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Important Factors Affecting the Quality of Indoor Air and a Bibliometric Analysis

Bahar TÜRK*[1]

Abstract

Indoor air quality is critical for human health, and as such, it must be continuously improved. As a result, it is critical to identify the factors influencing indoor air quality. In this context, the purpose of this study is to investigate the factors influencing indoor air quality and to conduct a bibliometric analysis of the studies on the subject. The method of bibliometric analysis was used to examine academic publications on indoor air quality published between 1975 and 2020. A total of 2398 academic studies from the Web of Science database were examined. According to the findings of the analyses, academic research has primarily been conducted in the fields of construction technology and environmental sciences, public environmental occupational health, and environmental engineering. Since 2010, there has been a significant increase in the number of publications. The year with the most publications was 2017, and especially after 2010, publications have been cited more and more. One-fourth of the publications were produced solely in the United States. Hong Kong Polytechnic University and Denmark Technical University had the most publications. It has been determined that ventilation and air flow rate are the most heavily researched factors affecting indoor air quality. On the other hand, a substantial amount of research has been conducted to investigate the effects of pollutants. Furthermore, publications on temperature, humidity, bacteria, and thermal comfort were discovered. There have been studies on indoor air quality in residential buildings, houses, schools, and hospitals.

Keywords: Air pollution, human health, bibliometric analysis, indoors environments, toxicity.

1. INTRODUCTION

Air quality is critical for human health, and the quality of indoor air is becoming increasingly important as people spend longer periods of time in enclosed areas [1, 2]. In the midst of today's pandemic (COVID-19), people

staying indoors for a long time and spreading the disease through the air emphasize the importance of indoor air quality once again. The factors

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affecting indoor air quality are discussed in this article. The factors that are effective in indoor environments and their effects will be revealed through an examination of the published studies. Between 1975 and 2020, academic publications on indoor air quality were analyzed using the bibliometric method. We analyzed 2398 academic studies that were registered in the Web of Science database [3].

1.1. Definition of IAQ

Due to the fact that individuals spend the majority of their time inside, exposure to indoor air pollution has a substantial influence on both human health and workplace performance. Both scientists and the general public have recently focused on the concerns associated with poor indoor air quality (IAQ), since research has demonstrated that indoor air is more polluted than outside air [4]. Indoor air quality, which cannot be fully defined due to the interaction of a variety of factors with varying and constantly changing levels, is generally defined as air that contains certain mixtures under normal conditions and is free of harmful substances to human health. The ASHRAE 62-1989 and 2001 standards define "satisfactory indoor air quality" as air in which 80% or more of those present do not express dissatisfaction with the quality of the air [5]. According to a similar definition, the US Environmental Protection The Environmental Protection Agency (EPA) defines healthy quality of indoor air as air that is free of known pollutants in harmful concentrations and approximately 80% of those who have been exposed to this air are satisfied with its quality [6].

The term "optimum quality of indoor air" refers to the air quality that is free of discomfort, disturbance, or health problems. The World Health Organization (WHO) defines better and healthier indoor air quality as not only the absence of disease, but also the sense of complete comfort experienced by individuals. On this basis, better and healthier indoor air can be air that is free of pathogens and comfortable for all occupants [7]. Indoor air pollution was identified by the World Bank as one of the most significant environmental aspects in developed countries in 1992 [8]. Indoor air pollution can be caused by two distinct sources. There are two types of pollution in the indoor environment: pollution caused by substances and activities within the space and pollution caused by the effect of pollutants entering the space from the outside.

1.2. Importance Of IAQ and Effects on Human Health

Approximately 90% of people end up spending a lot of their time indoors. Increasing the quantity of contaminants in indoor air might result in major health consequences. According to the World Health Organization, 4.3 million people die each year as a result of exposure to home air pollution [6]. Internal and external pollutants can contaminate the air in these enclosures. Numerous studies have been done to determine the causes of contaminants' physiological and psychological effects on humans when pollutants reach a predetermined level [9]. Many countries, boh high- and low-income, have identified indoor air quality issues as significant health risks. Air quality in the home affects particularly vulnerable population groups in residential, day-care, nursing homes, and other private settings as a result of indoor air pollution, poor health, or advanced age. In suitable humid conditions, microbial contamination is a significant factor in indoor air quality, causing the proliferation of hundreds of bacteria and fungi species [10]. Numerous organs in the human body are harmed by these pollutants, including the brain, lungs, skin, blood, kidneys, peripheral nervous system, and liver. Additionally, these pollutants attempt to enter our bodies through our breathing, making our bodies vulnerable to them [11-13].

1.3. Factors Effecting IAQ

Due to the fact that inadequate ventilation, a lack of air conditioning systems, human activities and a variety of materials, chemicals and gases primarily contribute to indoor pollution, various organizations such as United States Environmental Protection Agency (US EPA) and the World Health Organization (WHO) have recognized IAQ as a multidisciplinary

phenomenon and classified pollutants into several categories [14].

1.3.1. Temprature

In order to achieve thermal equilibrium, heat is exchanged in the human body through heat conduction. The body temperature is maintained between 36 and 37 degrees Celsius so that the organs do not get damaged and can work efficiently [15]. As a result, it is clear that the temperature of the environment in which humans live is also critical for maintaining a constant temperature. Therefore, indoor temperature is critical for indoor air quality. Due to the fact that extremely hot environments create more difficult working conditions, it is evident that a variety of health problems arise [16,17,18].

1.3.2. Thermal comfort

To continue living a comfortable life, an equilibrium of heat between a person and his or her environment must be achieved. It's all about the senses and feelings when it comes to thermal comfort. As a result, the principles of heat balance and comfort conditions are distinct. This is described by ASHRAE as a mental state expressing those who are content with their surroundings. Thermal comfort is aided by thermal stability, but it is not needed. Thermal equilibrium is not possible for someone in the thermal comfort zone. Thermal comfort can vary depending on individual preferences [19].

The characteristics of humans, their ages, sexes, dietary habits, body types, fat levels, heights, and weights, as well as their actions, clothing, and differences all affect thermal comfort, and there are no unbreakable rules [20, 21]. Thermal comfort parameters are classified into two types: individual and environment. Environmental factors include temperature, humidity, air flow, and average radiant temperature, while personal factors include metabolic activity level and clothing [22].

1.3.3. Relative Humidity

In terms of human health and quality, an environment's humidity should be between 40 and 60%. In humans, low humidity causes dryness of the respiratory airway, skin, eyes, and hair. Low humidity allows toxic compounds to penetrate the body more quickly and reduces the amount of water vapor in the air. Static electricity problems are often caused by low humidity levels in an area. High humidity levels impair people's ability to maintain thermal equilibrium and allow moisture to accumulate on the body's surface. Microorganisms grow more rapidly in high humidity. Humidity, in particular, can allow influenza virus to survive and spread [13].

Simultaneously, studies indicate that the COVID-19 virus's survival time increases as the humidity level in the environment increases [23, 24]. As a result, relative humidity is critical in determining the quality of indoor air.

1.3.4. Air Flow Rate

One of the environmental factors that influences quality of indoor air is the amount of airflow in a room. The airflow rate is the value of airflow in a given direction measured in units of time. In contrast, the airflow rate in the medium is the average of several samples taken from the medium and is measured in millimeters per second (m/s) [25].

The location and size of the intake air, the type and intensity of indoor activity, the ventilation system's location, the angle and power, the amount of air supplied, the relative humidity and the temperature of the environment influence the indoor airflow while low airspeeds are considered to be airless, high airspeeds are considered to be windy and unpleasant for occupants. The airflow limit values required to maintain a comfortable environment are determined by standards. According to ASHRAE, a comfortable environment should have an air flow rate of 0.15 m/s. This is different during the summer and winter seasons. Although human sensing of 0.1 m/s air is not possible, air of 0.2 m/s is usually considered comfortable. An airflow of 0.35 – 0.50 m/s on the other hand causes people to get agitated [26].

Standards are established for an ambient airflow rate of no more than 0.8 m / s. Airflows greater

than 1.5 m / s cause significant discomfort. The air velocity affects the thermal comfort of the user. The air speed is increasing and the water on the surface of the body evaporates faster and the person starts cooling down. The cooling increases as the increased air speed disappears and the available air mass decreases in humans. Air should be provided uniformly and at low speeds for comfort of the user during the design process or during use [27, 28].

1.3.5. Biological and Chemical Pollutants

When selecting building materials, it is critical to take biological considerations into account. According to [29], 30-40% organic material (ie wood, straw, reed) and 60-70% inorganic material (ie bricks, tiles, natural stone, lime) are used in buildings, except for materials that differ according to climatic conditions. Nowadays, between 90% and 100% of materials in modern buildings are synthetic, not related to nature, life and human metabolism, particularly in major cities. The structure, use, use and life expectancy of building materials are a result of indoor air pollution. Therefore, they should be classified as positive and negative when selecting building materials along with all associated characteristics so that those who are selected can minimize environmental damage over the material's life.

Indoor air quality is greatly influenced by the building materials. Krusche et al. [30] conducted research on ecological structures in 1982 for the purpose of classifying building materials. Krusche et al. [30] specified the following materials to be used:

- Pressed bricks and wood for the façade,
- Wood, brick, and mudbrick for the wall construction,
- Wallpaper, natural and man-made wood panels, bodywork, and fabric-covered surfaces
- Fluorine-coated stone, wood, and linoleum
- Carpets made of wool and linen
- As an insulating material, wood wool and straw are use d.
- Natural pigments, such as oil paints with a water base.

Krusche et al. [30] stated building materials that should not to be used in construction buildings as follows:

1. Tuile,
2. Mineral-based materials such as aluminum, zinc, lead, sheet metal, cement, asbestos boards,
3. Synthetic carpets,
4. Fiberglass, spread of perlite, moulds of polystyrene, plastic foam,
5. Paints with a synthetic resin base.

One of the most important biological and chemical pollutants in the indoor environment is volatile organic compounds. Volatile organic compounds (VOCs), sometimes called solvents, are organic molecules that readily evaporate at ambient temperature. The major contaminants in indoor air are volatile organic compounds (VOCs), which have a considerable influence on indoor air quality and hence on human health. Many VOCs are known to be toxic and considered to be carcinogenic, mutagenic, or teratogenic [31]. The degree of exposure to VOCs in an indoor setting is also highly dependent on the sources and rates of emission. The sources of VOCs in indoor air are numerous. Volatile organic compound emissions from building materials have been identified as the primary source of indoor air pollution.

Table 1 contains a list of VOCs and their sources that are often detected in indoor air.

As seen in the table, organic compounds are mostly prevalent in established buildings, wood-based paneling and furniture, and paints.In office environments, printers and copiers are significant source of volatile organic compounds (VOCs) in the air [32].

Table 1
Indoor air VOC classifications and emission sources [32,33]

VOC categories	Environment and sources
Aliphatic hydrocarbons	Established buildings, new and renovated buildings, carpets, floor coverings, paints, unflued gas heaters and electric ovens
Aromatic hydrocarbons	Established buildings, floor coverings, floor coverings, paints, unflued gas heaters and electric ovens
Alcohols	Established buildings, paints, unflued gas heaters and electric ovens
Ketones	Established buildings, floor coverings,
Aldehydes	Established buildings,
Esters	Established buildings, new and renovated buildings, floor coverings, paints
Siloxanes	unflued gas heaters and electric ovens
Organic acids	Established buildings, new and renovated buildings, carpets, floor coverings, paints
Other VOCs	Established buildings, new and renovated buildings, floor coverings, paints, unflued gas heaters and electric ovens

2. METHOD

In this study, academic studies published on indoor air quality between 1975 and 2020 were presented with the method of bibliometric analysis. Pritchard [34] pioneered the use of bibliometric analysis in the literature. According to Pritchard [34], the term "bibliometric" involves the use of statistical and mathematical tool that can be applied to various communication media such as books or other written material. Bibliometry originated in library studies and encompasses the study of books, articles,

publications, and citations in any discipline [35] In this context, 2398 academic studies published between the specified dates and registered in the Web of Science database were analyzed. The distribution of these studies were examined on the basis years, in which areas they were published, the number of citations they received, and the number of citations, countries where they were published. In addition and the most importantly, the number of publications carried out about the factors affecting indoor air quality is also revealed and the importance of these factors has been tried to be revealed. Finally, the distribution of the studies conducted for the type of indoor spaces where indoor air quality is examined has been revealed. Figure 2 shows the distribution of publications published on indoor air quality depending on the years. In this context, it has been determined that there has been a significant increase in the number of publications since 2010. The year with the highest number of publications was 2017, when 170 studies were conducted. On the other hand, 169 academic studies were presented in 2019.

3. FINDINGS

In the analyzes carried out, it was first investigated in which areas the indoor air quality was mostly examined. In this context, it has been determined that academic research has been mostly conducted in the fields of construction technology and environmental sciences, public environmental occupational health and environmental engineering. On the other hand, it has been observed that studies have been carried out in the fields of civil engineering, thermodynamics, energy fuels, mechanical engineering, meteorology and atmospheric sciences, electrical and electronic engineering (Figure 1). All of these areas stand out as areas where studies are carried out on improving indoor air quality. On the other hand, it is noteworthy that there is no medicine among these fields. However, it has been understood as a result of the literature survey that indoor air quality and human health are closely related.

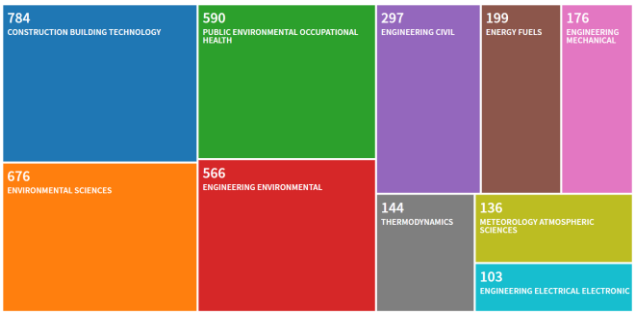

Figure 1 Treemap of areas publications on “Indoor air quality” [3]

Figure 2 shows the distribution of publications published on indoor air quality depending on the years. In this context, it has been determined that there has been a significant increase in the number of publications since 2010. The year with the highest number of publications was 2017, when 170 studies were conducted. On the other hand, 169 academic studies were presented in 2019.

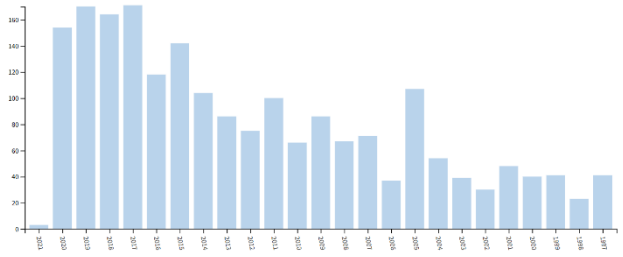

Figure 2 Distribution of publications by years [3]

The distribution of the publications carried out according to their types is shown in Figure 3. It was observed that the most common type of publication on indoor air quality was the articles published in journals. It was observed that 1414 articles on indoor air quality were published between 1975 and 2020 in academic journals. On the other hand, it has been determined that a significant amount of conference/symposium publications has been carried out on indoor air quality.

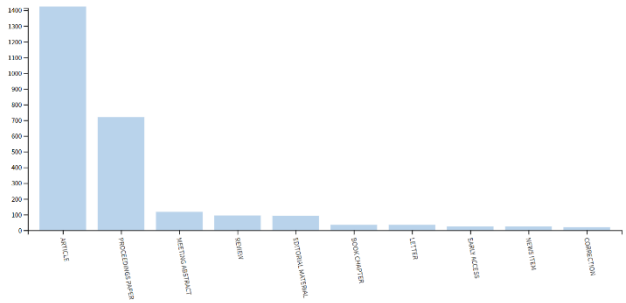

Figure 3 Distribution of publications by type [3]

The number of citations these studies received depending on the years is shown in Figure 3. In this context, it has been determined that especially the publications have been cited more and more after 2010. It was observed that 2398 publications received 29.298 citations in total. The first three study that received the most citations, respectively are related to "indoor air quality and health [10]", "indoor air quality and health symptoms in schools [35]" and "the effect of temperature, venlation and humidity on indoor air quality [16]".Due to the increase in the number of publications in 2010, it is seen that the number of citations has increased significantly since the same year.

Figure 4 Citation numbers of publications [3]

The distribution of the publications by country was examined and it was determined that the publications were made in 65 different countries in total. However, it was determined that one fourth of the publications were made in the USA alone. On the other hand, 67% of the studies were published in 10 countries where the most publications were made. These countries are shown in the table 2. In this context, it has been observed that the countries where the most publications are made are developed and developing countries.

Table 2
Countries with the highest number of publications [3]

Field: Countries/Regions	Record Count	% of 2,398	Bar Chart
USA	559	23.311 %	
Peoples R. China	330	13.761 %	
South Korea	125	5.213 %	
Canada	102	4.254 %	
England	100	4.170 %	
France	91	3.795 %	
Italy	91	3.795 %	
Portugal	87	3.628 %	
Germany	68	2.836 %	
India	63	2.627 %	

It was observed that the institutions with the highest number of publications were Hong Kong Polytechnic University and Denmark Technical University. In addition to the aforementioned educational institutions, it was determined that 26 publications were made by the US EPA.

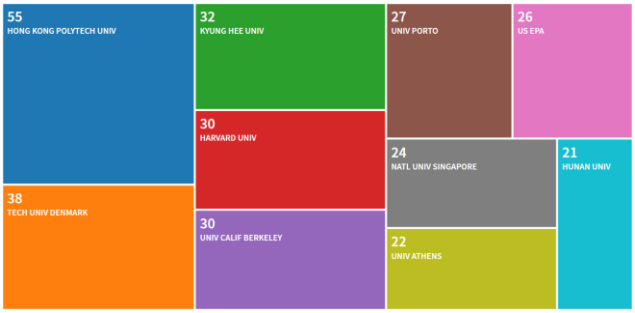

Figure 5 Institutions with the highest number of publications [3]

Since the main purpose of the study was to examine the factors affecting indoor air quality, the distribution of the publications dealing with the factors affecting indoor air quality was also

examined. In this context, it has been determined that among the factors affecting indoor air quality, ventilation and air flow rate are mostly examined. On the other hand, a significant amount of work has been carried out examining the effects of pollutants. In addition, it was observed that publications on temperature, humidity, bacteria and thermal comfort were also revealed.

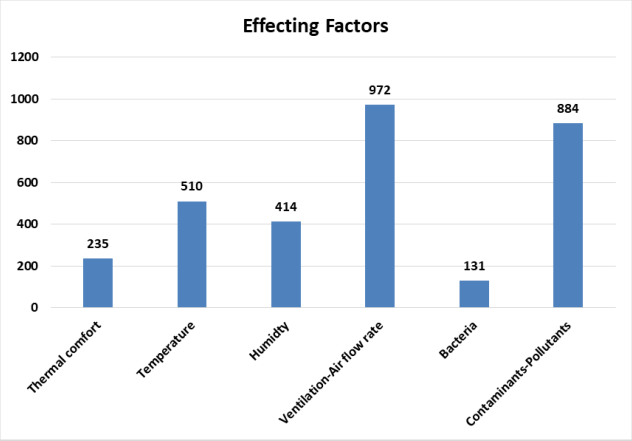

Figure 6 Distribution of publications examining factors affecting indoor air quality [3]

Considering the places where indoor air quality was examined, it was found that the workplacaes, offices and working environments were mostly examined. On the other hand, it has been observed that there are studies on indoor air quality in residential buildings, houses, schools and hospitals.

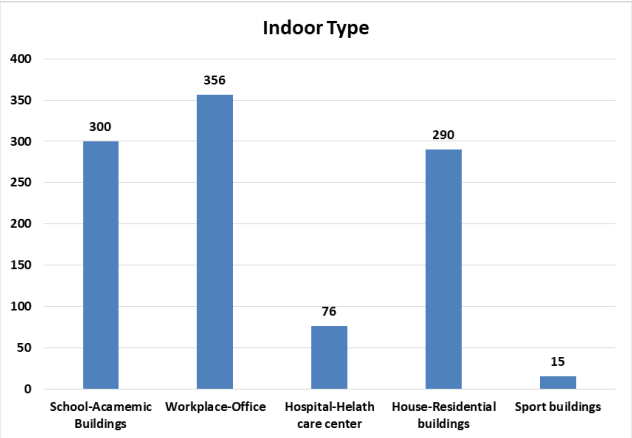

Figure 7 Distribution of publications examining specific indoor types [3]

4. CONCLUSION

As a result of the bibliometric analysis conducted in this study in which the factors affecting indoor air quality were examined, it was seen that the studies examining indoor air quality mostly worked on ventilation, air flow rate, indoor pollutants, volatile organic compounds, temperature and humidity. This shows that these factors affect indoor air quality. In addition to the analysis, in the literature review, it was also observed that humidity, temperature, air flow and pollutants are the most effective factors on indoor air quality.

Publications analyzed, generally conduct research on closed areas where people live collectively. In this context, it has been observed that studies have been carried out especially on indoor air quality in workplaces, schools and homes.

Considering the distribution of the publications, it was determined that there has been a significant increase in the number of publications, especially since 2010. It has also been found to be the most popular today. It has been observed that the number of citations received by the publications has increased especially with the increase in publications. It was note worthy that one fourth of the publications were made in the USA alone.

It is considered that the in-depth examination of only one factor that has an effect on indoor air quality in future studies will make a significant contribution to the literature.

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Authors' Contribution

The first author contributed 100%,

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The author of the paper declare that I comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that I do not make any falsification on the data collected. In addition, I declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science."

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