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INDOOR AIR QUALITY OF RESIDENTIAL TYPOLOGIES: A COMPREHENSIVE REVIEW

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Abstract:
People worldwide spend roughly 90 % of their time in various indoor locations. For health, comfort, and activity levels at home, in offices, schools, and hospitals, now more than ever, cleaning the air inside your home is a priority. The air outside dramatically affects the mood inside, and people with poor indoor air quality (IAQ) have long-term health problems. Most people have health problems because they spend so much time indoors, where the air seems more likely to be polluted. According to a study, in developing nations like China and India, indoor air pollution (IAP) was already connected to an increase in respiratory health issues. The Environmental Protection Agency (EPA) and the World Health Organization (WHO) have set up many standards to control indoor air pollution (IAP) [1], [2].Local, state, and federal governments could use these standards as guidelines. The health risks of remaining relaxed in a polluted environment may be severe.

Indoor pollutants are a vital contributor to illness in many parts of the world. No matter what season it is, the interior materials and products affect the air quality. In those places where people don't have enough ventilation, they have a more challenging time going about their daily lives and getting things done. Indoor pollutants, such as interior materials, dilute indoor air quality and human performance. Polluted indoor air can affect people's health with headaches, runny noses, tiredness, eye pain, coughing, unpleasant reactions, and asthma. Children may be more sensitive to the health dangers and risks of pollutants found within than adults[3]. The review study focuses on improving living conditions by enhancing the air quality within buildings and creating pleasant environments to spend time inside.

Using ventilation systems regularly helps make living spaces more comfortable for people in the winter and summer. Occupants may be at risk for sick building syndrome (SBS) if the air inside the building is polluted[4].

Pollutants can come from the outside air, but they can also be made inside by things like heating, ventilation, food, and the fumes from construction goods and materials. People spend most of their lives in controlled environments, so indoor activity dramatically affects their health and performance. Even though researchers have looked at indoor air quality (IAQ) from many different angles for years, there has yet to be a thorough analysis of peer-reviewed IAQ studies that focus on the effectiveness of the internal characteristics of different residential building contexts on IAQ. This paper review would help researchers worldwide understand how IAQ research has changed and its limits. It also highlights the trends and research gaps in indoor air quality (IAQ). I can also judge the IAQ of housing units in different countries and regions by looking at the data in the relevant literature, which reflects a much better understanding of IAQ worldwide. This review can be beneficial to architects and building designers by developing laws for the air within residential buildings that take into account all of the sources of pollution found inside residential buildings to produce building settings that are both sustainable and healthy.

Keywords: Indoor air quality; Parameters; Indoor air pollution ; Influencing factors indoor; Residential Buildings.

Introduction

Studies of people who live in cities show that they spend almost 90% of their waking hours inside. People spend a lot of time indoors in places other than their homes, such as workplaces, schools, and factories. In North America, adults spend 87% of their time indoors, compared to 6% for car travel and 7% for outdoor activities [5]. Exposure to indoor air pollution significantly affects human health and productivity because people spend so much time indoors. Until the last ten years, indoor air quality (IAQ) and its effects got much less attention than outdoor air quality (AQ) [6]. Recently, there has been an uptick in attention paid to IAQ hazards by both researchers and the general public [7]. Changes in lifestyle and building materials have greatly affected the types of indoor air pollutants and their chemical complexity, which has opened up new research areas.

1.1 Quality of indoor air

People's health depends on clean, healthy air. Breathing in a dirty atmosphere can be hazardous to one's health. [8] Air quality also aids in expressing the comfort and health of those who live inside. Indoor contaminants are a major cause of sickness worldwide. In all seasons, the interior materials and chemicals have an impact on the indoor air. Migraine, nasal congestion, infection, asthma, and dizziness are some of the health issues that occur quickly after exposure to indoor pollution, Human reaction to indoor pollutants[9]. Because of the health consequences that happen shortly after exposure or later, they build on different factors such as age and specific medical conditions. Other health problems that result from long periods of exposure include heart problems, cancer, lung problems, and a variety of other negative health effects. Indoor air quality is influenced by human density and activities, interior materials, and the environment Many scientists have investigated the connection between interior and outdoor air pollution and human health problems.

1.2 Quality of indoor air in residences

Indoor environment is essential to human life and comfort. [10]The outdoor air has the greatest influence on the quality of indoor air.[10] Most people have health problems because they spend so much time indoors, where the air seems more likely to be polluted. The daily routine and productivity of those who live in poorly ventilated spaces are harmed by poor air quality.[10] Indoor pollutants, such as interior materials, dilute indoor air quality and human performance. [11]The use of ventilation systems on a regular basis helps to improve human comfort in the living area during both the winter and summer seasons. It also needs a warning about air pollution inside and the upkeep of things that improve the quality of air inside. The three primary methods of controlling indoor air quality must be combined. [12]First, it helps control pollution sources by keeping them out of the building or keeping people away from them with physical barriers. Second, it aids in the diluting of contaminants and their removal from the building via ventilation. Finally, it aids in the filtration of contaminants. [12]In closed systems with air conditioning and mechanical ventilation, you need fresh air for the quality of the air inside and for your comfort.

2. P**urpose of study**

It's only natural that as the global population and economy expand, so does the need for a better quality of life. Indoor air quality necessitates the addition of new features to the built environment. In addition, there is a shift over time in the types of buildings, which influences IAQ and, by extension, human health. Because of this, it is essential to look at the IAQ of buildings with different final uses to find every possible indoor pollutant in various residential structures that could harm health. In the past 20 years, many articles written about indoor air quality (IAQ), but no systematic review has been done. This study help you learn about the factors affecting indoor air quality (IAQ) in different residential buildings. We need to learn more about how different building parts affect how much pollution is in the air. So, this study has shown the tendencies and gaps in scientific research for residential typologies that focus on quantitative changes in air parameters related to IAQ.

Furthermore, we analyzed the sample strategies used in scholarly works and the internationally accepted IAQ criteria. Indoor air quality (IAQ) testing is done to encourage and speed up future research into the best ways to design buildings to improve IAQ for future occupants. This review uses scholarly articles from many well-known scientific databases to do these things.

In the following sections, we will talk about:

1. Parameters, characteristics of IAQ and impacts of indoor pollution on human health and its causes (table 1)
2. Comparison of regulations and guidelines pertinent to indoor environments (table 2)
3. The paper's conclusions and potential future applications.

3.Methodology

Journal articles from reputable sources, including Science Direct and Wiley Online Library, were used to compile this review.

We primarily look at works from the last twenty years to understand how science has changed. The discussion also includes several journal articles found in supplementary sources. This analysis considers the indoor air quality (IAQ) of both homes and businesses. Therefore, it examines the conditions in the rooms where people spend the most time at each and in two types of commercial buildings (a hospital and a university). This analysis will not cover other commercial buildings like hospitals, shopping centers, and restaurants. This study aims to give a global view of the growing field of IAQ research by looking at the most recent findings published in academic journals around the world.This review draws from scholarly journals, conference papers, and official government reports. Many different permutations of the keywords "IAQ," "residential building," "indoor air pollution," "Parameters, "Influencing factors indoor," "home," and "IAQ standards" were used to query the database. For this reason, we searched for relevant terms in the titles, abstracts, and keywords of academic papers.

4.Parameters and characteristics of IAQ

For ordinary human life, clean air is critical. [12] Indoor air quality aspects comprise temperature, relative humidity, and airflow. Air quality factors make it challenging to maintain thermal comfort since they can drop to zero or grow to their maximum. [13] Human activities and occupants have a significant impact on indoor air quality characteristics. Polluting sources create gases, or particulate particles, that contaminate indoor air. Indoor air pollution, heat, and wetness can all rise due to a lack of fresh air

4.1 Requirements for the quality of the indoor air

People's health depends on clean, healthy air. Breathing in a dirty atmosphere can be hazardous to one's health. Indoor contaminants are a major cause of sickness worldwide. In all seasons, the interior materials and chemicals have an impact on the indoor air.[13] This study highlights the impact of indoor air pollution on people health which includes headaches, stuffy noses, fatigue, eye pain, coughing, adverse reactions, and asthmatic.[14] Indoor pollution may be more dangerous to children than to adults. The research focuses on increasing quality of indoor air and delivering a comfortable atmosphere for better living condition.

4.2 Impacts of indoor pollution on human health and its causes

As the energy crisis of the 1970s showed how important it was to save energy in construction, buildings worldwide became more airtight and insulated[15]. Less outside air is introduced into air conditioning systems to save power. As people's living standards have improved, more synthetic materials and chemicals have been used to build and decorate indoor spaces. Several things, including pesticides, cleaning products, air fresheners, and cooking emissions, cause indoor air pollution. Different groups, like the United States (WHO), have recognized IAQ as a multi-disciplinary issue and put pollutants into different categories. Poor ventilation, lack of air conditioning, human activities, and a wide range of materials, chemicals, and gases are the main things that hurt the quality of the air inside. There were almost 1.5 million deaths in 2000 due to poor indoor air quality, according to the World Health Organization [16]. The third most important cause of disability-adjusted life years around the world is indoor air pollution[17].

Indoor air pollutants and health effects table 1.

Pollutant	Health effects	References
PM 10	Type: Cumulative; Causes: heart attack, strokes and premature death.	[18], [19]
PM 2.5	Type: Cumulative, Causes: Respiratory Illness (upper and lower), Acute (Asthma) and chronic (COPD), Lung cancer,	[20], [21]
NO2	Type: Immediate: Causes: irritation to the skin, eyes and throat, cough etc	[22]
O3	Type: Immediate; Causes: eyes itch, burn, respiratory disorders, lowers our resistance to colds and pneumonia.	[23]
CO	Type: Immediate; Causes: headache, shortness of breath, higher conc. May cause sudden deaths.	[24]
SO2	Type: Immediate; Causes: lung disorders and shortness of breath	[25]
NH3	Type: Immediate; Causes: irritation to the eyes, nose and throat, blindness, lung damage and death.	[26]
PB (LEAD)	Type: Immediate; Causes: Anemia, weakness, and kidney and brain damage and damage a developing baby's nervous system.	[27]

Comparison of regulations and guidelines pertinent to indoor environments table 2 [28]
(Anyone who uses a value from this table should think about why it was used and how it was made.)

Environmental parameter	Enforceable and/or Regulatory levels			Non-enforced guidelines and reference levels			
	NAAQS/EPA (Ref. B-4)	OSHA (Ref. B-5)	MAK (Ref. B-2)	Canadian (Ref. B-8)	WHO/Europe (Ref. B-11)	NIOSH (Ref. B-13)	ACGIH (Ref. B-1)
Carbon dioxide		5,000 ppm	5,000 ppm 10,000 ppm [1 hr]	3,500 ppm [L]		5,000 ppm 30,000 ppm [15 min]	5,000 ppm 30,000 ppm [15 min]
Carbon monoxide [c]	9 ppm [g] 35 ppm [1 hr] [g]	50 ppm	30 ppm 60 ppm [30 min]	11 ppm [8 hr] 25 ppm [1 hr]	90 ppm [15 min] 50 ppm [30 min] 25 ppm [1 hr] 10 ppm [8 hr]	35 ppm 200 ppm [C]	25 ppm
Formaldehyde[h]		0.75 ppm 2 ppm [15 min]	0.3 ppm 1 ppm[i]	0.1 ppm [L] 0.05 ppm [L] [b]	0.1 mg/m^3 (0.081ppm) [30 min][p]	0.016 ppm 0.1 ppm [15 min]	0.3 ppm [C]
Lead	1.5 µg/m^3 [3 months]	0.05 mg/m^3	0.1 mg/m^3 1 mg/m^3 [30 min]	Minimize exposure	0.5 µg/m^3 [1 yr]	0.1 mg/m^3 [10 h]	0.05 mg/m^3
Nitrogen dioxide	0.05 ppm [1 yr]	5 ppm [C]	5 ppm 10 ppm [5 min]	0.05 ppm 0.25 ppm [1 hr]	0.1 ppm[1 hr] 0.004 ppm [1 yr]	1 ppm [15 min]	3 ppm 5 ppm [15 min]
Ozone	0.12 ppm [1 hr][g] 0.08 ppm	0.1 ppm	j	0.12 ppm [1 hr]	0.064 ppm (120 µg/m^3) [8 hr]	0.1 ppm [C]	0.05 ppm[k] 0.08 ppm[l] ppm[m] ppm[n]
Particles[e] <2.5 µm MMAD[d]	15 µg/m^3[1 yr][o] 65 µg/m^3 [24 hr][o]	5 mg/m^3	1.5 mg/m^3 for <4 µm	0.1 mg/m^3 [1 hr] 0.040 mg/m^3 [L]			3 mg/m^3
Particles[e]<10 µm MMAD[d]	50 µg/m^3[1 yr][o] 150 µg/m^3 [24 hr][o]		4 mg/m^3				10 mg/m^3
Radon	See Table B-2[f]				2.7 pCi/L [1yr]		
Sulfur dioxide	0.03 ppm [1 yr] 0.14 ppm [24 hr] [g]	5 ppm	0.5 ppm 1 ppm [i]	0.38 ppm [5 min] 0.019 ppm	0.048 ppm [24 h] 0.012 ppm [1 yr]	2 ppm 5 ppm [15 min]	2 ppm 5 ppm [15 min]
Total Particles[e]		15mg/m^3					

4.3 The evaluation of indoor air quality in residential typologies

Over the last two decades, governments have recognized the importance of establishing IAQ goals in light of the risks associated with indoor air pollution. Research has been conducted to investigate residential typologies' indoor air quality (IAQ)[29]. Three public rental homes and three private homes were chosen from a pool of six candidates based on a set of criteria. To select these six homes, set standards ahead of time. These included the type of home, a highly populated area, and the fact that none of the houses had recently bought furniture at the time of the indoor air sampling. During the experiment, air samples were taken from each chosen home's kitchen and living room. CO2 and PM10 concentrations were 14% and 67% higher in the kitchen than in the living room.

The average total bacterial count was also 23% higher in the kitchen. The increased CO2 levels in the kitchen were linked to poor ventilation, while the high PM10 levels were linked to factors like air infiltration from outside, a lack of regular cleaning, and the cleaning method used. Regarding volatile organic compound (VOC) emissions, cooking with liquefied natural gas had a much more significant impact than cooking with natural gas. Houses, both brand-new and long-standing, were rated.

The concentrations of volatile organic compounds and formaldehyde (HCHO) in Melbourne, Australia [30]. Although the findings suggested that VOC concentrations were lower in older homes when compared to newer construction, These levels were four times as high as they would have been outside. Higher levels of volatile organic compounds (VOCs) were also found in rooms with attached garages, damaged wool carpeting, and site contamination. When comparing the VOC emissions of new and renovated buildings to those of older, more established buildings, the former emits one to two orders of magnitude more.

Using both naturally ventilated (NV) and air-conditioned (AC) bedrooms, researchers in Singapore looked for a correlation between indoor air quality (IAQ) and sick building syndrome (SBS)[31]. The levels of carbon monoxide (CO2) in NV bedrooms were found to be lower than those in AC bedrooms. However, particulate levels showed the opposite pattern, with higher levels found in NV bedrooms. Another part of the study found that people with SBS symptoms were more likely to have air conditioning in their bedrooms. Several air quality parameters were analyses in 37 houses as part of a periodic review of building codes in England and Wales [32]. Extensive research has linked high levels of inorganic gas emissions to three factors:

1. The use of gas for cooking
2. The number of occupants in a house
3. The home's location

A study of homes in Ottawa, Canada, was conducted per CEPA[33]. All of the specified volatile organic compounds were detectable in indoor air, though at much lower concentrations than in outdoor air, compared to the results of a study from the previous year.

In China, researchers [34] looked at the link between indoor PM10 and oxidative damage to plasmid DNA. Air was collected from both smoking and nonsmoking homes. Research using various methods found that PM10 produced in smokers' homes was more toxic and could cause 50% plasmid DNA damage, while PM10 built in nonsmokers' homes was less bio-reactive. According to the findings, plasmid DNA damage was brought on by soot and other fine particles. The French Indoor Air Quality Observatory looked at 567 homes and published two studies [35], [36] with their measurements of indoor air pollutants. Formaldehyde, toluene, acetaldehyde, m/p-xylenes, and hexaldehyde were the most prevalent VOCs in these homes. Twenty volatile organic compounds were simultaneously evaluated indoors and outdoors, and the results revealed that the median levels of most compounds were much higher indoors. Later in 2017, an evaluation with the same sample size (567 homes) was conducted in mainland France to examine the correlation between air pollutant concentration and indoor air quality [37].The French government asked OQAI to do another study in 2018 to look at the IAQ in energy-efficient buildings, both new and old, using standard methods and questionnaires to measure the air quality.

Energy-efficient buildings use between 40 and 75 kWh/m2 of energy per year if they are brand new and between 64 and 120 kWh/m2 of energy per year if they are already built. The experimental data showed more hexaldehyde, alpha-pinene, and limonene than the French studies mentioned above. The winter in Delhi, India, had air pollutant concentrations ten times higher than the permissible limit, according to an assessment of indoor air quality in selected urban slums during the summer, rainy season, and winter[36]. This research provides a detailed account of where people live, including their ages, the size of their families, the types of stoves and fuels they use, and whether or not there are tools to open windows. There needed to be a comprehensive description of the building's layout (such as materials used for floors or furniture).

SBS was exposed by 14.5% of survey respondents, despite the Korean government's IAQ progress. Before and after people moved in, the study looked at how different environmental factors affected the IAQ of newly built apartments. [38]these factors included construction characteristics, temperature, humidity, and duration of occupancy. Except for formaldehyde and toluene, the average levels of pollutants met the Ministry of the Environment's standards. The study also looked for a link between how pollutants behave and temperature and humidity. This study strongly suggests that IAQ be evaluated based on the load ratio of the most important pollution sources. The research found that after one year of residence, there was a reduction in the pollutant levels to nearly half of what they were at the beginning.

Between 2006 and 2007, a study compared the aromatic volatile organic compounds (VOCs) found in Chinese and Japanese homes. [39] This study didn't look into smoking, which was a problem because smoking is one of the main ways that volatile organic compounds (VOCs) get into buildings. In China, the concentrations of volatile organic compounds found inside were much higher than those found outside. Results show that the concentrations of VOCs inside were higher than those outside. On the other hand, the results for both indoor and outdoor VOCs were the same for the Japan case study. The carcinogenic research for this study showed some disturbing information regarding an exposure risk that was ten times higher in China than in Japan. Lodi Province in Italy, which has a lot of people and a lot of pollution, was tested for gaseous and particulate pollutants [40].Investigations done in both summer and winter came to the same conclusion: in some situations, PM and NO2 levels were too high. In contrast, CO and O3 are considered satisfactory levels. Despite this, there was a focus on lessening the pollution caused by sources found inside. On the other hand, there was no transparent information regarding the households' features. The Indoor Air Pollution and Health (IAPAH) study, done in Ireland and Scotland, was mostly about testing IAQ in homes with open combustion sources [41]. We evaluated homes that used peat, coal, wood, and cooking gas for heating, in addition to homes that had no open combustion sources but had smokers as residents. Based on the WHO guidelines, air pollution levels were found to be acceptable in homes where gas stoves or solid fuels were used as the main source of heat. However, the IAQ was significantly lower in the homes where cigarette smoking occurred. An extensive investigation was carried out in Leipzig, Germany, to characterize the patterns of airborne volatile organic compounds (VOCs). This study utilized a survey to measure 60 distinct VOCs. [42] They used two methods to determine where the VOC chemicals came from. A large amount of sampling data was analyzed, and the results showed that occupant behavior, furnishing materials, ventilation, natural activities, and a combination of these elements considerably influence indoor air quality (IAQ). Gaseous and particulate materials were measured in Emirati homes in the United Arab Emirates (UAE) [43] to determine how good the IAQ was in harsh desert conditions. An attached garage less than five metres away from the house, the kitchen, and central air conditioning systems were found to be primarily responsible for indoor PM2.5 and PM10 levels. On the other hand, there was a strong link between CO levels and an attached kitchen, smoking, and split AC systems.

On an annual basis, the indoor air quality (IAQ) of a green building in the United States that was certified by the Leadership in Energy and Environmental Design (LEED) program was evaluated to ensure that safe levels of indoor air pollutants were met [44]. Green building rules contain ways to improve IAQ during design, such as adding fresh air and using safe materials. Still, there is little experimental data to show that these steps improve IAQ during operation. The study found that green buildings, which have better air quality than traditional buildings, have many benefits. As the ASHRAE guideline says, CO2 and relative humidity levels were within acceptable ranges.

Still, the results of this study showed that more sensitive evaluation methods were needed to accurately assess the IAQ in green buildings. Before and after the retrofitting, the impact of green remodeling on indoor air quality was evaluated in an apartment in low-income housing in Arizona, United States. There was a greater initial level of formaldehyde, which exceeded international requirements after one year of retrofitting, except for 4% of the apartments [36]. Before, during, and after the remodel, air samples were collected. TVOC averaged 50–2610 g/m3. [45], Researchers discovered that 32% of the studied homes in Macedonia had TVOC levels higher than the recommended limit.

Based on an analysis of data from Ireland, buildings with annual average concentrations of more than 100 Bq/m3 should have ventilation systems and know how they work [46]. Overall, the evaluation found that passive houses mostly meet the radon threshold limit and do better than traditional houses.

To find out how cooking fuels affect PM2.5 and CO levels in Paraguay, quantitative and qualitative studies of indoor air quality (IAQ) in rural areas with low-income families were done [47]. Houses cooked with charcoal and wood had much higher levels of PM2.5 and CO than houses cooked with electricity and LPG. These levels were higher than what the WHO recommends. In Lithuania and Finland, researchers looked at how building renovations affected indoor air quality [48]. When older homes in Finland got air conditioning, fungi and bacteria dropped significantly, but some VOCs went up. A study of radon concentrations in Lithuanian homes found a considerable increase due to the retrofit. In California, where more people live together, this study looked at the IAQ in both new and remodeled homes with gas stoves [49]. Compared to a recent study performed in code-compliant ventilated California buildings, this comparative study found a 165% increase in NO2, an 18% increase in CO2, a 25% decrease in formaldehyde, and a 4% decrease in PM2.5. The latter study was conducted in 70 detached buildings in California and resulted in a significant reduction in formaldehyde and PM2.5 compared to the survey conducted for new homes in California in 2006–2007 [50]. Despite their limitations, these findings are invaluable for improving IAQ in future retrofit housing.

Table 3 summarizes the findings of the residential IAQ research conducted in various locations.

S.NO.	THE PAPER /ARTICLE	YEAR	KEY WORDS	Study Area	Indoor Material	Ventilati on	Parameters Examined	Sample Number	Ref
1	A review of strategies and their effectiveness in reducing indoor airborne transmission and improving indoor air quality	2022	Keywords: COVID-19 Indoor air quality SARS-CoV-2 Ventilation Airborne transmission Indoor environmental quality Health policy						[51]
2	Investigation of indoor air quality at residential homes in Hong Kong—case study	Januar y 2002	HomeHong KongIndoor air qualitySuspended particulate matter (PM10)Total bacteria count (TBC)Volatile organic compounds (VOCs)	Living room, Kitche n	Plastering wall, wallpaper, tile/wood/viny l floor	Natural ventilati on with air conditio ning	CO2, HCHO, PM10, Bacteria, C6H6, C6H5CH3, C6H5CH2 CH3, C6H5(CH3)3, CHCl3, CH2Cl2	6	[52]
3	Volatile Organic Pollutants in New and Established Buildings in Melbourne, Australia	April 2002	Volatile organic compounds; Formaldehyde; Building materials; Model; Benzene; New building; Indoor/ outdoor	Living room, bedroo m	na	na	VOC, HCHO	27 (ED) * & 4 (NB) *	[53]

4	Comparative study of the indoor air quality of naturally ventilated and air-conditioned bedrooms of residential buildings in Singapore	September 2004	Indoor air qualityThermal comfortNatural ventilation	Bedroom		Natural ventilation with air conditioning	CO2, RH, particulate profile, bacteria, fungi, temperature	3	[38]
5	Ventilation and Indoor Air Quality in New Homes	September 2019		Living room, kitchen, other rooms	timber framed construction, traditional brick/block frame, cavity wall insulation	mechanical extract ventilation and passive stack ventilators	NO2, CO, HCHO, VOC, RH particulates, temperature	37	[54]
6	Selected Volatile Organic Compounds in Residential Air in the City of Ottawa, Canada	May 3, 2005	Aromatic compounds,Atmospheric chemistry,Hydrocarbons,Ketones,Volatile organic compounds	Living room and family room	na	na	37 VOCs	75	[33]
7	Associations between particle physicochemical characteristics and oxidative capacity: An indoor PM10 study in Beijing, China	August 2007	Plasmid DNA assayOxidative stressTrace elementIndoor airPM10	Living room, Kitchen	na	na	PM10	6	[35]
8	Indoor air quality in French dwellings	17 Apr 2012	Indoor air exposure, Dwellings, VOC, Allergens, Radon	Rooms, attached or integrated garages and outside the dwellings	na	na	CO, VOC, particles, Rn, dog, cat and dust mite allergens, radon and gamma radiation	567	[55]
9	Indoor air quality assessment in and around urban slums of Delhi city, India	18 November 2020	indoor air pollution, sick building syndrome,acute,respiratory infections, low grade fules, urban poor,urban rich.	Kitchen, bedroom	na	Natural Ventilation	particulate matter (RSPM), CO2, CO, SO2, and NO2	5	[56]
10	The effect of environmental and structural factors on indoor air quality of apartments in Korea		Indoor air quality, Volatile organic compounds,Formaldehyd, apartment (residential building)	Living room, kitchen, master room, other room	Wall & ceiling: Silk/Balpo, floor: PVC/wood, furniture: MDF	na	HCHO, VOC, C6H6, C6H5CH3, C6H5CH2CH3, (CH3)2C6H4, C6H4Cl2, C6H5CH=CH2	158	[57]
11	Comparative study on indoor air quality in Japan and China: Characteristics of residential indoor and outdoor VOCs	December 2009	Volatile organic compoundsIndoor air qualityEmission sourcesSource apportionmentCancer risk	Living room, kitchen, bedroom	Wallpaper (Japan); paint (China)	na	VOC (C6H6, C6H5CH3, C6H5CH2CH3, (CH3)2C6H4, C6H5(CH3)3	57 (Jp) & 14 (Ch)	[38]
12	Airborne particulate matter and gaseous air pollutants in residential structures in Lodi province, Italy	23 June 2011		Living room	NA	NA	PM, NO2, CO, O3	60	[39]
13	Contribution of solid fuel, gas combustion, or tobacco smoke to indoor air pollutant concentrations in Irish and Scottish homes	18 October 2011		Living room	NA	NA	PM2.5, CO, CO2, NO2	100	[55]
14	Relationship between sources and patterns of VOCs in indoor air	12 November 2013	Volatile organic compounds, non–negative matrix factorization (NMF), PCA, pattern	Living or child's room	NA	NA	60 VOC's	2246	[58]

15	Indoor Air Quality in the United Arab Emirates	6 June 2014	Indoor Air Quality, UAE, Particulate Matter, Pollution, Gases, Sources	Family room	na	Sealed AC	CO, HCHO, H2S, NO2, SO2, PM2.5, PM10	628	[59]
16	Indoor air quality in green buildings: A case-study in a residential high-rise building in the northeastern United States	16 Jan 2015	Green building IAQ LEED residential high-rise building particulate matter VOC	na	Hardwood floors, carpets	Natural ventilati on with air conditio ning	CO2, CO, RH, temperature , particulate matter, VOC, HCHO	17	[60]
17	The effects of an energy efficiency retrofit on indoor air quality	11 June 2014		Living room and kitchen	Low VOC carpet, flooring, carpet pad, zero VOC paint	HVAC system	PM, HCHO, VOC	86	[44]
18	Perceived indoor air quality and its relationship to air pollutants in French dwellings	05 May 2017		Bedroo m and living room	NA	Mechani cal ventilati on	CO2, RH, VOCs, HCHO, PM2.5, PM10	567	[61]
19	Indoor air quality in energy-efficient dwellings: Levels and sources of pollutants	5 May 2017		Living room, master bedroo m	Lightweight/m asonry facades, timber frame, thermal insulation	Mechani cal or hybrid ventilati on	CO2, CO, RH, NO2, VOCs, HCHO, Rn, airborne particles, temperature	72	[62]
20	Investigation of Indoor Air Quality in Houses of Macedonia	1 Januar y 2017	family house; temperature; humidity; TVOC; PM; sound pressure level; statistical analysis	Living room	na	na	Temperatur e, RH, TVOC, PM	25	[63]
21	A pilot study of radon levels in certified passive house buildings	Januar y 9, 2019		Main living area, bedroo m	Timber & Masonry	Balance d mechani cal heat recovery ventilati on or demand-controlle d ventilati on systems	Rn	5	[46]
22	Monitoring and modeling of household air quality related to use of different Cookfuels in Paraguay	12 Octobe r 2018	biomass, CO, household air pollution, multiple linear regression, outdoor air pollution, PM 2.5	Kitche n,	na	na	PM2.5, CO,	80	[47]
23	Effects of energy retrofits on Indoor Air Quality in multifamily buildings	28 March 2019		Living room	na	Natural and mechani cal ventilati on	CO, NO2, VOCs, Rn, microbial content	45	[48]
24	Indoor air quality in new and renovated low-income apartments with mechanical ventilation and natural gas cooking in California	18 Octobe r 2020		Bedroo m, living room, kitchen , dinning area	na	Mechani cal ventilati on	CO2, NO2, HCHO, PM2.5	23	[49]
25	Indoor air quality in California homes with code-required mechanical ventilation	18 April 2020		Bedroo m, living room,	na	Mechani cal ventilati on	CO2, NO2, HCHO, PM2.5, NOx, RH, temperature	70	[50]

5. Conclusions and Future Outlook

This paper talks about the last 20 years of research into indoor air quality. Its goal is to look at the IAQ sector from different points of view to understand how IAQ affects residential building environments. Because people spend 85–90% of their time in buildings, the IAQ of different types of facilities can significantly impact human health. This study looked at state-of-the-art and home IAQ data. Research on IAQ in several other countries was reviewed. A review specific to a region or place can also help find the major indoor air pollutants that need to be resolved in each area for long-term solutions. So, the goal of this review was to help building professionals develop new rules for indoor air that consider major air pollutants, all sources of indoor pollution, and the health effects of these things to create healthy and sustainable building environments.

Most developed countries consider and adhere to IAQ regulations during building environment design and maintenance by implementing appropriate measures.

Standards and rules don't apply in developing or underdeveloped countries, where poor IAQ hurts children, women, and the elderly more than anyone else [64]. Even though exposure to indoor air pollutants can cause serious health problems, most developing and underdeveloped countries and regions still don't have enough scientific research on IAQ. During this review, peer-reviewed journals were examined. Pollutants in the air should be studied in developing and underdeveloped countries, as should their effects on health. A study can be used as a starting point for improving IAQ policies in these areas. So, there needs to be more research in these areas to ensure that building environments worldwide are healthy and long-lasting. Along with indoor pollution sources, outdoor climatic conditions, such as high humidity, temperature, and dust intensity, exacerbate IAQ in some regions, such as the GCC countries. However, studies on the IAQ situation in GCC countries have largely excluded detailed VOC assessments. The reviewed studies looked at parameters such as PM, volatile matter, carbon dioxide, and carbon monoxide, but the majority focused on specific VOCs. Although a few studies examined VOCs in-depth, the majority of them were limited to TVOC, benzene, toluene, xylene, and ethylbenzene estimation. Most studies have preferred gas chromatography-mass spectrometry to analyze VOCs, demonstrating that it is the most popular VOC detection method. Analysis of carcinogenic air pollutants, such as radon, was uncommon among the studies reviewed. Furthermore, studies have not reported the building materials in walls or floors. In contrast, others still need to mention the finishing type, furniture material, cleaning agent, or household activities, all of which are critical elements for analyzing IAQ. In the same way, most studies on the air quality inside commercial buildings haven't yet gone into detail about the materials inside that have a big effect on air pollution.

Similarly, outside PM levels and nearby construction processes, tobacco smoke, the presence of carpets, and human movement have been linked to an increase in indoor PM levels. In contrast, concrete additives have been linked to the rise in indoor NH3 concentrations. So, this study suggests more research that focuses on a detailed assessment of exposure concentrations and finding the responsible sources in each type of building environment.

Directly comparing indoor air pollutant levels is difficult and time-consuming because evaluations were conducted over different time periods, with other instruments and sampling techniques, and in various indoor environments. This study recommends that more detailed scientific studies be conducted under standardized regulations, allowing for future inter comparison of IAQ from investigations to close the existing knowledge gaps regarding IAQ.

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