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Building Indoor Air Quality: A Comprehensive Review of the Factors Affecting Air Pollution in Residential and Commercial Structures

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Abstract - People spend nearly 90% of their time indoors in various indoor conditions across the world. Contaminants are formed in interior environments as a result of various activities such as heating, cooling, cooking, and emissions from construction items and materials utilised, in addition to the penetration of pollutants from the outside air. Because individuals spend the majority of their time indoors, this has a tremendous impact on human health and productivity. Despite two decades of IAQ research from various perspectives, a comprehensive evaluation of peer-reviewed IAQ studies that specifically covers the relationship between the internal characteristics of different types of building environments and IAQ to help understand the progress and limitations of IAQ research worldwide is still lacking.

As a result, this overview of scientific publications highlights the trends and gaps in IAQ research by presenting a broad range of contaminants detected in both residential and commercial indoor settings. Furthermore, we were able to use data from the literature to help us. to evaluate the various IAQs in buildings in various countries/regions, therefore representing the current scientific understanding of IAQ on a worldwide scale. This evaluation has the potential to be beneficial to the construction industry. By developing indoor air rules that account for all indoor pollutant sources, specialists can help.

INTRODUCTION

People in metropolitan areas spend more than 90% of their daily lives indoors, according to research. People spend a considerable majority of their time indoors, outside of their homes, at workplaces, educational institutions, and other commercial and industrial structures. According to study conducted in North America, individuals spend 87 percent of their time in buildings, with the remaining spent in automobiles (6 percent) and outdoors (7 percent) . Exposure to indoor air pollution has a substantial influence on both human health and workplace effectiveness since individuals spend the bulk of their time inside.

However, air quality research has been concentrated on the outdoors, with interior air quality (IAQ) and its consequences receiving far less attention until the last decade Because research has shown that indoor air is more polluted than outside air , both scientists and the general public have recently focused on the hazards connected with IAQ. There have been considerable changes in the type and complex compositions of indoor air pollutants as a result of continual changes in living style and the materials used in interior settings, which opens up avenues that need to be researched further.

INDOOR TIME-SPENDING PATTERNS

People spend the bulk of their time in a variety of facilities, including dwellings, workplaces, schools, and restaurants, according to their various daily activities . The quality of air in interior places has a considerable impact on human health and well-being. Several studies have found a correlation between better indoor conditions and enhanced human health . In the worst-case situation, low IAQ leads to unfavourable health outcomes, including death. This emphasises the significance of indoor air quality in any interior place where people spend the bulk of their time.

SOURCES OF INDOOR POLLUTION AND THEIR HEALTH CONSEQUENCES

The energy crisis of the 1970s highlighted the necessity of energy conservation in buildings, resulting in more airtight and insulated structures throughout the world . Reduced volumes of fresh air are pumped in air conditioning systems to save electricity. Furthermore, as people's living conditions rise, more synthetic materials and chemicals are employed in buildings for indoor construction and decoration. Other forms of indoor air pollution include insecticides, cleaning chemicals, air fresheners, and cooking emissions.

Because indoor pollution is primarily caused by poor ventilation, a lack of air conditioning systems, human activities, and a

variety of materials, chemicals, and gases, organisations such as the United States Environmental Protection Agency (US EPA) and the World Health Organization (WHO) have recognised IAQ as a multi-disciplinary phenomenon and classified pollutants into several categories. Indoor air pollution was responsible for about 1.5 million fatalities in 2000, according to the WHO . Furthermore, indoor air pollution has been identified as the third leading cause of disability-adjusted life years in the world .

THE STUDY'S GOAL

Demand for excellent quality of life has introduced several new components in indoor building settings as the population and economy continue to expand. In addition, different types of buildings change over time, affecting indoor air quality and human health. As a result, analysing the IAQ in a variety of end-use buildings is critical in order to identify each probable indoor pollutant in certain types of buildings that causes negative health effects. Despite two decades of IAQ research from many angles, a structured evaluation of peer-reviewed IAQ studies that particularly address both residential and commercial building settings is still lacking.

These would aid in understanding the elements that influence IAQ in various types of building settings, as well as the ability to highlight the advances and limits of IAQ research throughout the world. Int. J. Environ. Res. Public Health 2021, 18, 3276 4 of 25 To allow viable sustainable solutions for better IAQ, a deeper knowledge of the relationship between different building attributes and air pollutant concentrations is necessary.

To close this gap, we looked at scientific research from across the world that looked at IAQ in both residential and commercial buildings. As a result, this analysis has highlighted trends and gaps in scientific research for both the residential and commercial sectors that focus on quantitative changes in air parameters as a result of IAQ. We also looked at the internationally accepted IAQ standards as well as the sampling procedures used in peer-reviewed publications. This evaluation was conducted in order to promote and expedite future research on the design of optimal building settings in order to give the highest potential IAQ advantages for future healthy indoor environments.

This review contains scientific research from many relevant scientific databases in order to achieve these goals. The remaining sections of this review article are divided into four sections:

(1) worldwide IAQ standards and assessment techniques,

(2) residential buildings and IAQ assessment,

(3) commercial buildings and IAQ assessment, and

(4) conclusions and future scope.

METHODOLOGY

This analysis is based on peer-reviewed journal papers from a variety of reputable databases, including ScienceDirect, Wiley Online Library, and Taylor & Francis. To see how scientific research has progressed over the previous two decades, we generally look at publications published in the recent two decades. The household areas where individuals spend the bulk of their time, as well as the IAQ in two separate business buildings (offices and educational institutes), have been studied since this assessment addresses the IAQ of both residential and commercial structures.

Hospitals, malls, and restaurants are not included in this analysis since the percentage of time spent in these venues is minimal when compared to time spent in offices and educational institutions. We attempted to describe the global advancement of IAQ research in this review, hence peer-reviewed papers from all around the world were evaluated.In addition to journal papers, a few conference papers and government reports were examined to improve the review's quality.Several keyword combinations were used to search the database, including IAQ, residential building, commercial building, office, school, indoor air pollution, educational institute, house, and IAQ requirements. Phase 1 screening was completed to exclude papers that were qualitative in nature and to concentrate on IAQ for other types of commercial facilities such as hospitals, malls, and restaurants, which are beyond the scope of this review research. These keywords were only searched in the title of conference papers and reports. Phase 2 featured a three-stage literature screening procedure after the basic search. After carefully reviewing the abstracts and applying the inclusion criteria, the first stage of the literature filter (filtration step 1) was completed.

STANDARDS FOR INDOOR AIR QUALITY AND METHODS FOR MEASURING IT

People spend a large amount of time inside, and there are several pollution sources in those places, such as conventional and newly created construction materials, finishing goods, furniture, cooking systems, and cleaning chemicals. As a result, several international organisations, such as the World Health Organization (WHO), have established guidelines and threshold values to maintain optimal IAQ . A part from the WHO, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the US EPA, the National Health and Medical Research Council in Australia, Health Canada, the State Environment Protection Agency in China, the Hong Kong Indoor Air Quality Objectives, the Danish Society of Indoor Climate, and the Finnish Society of Indoor Climate are among the most well-known organisations involved in IAQ regulations.

COMMERCIAL BUILDINGS AND INDOOR AIR QUALITY ASSESSMENT

Because children are more vulnerable to air pollutants than adults and spend a large amount of time in schools, researchers have focused their attention on IAQ in schools. Similarly, IAQ in office buildings has been a source of worry since it has a major impact on worker productivity. Recognizing a study need in this sector, a large number of commercial buildings (including 20

workplaces, 4 schools, 1 hospital, and 1 nursing home), as well as homes and construction goods, were surveyed in Australia in 2003 to explore the occurrence of indoor VOCs .

Chemical emissions from building materials or furnishings, as well as inadequate ventilation, were mentioned as contributing contributors to indoor air pollution in schools. The HCHO concentration was determined to be much greater than the Korean government's standard value. Another research concentrating on preschools was undertaken in Korea due to the increased vulnerability of younger children compared to older children. According to the findings, preschools in metropolitan regions had much higher levels of indoor pollution than outdoor and rural preschool environments in Korea.

This study also revealed the drawback of low-efficiency filters in the majority of the buildings studied, which enabled external pollutants to enter the building. The role of humans in IAQ was assessed using a continuous VOC measurement process in a university classroom in Boulder, Colorado, USA . Apart from building materials and other processes inside buildings, the Int. J. Environ. Res. Public Health 2021, 18, 3276 17 of 25 role of humans in IAQ was assessed using a university classroom in Boulder, Colorado, USA. The indoor VOC concentration is influenced by human respiratory emissions and the interaction of O3 with their skin lipids, according to the VOC measuring study. An investigation was conducted in nursery schools in Poland to better understand the impact of children's activities on IAQ. Indoor pollutant concentrations were found to be higher than those found outside, with PM2.5 and PM10 concentrations exceeding WHO indoor guidelines of 41.17–106.06 g/m3 and 68.26–149.81 g/m3, respectively. In 18 classrooms in the Netherlands, the effect of improved ventilation on classroom IAQ was tested . Increased ventilation resulted in significantly reduced concentrations of endotoxin, b(1,3)-glucan, and PM10, but had no influence on PM2.5 or NO2 levels. Significant PM concentrations in indoor areas are mostly generated by ventilation, poor building envelopes, and windows, according to the research. During a study of Qatari schools, CO2 and particulate matter concentrations were substantially higher than the ASHRAE and US EPA IAQ guidelines, and outdoor PM levels were identified as the major explanation for excessive indoor particulate matter levels . A study of Turkish university classrooms found greater CO2 and PM levels, as well as a radon concentration that was lower than the International Commission on Radiological Protection's standard value but higher than other global values .

CONCLUSIONS AND FUTURE SCOPE

The goal of this article, which covers the previous 20 years of indoor air research, was to evaluate the IAQ sector from many perspectives in order to better understand the connection between IAQ and building settings, which were mostly residential and a few commercial. Because individuals spend more than 85–90 percent of their time in buildings, the indoor air quality of different types of buildings can have a significant influence on human health. As a result, this study has conducted a review of the present state of the art and knowledge in the field of indoor air quality in various residential and commercial buildings.

Furthermore, papers from various nations were evaluated in order to comprehend the advancement in IAQ research throughout the world. A region/place-specific evaluation can help identify the primary indoor air pollutants in each area that need to be addressed for long-term solutions. As a result, the purpose of this analysis was to assist building experts in developing new indoor air rules that take into account main air pollutants, all indoor contaminant sources, and related health effects in order to promote safe and sustainable building environments. During the design and maintenance phase of building environments, most developed nations evaluate and implement IAQ laws through suitable procedures. However, in poorer or impoverished nations, where low IAQ disproportionately impacts children, women, and the elderly, this scenario does not apply Despite the serious consequences of indoor air pollution, most poor and impoverished countries/regions still lack adequate scientific study on IAQ.

Int. J. Environ. Res. Public Health 2021, 18, 3276 21 of 25 VOCs were studied in most of the reviewed studies. Despite the fact that a few research have looked at VOCs in depth, the most of them have focused on estimating TVOC, benzene, toluene, xylene, and ethylbenzene. The most common method for analysing VOCs has been gas chromatography-mass spectrometry, indicating that it is the most widely used detection method. Carcinogenic air contaminants, such as radon, were seldom examined in the research evaluated.

Furthermore, only a few studies have explicitly recorded the building materials used in walls and floors, while others have failed to indicate the kind of finish, furniture material, cleaning agent, or household activities, all of which are important factors to consider when studying IAQ. Similarly, most research on commercial building IAQ haven't gone into great depth on the indoor materials that have the greatest influence on air pollution. The key factors for the high VOC content in the analysed commercial buildings have been identified as the building construction and/or materials, surface coatings, and resident activities in general.

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