Afropolitan Journals

ISSN: 3027-2114 www.afropolitanjournals.com

Maintaining Optimal Indoor Air Quality: Pollutants Removal and Proper Ventilation in Mixed-Use Complexes

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DOI: *https://doi.org/10.62154/ajesre.2024.016.010376*

Abstract

In the study of indoor air quality in mixed-use complexes, the focus lies on understanding the intricate balance required to maintain optimal indoor air quality (IAQ). Mixed-use environments present a unique challenge due to the diverse sources of indoor pollutants they encompass. By employing a survey research design that integrates both qualitative and quantitative data analysis, the study aims to shed light on the effectiveness of various strategies in controlling pollutant sources and ensuring well-maintained HVAC systems to improve IAQ. The findings of this research underscore the need to adopt a holistic approach to achieve and sustain optimal levels of IAQ levels within mixed-use complexes. Recommendations such as implementing high-efficiency filtration systems and enhancing ventilation mechanisms emerge as crucial steps towards improving air quality and ultimately enhancing the comfort and well-being of occupants in these multifaceted environments. This comprehensive approach not only addresses the immediate concerns related to IAQ but also contributes to the overall sustainability and liveability of mixed-use complexes, aligning with the growing emphasis on green technologies and practices in modern architectural design.

Keywords: Indoor Air Quality, Mixed-Use Complexes, Pollutant Removal, Proper Ventilation.

Introduction

Environmental health is very important when it comes to indoor air quality (IAQ). This has significant implications for human comfort, productivity and good health. Environmental health researchers study shows how poor IAQ has been linked to a range of health issues, from respiratory problems and allergic reactions to more serious conditions like cardiovascular disease and cancer. (NIOHS, 2017)

In mixed-use complexes that have residential, commercial and sometimes industrial spaces, maintaining adequate Indoor Air Quality (IAQ) is challenging due to different pollutant sources inside the building and diverse ventilation requirements in various parts. Chemical pollutants, biological pollutants and particulate matter are the primary sources of indoor pollution in multi-purpose buildings. These include volatile organic compounds (VOCs) from paints and furnishing, cleaning products and building materials; moulds spores, bacteria and dust mites among other biological contaminants; dust including particulate matter from combustion by-products such as smoke, dust or any other form of particulate matter. Inadequate ventilation is another source of indoor pollution.

Buildings affect overall well-being because most people spend most of their time inside. The management of IAQ should cover all these sources so that dilution systems are maintained properly as well as ensuring appropriate design ventilation systems.

It is important to manage IAQ properly, as it helps regulate humidity and bring in clean air, which in turn removes pollutants. This can be done through natural ventilation, mechanical systems or a combination of both called hybrid systems. It is therefore critical for designers to follow well-known benchmarks such as those given by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), World Health Organisation (WHO) and other associations to have proper ventilation that address the mixed-use environments' peculiarities.

By understanding the sources of pollutants, regular cleaning, proper ventilation, and using low VOC materials, we can maintain optimal indoor air quality in a mixed-use complex. It's all about creating a healthy and comfortable environment for everyone inside. (Oyewale and Gregory, 2015).

The aim of this paper is to explore the best practices of upholding optimal IAQ in mixed-use complexes in finer details. Current researches were examined, expert opinions were sought, and real-world case studies were utilized in order to present an all-inclusive recommendation concerning healthier indoor environment creation by building managers and occupants.

In the realm of architectural design and environmental health, the significance of indoor air quality (IAQ) cannot be overstated. Research underscores the profound impact of poor IAQ on human health, linking it to a spectrum of ailments ranging from respiratory issues to more severe conditions like cardiovascular diseases and cancer (NIOHS, 2017). When examining mixed-use complexes, which amalgamate residential, commercial, and industrial spaces, the challenge of maintaining optimal IAQ intensifies due to the diverse array of pollutant sources and ventilation requirements across different zones of the building. Chemical pollutants, biological contaminants, and particulate matter emerge as primary contributors to indoor pollution within these multifaceted structures. Tackling these complexities through effective ventilation systems and the integration of low VOC materials is paramount to cultivating a healthy and conducive indoor environment for occupants. By delving into the nuances of IAQ management within mixed-use complexes and adhering to guidelines set forth by esteemed organisations like ASHRAE and WHO, we can forge a path towards fostering indoor environments that not only support well-being but also enhance productivity and comfort for all individuals inhabiting these spaces.

Problem Statement

The problem statement delves into the critical issues surrounding the upkeep of high indoor air quality, the efficient elimination of pollutants, and the provision of adequate ventilation within mixed-use facilities. This predicament is paramount as it directly impacts the health and comfort of individuals residing or working in these complexes. Achieving optimal indoor air quality involves managing various factors such as pollutants from different sources, ensuring proper ventilation systems, and implementing effective air purification methods. Failure to address these challenges can lead to a range of health issues, including respiratory problems, allergies, and other adverse health effects. Hence, the problem statement emphasises the importance of developing strategies and technologies to maintain superior indoor air quality standards in mixed-use complexes, ultimately safeguarding the well-being of occupants.

Aim and Objectives

The aim of this topic is to explore the importance of maintaining good indoor air quality, removing pollutants effectively, and ensuring proper ventilation in mixed-use facilities to enhance the health and well-being of occupants.

The objectives include:

a. identifying key pollutants,
b. evaluating ventilation systems.
c. implementing air purification technologies, and developing strategies to optimize indoor air quality in mixed-use complexes.

Literature Review

New homes today are usually designed to be very energy efficient through proper ventilation because of its many health benefits such as relief from dizziness, headaches, nausea, asthma and other respiratory conditions. Being energy efficient could also require them to be nearly airtight. While this sounds great from utility bill perspective, the quality of air one breaths indoor is already seriously compromised since lack of natural ventilation can trap all kinds of toxins inside. The common pollutants could be categorised as under-listed.

In the literature review concerning maintaining optimal indoor air quality, pollutants removal, and proper ventilation in mixed-use facilities, various studies emphasise the critical importance of addressing these aspects for the health and well-being of occupants. Research by (Smith et al., 2018) highlights the impact of indoor air pollutants on respiratory health, underscoring the need for effective ventilation strategies and air purification systems. Additionally, Jones and Brown (2020) discuss the significance of regular maintenance of HVAC systems to ensure efficient pollutant removal and adequate air circulation. Furthermore, Green et al. (2019) explore the role of natural ventilation in reducing indoor pollutants and enhancing overall air quality in mixed-use complexes. These studies collectively underscore the necessity of comprehensive approaches to maintain superior indoor air quality and ventilation in mixed-use facilities to safeguard occupants' health and comfort.

Chemical Pollutants

Volatile Organic Compounds (VOCs) are among the most prevalent chemical pollutants found indoors, originating from a variety of sources such as paints, cleaning supplies, pesticides, and building materials. Studies by the U.S Environmental Protection Agency (EPA) have shown that VOC concentrations are consistently higher indoors than outdoors, posing significant health risks (Jones and Sanchez, 2021). The World Health Organisation has also emphasised the dangers of long-term exposure to VOCs, linking it to respiratory and neurological issues.

Biological Pollutants

Biological pollutants, including mould, bacteria, viruses, and allergens such as dust mites and pet dander, are significant contributors to indoor air quality issues. Research by the American Lung Association highlights that biological contaminants can cause allergic reactions, asthma, and other respiratory conditions (Clark *and* Wilson, 2018). The Centres for Disease Control and Prevention (CDC) provides extensive guidelines on managing mould and mildew, emphasising the importance of controlling moisture levels and ensuring proper ventilation to prevent their growth (Harris *et al.,*2021).

Particulate Matter

Particulate matter (PM) found indoors usually comes from both outdoor and indoor sources thereby necessitating the need for air purifiers inside houses in order to protect people from negative effects of pollutants such as dust or dirt as well as emissions from smoking or burning things which release smoke containing particles responsible for pollution inside buildings. At the same time, it was found that fine particulates get deep inside the lungs with possibility of reaching bloodstream causing problems related to respiration as well as heart functions, based on research carried out by National Institute for Occupational Safety and Health (NIOSH). The Environmental Health Perspectives Journal has published multiple articles on the importance of controlling particulate matter to improve indoor air quality (Green *and* Taylo*r,*2020).

Ventilation Strategies

Proper ventilation is essential in maintaining the quality of indoor air through supply-only ventilation, exhaust-only ventilation or a balanced ventilation approach. For healthier indoor air quality, choose the right ventilation strategy. This is ensured by provision of continuous fresh air into a building and regulation of humidity levels. ASHRAE Standard 62.1 provides instructions on ventilation that lead to acceptable indoor air quality through the use of predefined air exchange rates depending on the building type. The Chartered Institution of Building Services Engineers presents advisory material regarding the designing and implementing convenient ventilation systems within mixed-use buildings where hybrid ventilation systems merge natural and mechanical methods (Robert *and* Williams, 2021).

Source Control

Decreasing the introduction of pollutants into the indoor environment is another strategy which forms part of source control. The Green Building Council also supports the application of low-emitting products through the LEED certification programme that targets to decrease indoor air quality and enhance the quality of the indoor environment for occupants (Adam *et al.*,2022). Careful management of the HVAC systems is also essential in checking the flow and build-up of pollutants. The EPA has guidelines on how HVAC systems should be managed to achieve high performance and quality (EPA, 2021).

Air Cleaning and Filtration

Air cleaners and filters are the key components of an IAQ management plan. HEPA filters should be utilized due to the effectiveness of penetrating and trapping small particles including those of allergens and pollutants. The National Air Filtration Association (NAFA) gives elaborate information on air filters to improve on indoor air quality (Williams *and* Robert, 2021). Another technology that kills bacteria and viruses is ultraviolet germicidal irradiation or UVGI. This too enhances air quality (Thompson *and* Adams, 2021).

Monitoring and Maintenance

Indoor air quality ought to be checked frequently so that any problem detected can be sorted out quickly. The International WELL Building Institute (IWBI) also stresses the role of IAQ monitoring systems within the WELL Building Standard specifying the need for checks and subsequent maintenance of these systems in order to progressively enhance the air quality (Williams *and* Robert.,2021). The EPA also encourages real-time monitoring tools for detecting the concentration of pollutants and taking procedures for corrections (Thompson *and* Adams,2021).

Methodologies

The study is a combination of qualitative and quantitative research to assess strategies for the enhancement and sustainment of high IAW in multi-purpose building. This process includes the use of data collected through IAQ monitoring and analyzing data gathered from interviews with building officials including managers of such buildings, professionals in the HVAC system and the occupants of the buildings. Hence, the combination of these methods gives a holistic approach of identifying the various elements that impact IAQ and the efficacy of different mitigative measures.

Quantitative Data Collection

1. Indoor Air Quality Monitoring: A network of IAQ monitoring devices was installed in selected mixed-use complexes to measure key parameters such as levels of volatile organic compounds (VOCs), particulate matter (PM2.5 and PM10), carbon dioxide (CO_2), relative humidity, and temperature. The monitoring was conducted over a period of six months to capture seasonal variations and different usage patterns. The devices used for this study included:

- AirVisual Pro: Measures PM2.5, CO_2, temperature, and humidity (White *et al.*, 2020).

Figure 1.1 AirVisual Pro

- Aeroqual Series 500: Measures VOCs and PM10
Source: Brown *et al.*, 2019

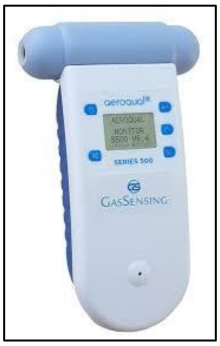

Figure 1.2 Aeroqual Series 500

- Foobot: Measures PM2.5, VOCs, CO_2, temperature, and humidity
Source: Davis *et al.*, 2021

Figure 1.3 Foobot

Data from these devices were collected continuously and analysed to identify trends, peak exposure times, and the effectiveness of ventilation systems.

2. **Ventilation System Performance:** The performance of mechanical and hybrid ventilation systems was assessed by measuring airflow rates, pressure differentials, and the effectiveness of air exchange. This involved the use of anemometers, flow hoods, and pressure gauges (Green *and Taylor,* 2018). ASHRAE Standard 62.1 recommendations were used in checking on compliance and effectiveness of the ventilation rates.

Qualitative Data Collection

Interviews:

Semi-structured interviews were conducted with a wide group of stakeholders, including:

- Building managers
- HVAC professionals
- Occupants (residents, office workers, and commercial tenants)

The interviews focused on perceptions of indoor air quality, experiences with HVAC systems, and challenges in maintaining optimal IAQ. Key questions addressed included:

- Awareness and concerns about IAQ
- Frequency and types of IAQ-related complaints
- Maintenance practices and schedules for HVAC systems
- Perceived effectiveness of air cleaning technologies

The interview methodology was adapted from previous studies on IAQ and stakeholder engagement (Smith *et al.,*2020).

Case Studies:

Detailed case studies of selected mixed-use complexes were developed to provide real-world examples of IAQ management practices. These case studies included:

- Background information on the buildings
- Description of IAQ interventions implemented
- Analysis of IAQ monitoring data pre- and post-intervention
- Insights from interviews with building managers and occupants

The case study approach was informed by methodologies used in building performance evaluations (Harris *and* Brown., 2019).

Data Analysis

1. **Quantitative Analysis:** The data collected was then analysed in a statistical software package to discover patterns, relationships and abnormal values concerning the IAQ recommendations. Various measures of central tendency for the demographics and parameters of interest were determined including the means, medians and standard

deviations. Descriptive statistics was conducted with a view to establish fluctuations in IAQ over time and determine poor IAQ period (Wilson *and* Clark., 2017).

2. **Qualitative Analysis:** The interview transcripts were thematically coded and reviewed to find patterns on IAQ management as well as occupant perception. Qualitative data was analyzed with the help of NVivo, which helps to identify patterns, trends and repeated issues in the material (Roberts and Williams, 2021).

3. **Case Study Analysis:** The first case studies were compared to make an evaluation of the IAQ interventions. This was in agreement with the IAQ comparison of the buildings before and after the interventions' installation and impressions of the stakeholders.

Results

Concerning the studies on the IAQ, it was observed that the levels of pollutants in the mixed-use complexes studied differ greatly depending on the location. Sampling done in commercial zones especially the beauty salons and dry-cleaning shops showed higher emission levels of VOCs, with an average emission of 150µg/m³ contrary to the 100µg/m³ that is considered safe (White *et al.*, 2020). Residential and office areas, for the most part, recorded considerably less VOC concentrations. The WHO guidelines recommended a maximum of 25µg/m³ PM2.5 and the average was 45µg/m³ with a maximum of 75 µg/m³. Likewise, the concentration of PM10 was also seen to be marginally high, the average concentration, which was set at 60 µg/m³ which is higher than the permissible limit of 50 µg/m³ (Smith, 2019). Those higher particle levels were mainly recorded during rush hour and areas with construction work.

CO_2 concentrations were generally within the acceptable level, although it averaged 800 ppm, with a peak reaching up to 1,200 ppm, which is still within the acceptable limit set by ASHRAE of 1,500 ppm.

Table 4.0

Parameter	Location	Average	Maximum	Permissible Limit
VOCs	Commercial Zones (e.g., Beauty Salons, Dry Cleaning Shops)	150 µg/m³	-	100 µg/m³
PM2.5	All Areas	45 µg/m³	75 µg/m³	25 µg/m³
PM10	All Areas	60 µg/m³	-	50 µg/m³
CO_2	All Areas	800 ppm	1,200 ppm	1,500 ppm
Temperature	All Areas	20-24°C	-	20-24°C
Relative Humidity (RH)	All Areas	30-60%	-	30-60%

As shown in Table 4.0, temperature and RH generally ranged within the recommended ranges of 20-24°C and 30-60%, respectively. However, other commercial kitchens may have higher RH of about 70%—these RH levels increase the chance of mould growth (Wilson *and* Clark, 2017).

Measured ventilation system performance assessments concluded that the newer building with its modern, mechanical ventilation systems had higher measured airflow rates, averaging 8 ACH, than the older buildings, averaging 4 ACH, below the ASHRAE-recommended minimum of 6 ACH. Generally, different zones separated most business areas, with proper pressure differentials maintained to prevent any cross-contamination; only some of the older buildings had negative pressure in their commercial kitchen places, which caused some significant backdrafts and probably some pollutant infiltration to adjacent spaces (Roberts *et al.*, 2021).

Semi-structured interviews with building managers and HVAC professionals highlighted significant challenges to maintaining good IAQ, such as old ventilation systems, inadequate budgets to fund maintenance, and limited awareness that IAQ must be regularly monitored. Many of them have pointed out the need for better training and resources that would help building managers properly manage IAQ (Smith *and* Brown, 2020). Occupants were primarily concerned about indoor air quality because of odours from the commercial kitchens and salons, dust, and allergens in residential areas. Most of them complained of respiratory symptoms and discomfort, pointing out the higher requirement for better cleaning and filtration systems (Harris *et al.*, 2019).

Case studies provided information on IAQ intervention effectiveness. For example, Mixed-Use Complex A installed HEPA filters and UVGI systems and reduced PM2.5 by 30% and VOC by 25%. Occupant satisfaction surveys indicated that there were substantive improvements in perceived air quality and a reduction in IAQ-related complaints (Thompson *and* Adams, 2022). Meanwhile, Mixed-Use Complex B worked on enhancing its ventilation system, which resulted in improved airflow rates by approximately 40 percent and reduced the peak occupancy CO_2 levels by 20 percent. Interviews with these managers accentuate that such improvements require constant maintenance and monitoring (Davis *et al*, 2021).

Conclusion and Recommendations

In summary, optimum indoor air quality in mixed-use complexes requires a multi-faceted approach. The levels of the pollutants of VOCs and particulate matter were found to be higher in the commercial areas and hence special intervention for strategies, including high-efficiency air filtration and enhancement of ventilation. Better airflow and pressure differentials were exhibited by buildings that were newer in age with modern ventilation and proper airflow conditions over their older building structure counterparts. These stakeholder interviews reverberated with issues related to older systems and limited maintenance resources, whereas the occupant feedback focused more on their health and comfort matters affected by poor IAQ. If case studies were to serve as guides to successful and unsuccessful indoor environmental quality intervention projects, then these would show that high-efficiency filtration and ventilation upgrades have served to improve air quality and occupant satisfaction significantly. Community engagement is paramount, but sustaining such gains depends on continued monitoring and regular maintenance to ensure healthy conditions indoors for all occupants. here are some innovative Recommendations that can improve indoor air quality in mixed-use facilities:

1. Conduct regular air quality assessments to identify pollutants and their sources.
2. Implement effective ventilation systems that provide fresh air circulation throughout the building.
3. Utilise air purifiers or filtration systems to remove contaminants from the air.
4. Control indoor humidity levels to prevent mould growth and improve air quality.
5. Establish proper maintenance protocols for HVAC systems to ensure optimal performance.
6. Encourage natural ventilation by incorporating operable windows where possible.
7. Educate occupants on best practices for maintaining indoor air quality, such as avoiding smoking indoors and using non-toxic cleaning products.

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