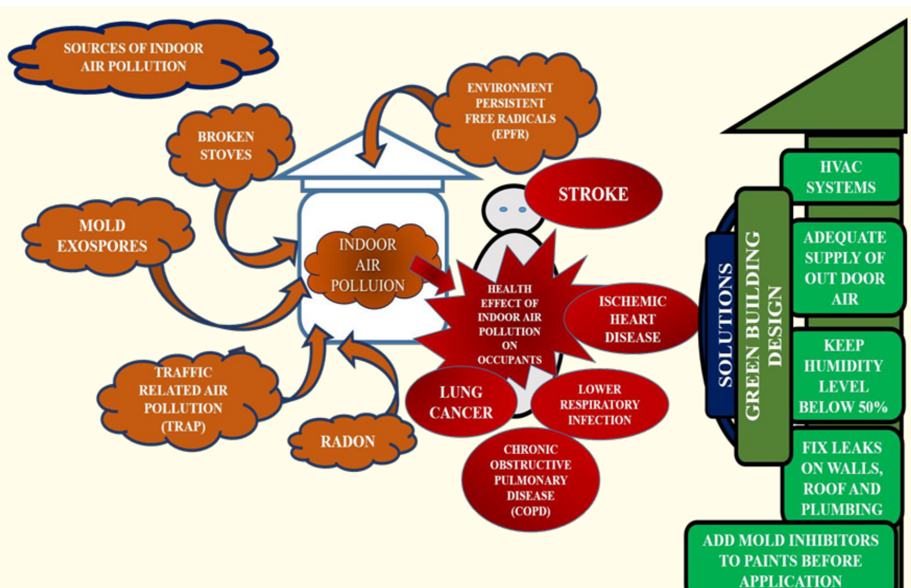
Abstract

This review centers an attempt to examine the complex relationship among indoor air quality, human health, and architectural design principles. With the fast pace of urbanization, the air pollution inside has been blatantly emerging as a public health issue, with over 3 million deaths per year attributed, directly or indirectly, to the contamination of indoor environments, according to WHO data. The irony starts when one tries to weigh their aesthetic aspirations against the toxicity these environments entail. The analyses presented in this review bring together existing research on several major indoor pollutants such as VOCs, ETS, mold spores, and TRAP, along with their immediate and long-standing health effects, ranging from respiratory irritation to the development of COPD or animal. Parallel to these, it also reflects upon foiled efforts in the cutting- edge improvement of indoor air quality through architectural innovations by way of building materials, ventilation methods, and the implementation of a heating, ventilation and air conditioning (HVAC) system. The framework is a healthy building concept upon four pillars: architectural and technical concepts, detailed construction design, environmental engineering, and operational control systems. Such an integrated approach takes into account that from an environmental point of view, truly green interior spaces have to provide a blend of human wellbeing, function in a modern world, and technological considerations. Findings established that newest green building technologies supported by increased policy and public awareness will get us far in resolving the paradox of toxicity and aesthetics in indoor spaces.

Keywords: Indoor Air Quality; Sustainable Architecture; Building Design; Air Pollution; Healthy Buildings; HVAC Systems; Volatile Organic Compounds; Environmental Health

Graphical Abstract



Introduction

As the world grows, the quality of air in our ambience is becoming more contaminated due to diverse factors [1,2]. Human activities in the name of science and technology have turned our natural air into invisible fume of gases. It is almost impossible to take a breath in developed and developing cities without taking in hydrocarbons, oxidants in form of sprays/fragrance, fumes from gadgets and industrial effluents to mention a few [3,4]. Facing this challenge in open air or along busy street could be negligible but having a poisonous fume as an indoor air is a death sentence. According to WHO [5] over 2 billion people around the world cook using faulty stoves and open fires fueled by plant waste, log of woods and petroleum [5].

It was also discovered that indoor air pollution had been recorded to be responsible for over 3 million deaths per year including 237000 mortality rates in children bellow the age of 5 as at 2020 [5]. The accumulated effects of indoor air contamination have been reported to be associated with over 6 million premature deaths yearly. Furthermore, indoor air contamination exposure always leads to noncommunicable health complications like stroke, chronic obstructive pulmonary disease (COPD), lung cancer and Ischaemic heart disease [5,6]. These threats associated with indoor air pollution have triggered inquisitive mind on how to know the quality of air man needs to live a healthy life while enjoying the aesthesis of the indoor ambience free of poisonous emissions.

According to EPA [1], indoor air quality (IAQ) is the pureness in quality of air found within and around a building or a structure most especially as it has to do with the comfort and wellbeing of the building inhabitants. It is a fact that indoor air quality pollution level in one residence may differ from the other depending on the ventilation and different sources of pollutants present in the residence [7]. Exposure to polluted indoor air is almost impossible to quantify because it is based on micro-environmental characteristics [8]. Over the years, many approaches have been routinely used for the determination and quantification of ambient air pollution, but all are not quite suitable for indoor measurement due to conditions like the amount of air displaces, noise, bulk and cost of operation [8]. As technology improved, miniaturized measuring devices were made mainly for indoor uses, but the techniques involved in operating these devices only measure average concentrations for days or several hours which incurred a limitation to their effectiveness in areas of pollutant measurements especially with ones with acute effects such as carbon II oxides (CO), or the ones attributed to short term peak levels than long term average for example nitrogen dioxide [8].

Pollutants like environmental tobacco smoke (ETS) and volatile organic compounds (VOC) are within the confines of interest as a result of their effect on human health when exposed for longer period of time, so, these latter pollutants, the measurement approach with average concentrations over a longer period of time could be sufficiently informative [9,10]. It is certain that the health effects incurred by contaminated indoor air would be experienced soon after some time of exposure or years later possibly [10].

Enhancing air quality through healthy building designs and air quality management

It has been reported that people spend most of their lives indoors, either at work or at home, thus, it is evident to say that the indoor environment is very crucial to our wellbeing for a life time. Some researchers have come to the realization that the indoor air within some buildings could be more contaminated than the outside air even in developed countries [17]. Buildings serve their main purpose in modifying conditions to dissuade people and processes from functioning effectively indoors rather than outside [17,18]. However, the impact a building or shelter has is not just limited to the thermal atmosphere but brings strict intervention for space without the same free passage of air between indoor and outside. It hinders the further mixing and dilutes so much close-source pollutants next to a human inhaling them [6].

Polluted indoor air is greatly evident in the buildings having poor ventilation. Clearly, there is further need to inject outdoor air into the indoor environment of buildings to limit the exposure to indoor pollutants [19]. Moreover, building materials, the construction of buildings, and activities carried out indoors have to be selected on the principle that indoor air levels should be of best quality or the concentration of negative agents should be as low as reasonably achievable. For instance, two are classical approaches to getting a specified level of indoor air quality in terms of pollutants: One is through dilution, the other through source control [19].

Sources of Indoor Air pollution	Health effects	Solution	References
Broken stoves, Indoor open-air cooking fueled by kerosene	Irritation of the skin, eyes, throat and nose	The usage of broken stoves and open-air fire mode of cooking should be stopped Adequate supply of outdoor air, HVAC systems installed	[6,11-13]
Mold exospores. Traffic related air pollution (TRAP)	Sneezing, running nose, skin and eye irritation Allergic bronchopulmonary aspergillosis (ABPA): coughing, shortness of breath and wheezing, fatigue and weight loss	Wipe damp hard surfaces with highly diluted beach solutions. Always keep surfaces dry after use to prevent mold from thriving. Wear an N-95 respirator when cleaning mold to help prevent mold spore's inhalation. Keep humidity levels below 50%. Fix leaks on walls, roof, and plumbing to check moisture availability for mold growth. Add mold inhibitors to paints before application. Adequate supply of outdoor air	[14]
Traffic Related Air Pollution (TRAP), Environmentally Persistent Free Radicals (EPFR)	Fatigue/dizziness Headaches	-Identify and remove or eradicate the indoor air pollution sources that may be possible causes. - HVAC systems installed	[6,13]

Table 1: Immediate Effects of Indoor air pollution on occupants.

Nowadays, it seems that dilution is still the more accepted approach. It is the methodology for improving indoor air quality. Thus, this is the cause of need for ventilation and for the debates on indoor air quality [6]. Hence, the aim of building ventilation is to make air quality much better for persons and processes concerned than that which occurs naturally inside unventilated buildings; to reintroduce the beneficial value of exposure to the wind; for dilution and removal of contaminants produced by humans, their activities, and the indoor surrounding. Large contribution in building sustainable design emerges from criteria used in establishing indoor environment and building design as well as operation. Indoor environment also influences health, productivity as well as comfort of the occupants inside. Cost incurred by deteriorated indoor environment cut across the society, employer, and building owner, and is often found to be higher than even costs accrued through energy consumed by such buildings [6,13].

Energy declaration in absence of declaration related to indoor environment does not make sense. This also calls for specifying criteria for the indoor environment for design, energy calculations, performance, and operation. The last research works' additional aim is perceived air quality. The interaction of building materials and structures with HVAC systems and occupancy performance is continuously observed [5].

Indoor environments

An indoors Environmental Quality concept is the principle approach of architectural, constructional and environment design growth. Healthy/green/sustainable buildings are mass- related and environ-related [12]. Mass aspect is determined by the system Building-Material- Subject and environs aspect is influenced by Building-Fluid-Subject system. Indoor environmental factors are determined by operative perceived comfort and hygiene criteria of indoor physical, chemical and biological compounds. The proper healthy/green/sustainable building design is doubtless task of mass and energy flow reduction. The mass flow reductions mostly consist in material recovery [6,13,20].

The problems with indoor air quality occur when energy flow reduction works together with changed material base composition and used services technology became dominant [5]. There is no contradiction between indoor air quality and energy performance, but the more mass is changed the more energy flow is needed [7]. The investigation of selected chemicals (volatile organic compounds, particles, odors, formaldehyde, radon and nitrogen oxides) as well as were the major objects of research in the last period [21]. It is starkly clear that variety building materials serve as the primary source of indoor volatile organic compounds. Indoor material air pollutants causing alteration Concentration in Contaminants indoor air spaces generally accepted interior surfaces as the main sources of emissions from VOCs [15,21].

Growing evidence indicates that it can build materials, influence the transport and exposure of indoor VOCs through sorption. Re-emission of adsorbed VOCs dramatically increases VOC concentrations indoors for several months or even years after such a source event [15,21]. These surface sorption from material emissions can reduce the concentration and improve the perceived air quality. Therefore, it is suitable to study interactions of individual indoor materials (sorption ability of materials) [21]. The highest priority of chemicals consists primarily of volatile organic compounds, odors, particles, radon and some oxidants, as these are the factors presented in the results. Indoor air quality becomes a major integrating factor of comfort and hygiene perceived indoors. Some of the most interesting factors meet under an environment of material, construction, HVAC, health, economic productivity Prodigy [5,15,21].

Provision of good indoor air quality, contrary to the old perception that it is always expensive and energy inefficient, is brought through avoidance and reduction of indoor air pollution sources and selecting low polluting building materials [5]. Sick building is a syndrome that may cause symptoms in its occupants by creating irritation in the nose, throat, eyes, and skin and producing shortness of breath, nausea, dizziness, and fatigue [15,21]. Here, you will find new ideas presented, which would bring in a wider audience. Indoor air may vastly provide a large amount of interaction between ambient materials and ambient pollutants to change the concentrations in indoor air. Most people accept the internal surfaces as the main cause of emissions from sources that can collect VOCs [21]. There are more and more proofs that it can manipulate building materials in such a way that the indoor transport and exposure of VOCs would occur through the medium of absorption [15,21].

Buildings have caused symptoms such as irritation in the nose, throat, and eyes, and skin irritation, with other symptoms like shortness of breath, nausea, dizziness, and fatigue. And give new ideas introduced, which could create almost a broader audience. Indoor air might vastly open an amount of interaction between ambient materials and adjacent indoor air pollutants to change percentages indoor [4]. Most people accept the internal surfaces as the main cause of emissions from sources that can collect VOCs. More proof exist that can manipulate building materials in such a way that indoor transport and exposure of VOCs would occur by adsorption [3,5,15,21].

Emission from surface sorbents of materials can also decrease levels and improve perceived air quality. Materials such as these would be a proper subject for studies on individual indoor materials' (sorption ability of materials') interactions [4,5]. The most priority chemicals in their results were mainly volatile organic compounds, odors, particles, radon, and some oxidants. Indoor air quality has become the integrating factor for perceived comfort and hygiene indoors. Some interesting prodigies meet each other in an environment of materials, constructions, HVAC, health, economy, and productivity [3-5]. The provision of good indoor air quality was brought out of this old perception that it was always quite expensive or energy inefficient into avoidance and reduction of indoor air pollution sources and selection of low-polluting building materials. The signs of sick building may include irritation in the nose, throat, eyes, and skin as well as shortness of breath, nausea, dizziness, and fatigue [3,4,15,21].

Commonly, these are called Sick Building Syndrome (SBS) symptoms. When the suffering persons leave the building, such diseases tend to be mild and tend to disappear. Often implicated is the low rates of ventilation as a contributing factor. Sickness is concatenated with one airborne allergen that is indoor [2]. Indoor air contaminants can be fine dust, fumes, fibers, odors, or gases that are not removed by air conditioning filters or cleaning. Health effects can manifest right after exposure to indoor air pollutants as well as later, possibly years after exposure. Immediate effects may present themselves after a singular event or after many exposures. These include irritation to the eyes, nose and throat, headache, dizziness, and fatigue. Such immediate effects tend to be transitory and treatable [1,2,4].

Sometimes, it requires nothing more than removing the person from contact with the pollution source, if identified. Some symptoms of diseases, such as asthma, hypersensitivity pneumonitis, and humidifier fever, can almost coincide with exposure to some indoor air pollutants [1,2]. An immediate reaction or symptom following exposure to indoor air pollutants depends on several things. Age and previous health conditions play a key role in determining whether one has such symptoms. In rare cases, whether a person reacts to a pollutant would depend on the individual's sensitivity to it, which varies vastly from person to person. Some people do develop a sensitivity to biological pollutants after a number of exposures, and it seems that some become sensitized to chemical ones as well. Another approach for assessing whether a living environment actually has or will develop indoor air problems is identifying possible sources of indoor air pollution [2,5]. The presence of such sources does not necessarily mean the person has an indoor air quality problem; however, knowing what potential sources exist is an important first step toward assessing air in the indoor environment [2,4].

Buildings design

Two primary aspects, together with others such as standards required by customers, technology knowledge or data on materials, are to be taken into consideration in design formulating a building. Such factors serve as goals - within these healthy buildings [2]. Unfortunately, there are other benchmarks-theories which should be satisfied by each of these factors, say-the factor cost: minimum area. Most of the performance targets will not be common across the various factors, making it at times difficult to find an appropriate design solution for indoor environments, even if sufficient knowledge is present. He had no little doubt that massive strides could be made in the understanding of the design and construction practices that result in healthy buildings in terms of the impacts that buildings have on the health of their occupants and well-being [2,4].

Such a bigger definition of healthy buildings is the impact, again not just onto their occupants but a healthy building is that which adversely affects neither the health of its occupants nor the wider environment. Such a healthy buildings project would entail design recommendations, design criteria and parameters, methods of solution design for healthy buildings and reference to standard controls. The building design, then, is dependent on what environmental safety has to mean and what priorities have been established for designing works. Building design should include calculation of surface area and mass of major materials and products used in construction buildings [2,18]. Specify the use of the building and its operation for entire life with application of effective ventilation strategy in building design process. Analyzed distinct attributes of buildings with enough indoor air quality capable of achieving effective characteristic of healthy building into four basic headings of tools [2,4,18]:

- Architectural and essential technical concept,
- Detailed architectural and construction design,
- Building environmental engineering,
- Operation and control systems.

The awareness of local and global environmental problems has encouraged the long process that has gone through the past 30 years into comprehension understanding on the designs and constructions of healthy buildings [5]. Towards these building designs and constructions to sustainable practices, environmental problems have gradually shifted awareness. Many environmental-friendly principles of design and construction have been widely accepted, but designers and constructors do not usually recommend these practices, or their clients do not adopt such "state-of-the-art" practices. These failures arise due to the wide preference for and adherence to traditional practice, lack of expertise, or short-term financial pinch. However, increasing awareness of environmental problems has led to an emerging turn toward alleged greener building practices that purportedly include such buildings as healthy ones for their occupants [2,4,5].

The concept of energy-efficient, healthy construction has been around since time immemorial, but in this dispensation, it is just becoming of major concerns regarding it [18]. Perhaps among these daily increasing concerns are global warming, the rising costs of energy, increasing awareness and liability costs relating to sick building syndrome, depleting oil reserves, and more worries towards the limited circulatory water supply [18]. The list goes on but whatever the reason- or reasons-sustainable building comes as a very much anticipated concept. However, green and sustainable are different words, which are used almost synonymously and where sustainable very often takes on a much more specific meaning that is quite frequently obscured, distorted, and diluted by the commercialization and marketing of the green movement. The personal understanding of green is simple: a building is green if its design brings about reduction of several possible harmful effects created by buildings to the environment and occupants of the building [1,2,4,5]. Thus, green building design deals with four major issues:

- Designing for energy efficiency, including the usage of renewable energy sources;
- Creating a healthy indoor air environment with adequate ventilation;
- Choosing materials that minimize volatile organic compounds; and
- Specifying building materials and resources that are sustainable, low embodied energy, and produce minimal quantities of upstream environmental impact.

Sustainability at the end is a question of mass flows-this is so; it makes less an expensive means to keep a building more sustainable [2,4]. Four main strategies exist for reducing mass flow within buildings:

- Re-use existing buildings;
- Re-use building materials;
- Recycle building materials that cannot be reused;
- Accommodate exactly the same function in buildings.

Sustainability, in broadest sense, is an ethic of minimizing effects humans make on the environment, thereby addressing the need of present without compromising that of future needs [2,4]. Planning, design and development then become practices and interventions focused towards satisfying the needs of present human habitation conditions while taking into consideration the entire cross-section of natural and cultural systems indigenous to a site and directing a course of action that is minimally disruptive to those systems, and ideally, it enhances and develops them toward long-term viability [2]. Sustainable design focuses more on relationships and processes than it does on objects. Trying their best to create buildings that are sustainable, the designers face a lot of challenges when they get down to a project. First, because many definitions exist for what a sustainable building is, it is usually hard to pinpoint which strategies should go under the sustainable project umbrella. A significant part of this concern is caused by the rapidly developing and changing information. Secondly, the vast body of information on the subject is much too cumbersome to truly dig through or too fragmented as if to make any coherent whole [4,18]. Thirdly, indeed there are excellent rating systems for sustainable building, but tend to deal more with the strategies than with the process one should go through as applied in an actual project [2,4].

Every strategy mandate action at some point or other in the life cycle of a building, which has been segregated into the following parts: planning, design, construction occupancy and next use. The planning phase covers project initiation, programming and site selection [4,18]. The subparts of the design process are schematic design, design development and construction documents. Planning, design and construction portion stand for building delivery process. The guide should also incorporate the entire occupancy period of the facility as these buildings would typically be owned and operated by public agency. For occupation, many strategies must be carried out [18,20]. The environmental impacts, especially the operating and maintenance part in a buildings life cycle, give critical opportunities in optimizing energy performance in the facility. Once the building reaches its end of life, under a specific use, the next use will be analyzed and planning, designing, constructing and operating will begin all over again [4,18,20].

Conclusion

In the dispensation times, the aesthetic, quality, and the green building will become a strong point for improving indoor environments. Solutions to indoor air pollution should include new technologies and less polluting materials but also a change in attitudes and policy at the community level. In this way, healthy and practical indoor spaces can help achieve a compromise between human wellbeing, the environment, and modern needs. Energy-efficient building designs coupled with air quality improvement are important in reversing the health damage caused by air pollutants and meeting sustainability goals. Ultimately, awareness development, multi-disciplinary collaborations, and progressive policies will create greener, inclusive, and healthier living environments for everyone.

Authors Contribution

The authors contributed equally to this work.

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Conflict of Interest

The authors declare no conflicts of interest.

Bibliography

1. "EPA Indoor Air Pollution and Health" (2020).
2. Mannan M and Al-Ghamdi S. "Indoor Air Quality in Buildings: A Comprehensive Review on the Factors Influencing Air Pollution in Residential and Commercial Structure". *International Journal of Environmental Research and Public Health* 18.6 (2021): 3276.
3. Guanqiong W., *et al*. "A review and comparison of the indoor air quality requirements in selected building standards and certifications". *Building and Environment* 226.109709 (2022).
4. Baeza-Romero MT., *et al*. "A review of critical residential buildings parameters and activities when investigating indoor air quality and pollutants". *Indoor Air* 32.11 (2022).
5. WHO. Tracking SDG 7: The Energy Progress Report. World Bank, Washington D.C. World Bank. License: Creative Commons Attribution—Noncommercia (2024).
6. Puthumana S., *et al*. "Risk factors for cooking-related burn injuries in children, WHO Global Burn Registry". *Bulletin of the World Health Organization* 99.6 (2021): 439-444.
7. Senitkova J. "Indoor air quality-buildings design". *MATEC Web of Conferences* 93 (2017): 03001
8. Hromadka J., *et al*. "Multi- parameter measurements using optical fibre long period gratings for indoor air quality monitoring". *Sensors and Actuators B: Chemical* 244 (2017): 217–225.
9. Koivisto A., *et al*. "Source specific exposure and risk assessment for indoor aerosols". *Science of the Total Environment* 668 (2019): 13-24.
10. Hamanaka RB and Mutlu GM. "Particulate matter air pollution: Effects on the cardiovascular system". *Frontiers in Endocrinology* (2018).
11. Yu K., *et al*. "Indoor air pollution from gas cooking in five Taiwanese families". *Building and Environment* 93 (2015): 258-266.
12. Kim H., *et al*. "Measurement of particulate matter (PM2.5) and health risk assessment of cooking-generated particles in the kitchen and living rooms of apartment houses". *Sustainability* (2018).
13. Young C., *et al*. "Illuminating the dark side of indoor oxidants". *Environmental Science: Processes and Impacts* 21 (2019): 1229.
14. Center for Disease Control and Prevention CDC. Mold (2024).
15. Zhang Q and Jenkins L. "Evaluation of ozone emissions and exposures from consumer products and home appliances". *Indoor Air* 27 (2016): 386-397.
16. Harris JL. "Mold: An Indoor Air Pollutant" (2016).
17. Argunhan Z and Avci A. "Statistical evaluation of indoor air quality parameters in classrooms of a university". *Advances in Meteorology* (2018): 4391579.
18. Peng Z., *et al*. "Investigation of indoor air quality and the identification of influential factors at primary schools in the north of China". *Sustainability* 9 (2017): 1180.
19. Zhang X., *et al*. "Effects of exposure to carbon dioxide and bio effluents on perceived air quality, self-assessed acute health symptoms and cognitive performance". *Indoor Air* 27 (2017): 47-64.
20. Vornanen-Winqvist C., *et al*. "Effects of ventilation improvement on measured and perceived indoor air quality in a school building with a hybrid ventilation system". *International Journal of Environmental Research and Public Health* 201.15 (2021): 1414.