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Article

A Comprehensive Review of Indoor Microbiological Contaminants

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ABSTRACT

Indoor air quality (IAQ) comprises a complex composition of different pollutants including biological contaminants such as bacteria, algae, and fungi. It is noticeable that on average 2000 l of air that a person breathes every day is filled with contaminants that will pose severe health hazards. Although many studies have repeatedly reported the health risk caused due to IAQ yet people are still unaware of the same specifically regarding biological contaminants which act as a potential source for the cause and spread of various diseases. Numerous infectious disorders, allergic reactions, bacterial infections, and malignancies are the chief consequences of microbiological contaminants prominently present in indoor settings. This review paper presents a thorough theoretical overview that covers IAQ, health risks, sources, and significant studies on microbiological pollutants persistently present in various indoor scenarios. Further, it also illustrates the work conducted in this field by various research professionals globally. The present review article may provide a better vision to the researchers working in this area further helping in the regulation and implementation of standards required for various crucial indoor settings.

Key words: Indoor air quality, Bacteria, Fungi, Bioaerosols.

1. INTRODUCTION

One of the primary aspects affecting human health is the quality of air. Living microbiota is the source of the airborne particles (bacteria, mould, fungi, and viruses) found in indoor as well as outdoor environments [1]. Although ambient air quality is being monitored throughout the world yet indoor air quality (IAQ) is totally neglected. Indoor air pollutants include organic and inorganic as well as biological pollutants [2]. Microbial pollutants, which include bacteria, fungus, viruses, and mould, are a major issue with IAQ in homes and have adverse impacts on people's health and well-being [3]. The most of the time is spent indoors, roughly 90% of the time by the population around the world. Numerous infectious disorders, allergic reactions, bacterial infections, and malignancies contribute to the settling of microbial pollutants present indoors [4]. An enlarged concentration of germs in the air also results in skin issues and other respiratory illnesses [5]. According to F. Squinazzil, numerous origins for microbiological contamination are (Figure 1).

- Human behaviors, such as coughing, talking, and sneezing, which cause microorganisms to spread across the environment
- Airborne particles, such as bacteria, fungus, and viruses, that are brought on by structures, occupants
- Wet area, which leads to the growth of microbiological fungus and bacteria.

Approximately 30% of office employees get ailments as a result of poor IAQ, according to prior research [6]. Exposure to these pollutants may lead to a variety of molecular reactions, such as allergic reactions, infections, and intoxication [7,8]. The status of airborne microbes to human well-being has been highlighted by the WHO [9]. Numerous studies have been carried out around the globe to evaluate the microbiological concentration in various outdoor and indoor locations, such as different hospital sites, private sectors, buildings, libraries, and universities. Residential housing, meanwhile, has gotten less attention. Further, Sick Building Syndrome is another term for the respiratory and other health issues that office workers experience as a result of the deteriorating IAQ in the built environment [10]. *Aspergillus*, *Curvularia*, *Penicillium*, and *Rhizopus* are the most prevalent fungal taxa identified in a recent study conducted in Kolkata. Seasonal variations in air microbial concentration have been observed and may be affected by the ventilation system, presence of moisture content, temperature, etc. [11,12-14]. A large particle <2.5 in the respiratory concentration of airborne fractions can more thoroughly penetrate deeper into lungs and blood streams [15]. In residential settings, the bulk of the microbiome is composed of bacterial resistance and allergies [16]. The presence of air microorganisms in pre-nursery schools has also been estimated and reported to cause an adverse impact on their pediatric and respiratory health [17]. Hospital is very crucial indoor microenvironments for the development and spread of microbiological contaminants. According to a study on air sampling done in a hospital for hematology by Cho and Colleagues, *Aspergillus niger* and *Aspergillus flavus*, and *Penicillium* were the furthermost prevalent fungus species both outside and inside of homes, hospitals, and buildings [18].

Hence, this review illustrates the studies conducted on various indoor environments targeting biological contaminants and explaining their health effects on human beings principally women and children as they

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are the most vulnerable section of society. The review will give a better insight to the policymakers of the field implementing precautionary measures for public health for healthier indoor environments.

2. IAQ

Air quality indoors are principally important to human beings since people spend up to 80–90% of their time indoors. Sources can be roughly categorized as being connected to the actions of building inhabitants and further biotic contaminants, activities, burning of chemicals for fuel, or heating, as well as pollutants from construction constituents. Outside penetration by air, water, and soil can potentially be a substantial cause of some toxins (Tables 1 and 2). They are also released as the byproduct of the activities carried out within building materials. The relationship between the amount of air present indoors and the rate of production or release of the pollutant determines the concentration of a pollutant indoors [19]. IAQ issues were undoubtedly far more noticeable in the past than they are now. The soot found on the walls of ancient shelters gives solid proof of the high pollution levels linked to insufficient ventilation [20].

3. HEALTH EFFECTS OF EXPOSURE TO IAQ

Indoor air contaminants have the potential to induce temporary illness, impairment, disease, and, in severe situations, death. It is evident

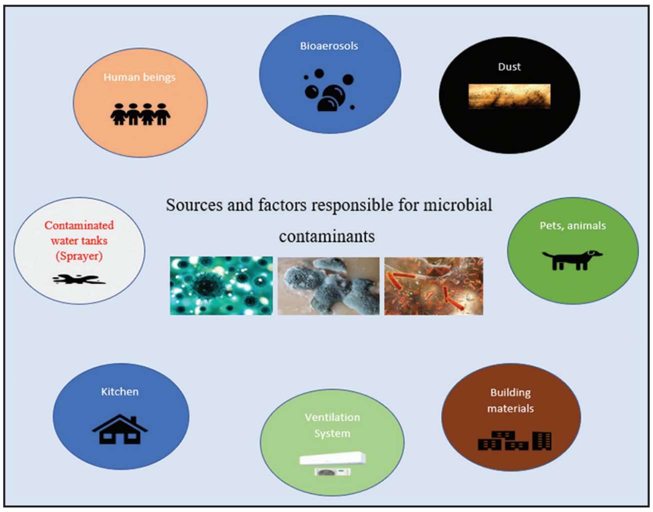

Figure 1: Major factors and sources responsible for microbial contaminants.

Table 1: Major indoor sources and their emission

Emission	Sources
CO_2	Burning of fossil fuel, (coal and natural gas) decomposition, and cement production
NO_2	Vehicles, burning of fossil fuels, and power plants
Ozone	Refineries, industrial boilers, power plants, and cars
Micro-organism	HVAC, ventilation system, and pets
Organic substances	Combustion, tobacco smoke, and paint
Particles	Resuspension
Pollens	Plants, grass, and weeds
Radon	Concrete and stone
PAHs	Incomplete combustion of fossil fuel, coal, wood garbage, and tobacco is burned
Fungal spores	Foodstuff

in underdeveloped and developing countries that burning biomass (particularly for cooking) creates a lethal cocktail of contaminants. Every year, more than 2 million individuals, primarily women, and children are killed as a result of poor IAQ [21]. This is one of the world's major environmental/health challenges, although it has received little attention thus far. The IAQ health effects on different age groups have been shown in Figure 2.

4. MICROBIAL CONTAMINANTS PRESENT IN THE DIFFERENT MICROENVIRONMENTS

Poor IAQ is also a result of excessive bioaerosol levels in homes. Since individuals specifically women spend over 90% of their time indoors, exposure to poor IAQ has a greater impact than exposure to the ambient air [22].

Compared to business and residential sectors, communities close to industrial zones are more prone to have health problems. A study is shown in Finland on workers in which the workers observed many infections and diseases, that is itching, burning, irritating eyes, and nose [23]. Different concentrations of microbial contaminants (bacteria, fungi, and viruses) and pollutants (CO, PM, and TVOC) also cause hazardous health impacts on staff members, students, women, children, etc. [24,25]. Table 3 depicts a brief overview of the health effects caused due to microbial contaminants by different researchers. Bioaerosols can interfere with routine tasks in a variety of settings, including hospitals. There is a very high danger of airborne infection in confined spaces because infectious aerosols typically have a diameter of lesser than 5 micrometers and can, therefore, stay suspended and viable in the air stream for extended periods of time [26-28]. According to estimates, up to 10–20% of all endemic nosocomial illnesses may be transmitted through air. Research on airborne microorganisms, development, and quality control, as well as knowledge of their current condition, may all be done with the help of biological bio-aerosol monitoring in various indoor settings [29,30]. The prevalence of infections linked to health-care facilities not only reflects patient safety but also the overall standard of hospital services [31-33]. To detect nosocomial infections and stop the transmission of airborne germs that cause hospital-associated diseases, bio-aerosol surveillance

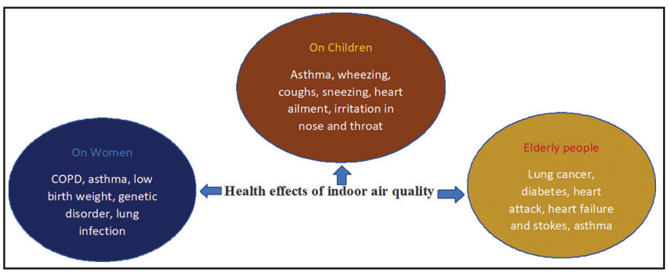

Figure 2: Major Health Effects of Indoor Air Pollution on different Age Groups.

Table 2: Major outdoor sources and emissions

Outdoor Sources	Pollutant emissions from industry (%)	Pollutant emissions from transport (%)
Pb	31	60
CO	3	90
NO_X	38	49
PM_{10}, $PM_{2.5}$	56	25
VOCs	52	34
Benzene	32	65

Table 3: Presence of bacteria and fungi in an indoor environment and their health consequences on human beings

Microbes	Health hazards	References
Bacteria		
Micrococcus	Septic arthritis, pneumonia, and endocarditis	[38]
Staphylococcus	Pneumonia and infections	[38]
Fungi		
Aspergillus	Skin diseases, allergic rhinitis, and skin infection	[39,40]
Alternaria	Rhinitis, skin disease, and infections	[41]
Mucor	Conjunctivitis and allergic diseases	[39]
Cladosporium	Asthma	[39]
Penicillium	Respiratory problems and infection in the lung	[39,40]
Candida	Urinary infections, digestive problems, sinus, and skin infections	[41]

in hospitals is crucial (HAI) [34,35]. Furthermore, limited there has been researched done on residential households, to evaluate the bacteriological contaminants in India.

A study conducted in the capital city of India, that is, Delhi reported the total concentration of bacteria in houses as 1654 ± 876.87 CFU/m^3 and the total fungi concentration ranges from 1275 ± 645.22 CFU/m^3 which was the highest. Sharma and colleagues conducted yet another research in Delhi and recorded high fungal colonies as 110,091 and 107,070 in CFUm^3 in an outdoor and indoor environment [36]. In a study done in the indoor environment at JNU libraries, the total concentration of microbial contaminants, that is, bacteria ranges from 911 to 1460 CFU/m^3. A study was also performed by Jimma University, Ethiopia at libraries for the evaluation of the concentration of bacteria and fungi aerosols. The study revealed that the highest concentration of bacteria in CFU/m^3 was 2595 and the lowest concentration. was recorded as 367 CFU/m^3, at 90-min exposure through using open Petri dishes also known as the settled plate method [37]. While the high fungi concentration recorded in CFU/m^3 was 1992, and the lowest concentration was 524 in colony-forming units/m^3. Studies conducted for the assessment of microbiological contaminants in hospital sites revealed different levels of bacteria and fungi concentration in Portugal displayed (240–736) and (27–933) in CFU/m^3, respectively. Another study conducted in Takalar (Indonesia) by Ikhtiar *et al*., 2017 in an indoor environment of a hospital, reported a high concentration of bacteria, that is, 1413 CFU/m^3 which exceeded the guidelines governed by the American Conference of Government Industrial Hygienists. More similar work done by various scientists around the world has been given in Table 4. The WHO expert group's research on determining the health risks posed by biological agents in indoor environments concluded that the microbial load should not be more than 1000 CFU/m^3, despite the lack of a standard uniform international estimation on the levels and acceptable microbial load in indoor air. On the other hand, the European Commission's sanitary standards for non-industrial premises classified bacterial loads as "very low" if they are <50 CFU/m^3, "low" if they are between 50 and 100 CFU/m^3, "intermediate" if they are between 500 and 2000 CFU/m^3, and "very high" if they are more than 2000 CFU/m^3.

In private homes, resistant bacteria and allergens make up the majority of the microorganisms. Many research has been conducted across the globe to evaluate the microbiological concentration in various indoor locations, such as schools, universities, hospitals, and public libraries; however, private homes received less attention.

Table 4: Summary of work conducted around the globe

S. No.	Country	Bacterial Concentration	Fungi Concentration	Reference
1.	Portugal	736	933	[10]
2.	Turkey	535	156	[42]
3.	Chennai	150	13	[43]
4.	Maharashtra	1179	262	[44]
5.	Delhi	1654	1275	[34]
6.	France	14	7	[45]

5. CONCLUSION

IAQ has been the subject of several research initiatives and continues to be a key issue for many organizations around the globe. Along with several other indoor air pollutants such as volatile organic compounds, SO_x, NO_x, particulate matters, etc., biological contaminants also affect the health and well-being of humans flagrantly exposed to the same. Numerous sources of such pollutants are present in the indoor environment which initiate and promote the growth of microbes making its assessment and abatement more important. This review paper fulfills its aim to give a quick explanation of IAQ, human health consequences, numerous bacteria and fungi found in diverse microbiomes, their origins, and various investigations conducted previously. It has been observed during the study that scarce results in this area have been reported in India examining the total bacterial and fungal composition in residential areas, hospitals, and library settings. Although some technologies have been invented claiming to inactivate and abate microbial pollutants, it is still a prominent area of research for many.

6. REFERENCES

1. E. Baurès, O. Blanchard, F. Mercier, E. Surget, P. Le Cann, A. Rivier, A. Florentin, (2018) Indoor air quality in two French hospitals: Measurement of chemical and microbiological contaminants, ***Science of the Total Environment***, **642:** 168-179.
2. A. A. Jaffal, I. M. Banat, A. A. El-Mogheth, H. Nsanze, A. Benar, A. S. Ameen, (1997b) Residential indoor airborne microbial populations in the United Arab Emirates, ***Environ International***. **23(4)**: 529-533.
3. P. Kumar, M. Kausar, A. B. Singh, R. Singh, (2021) Biological contaminants in the indoor air environment and their impacts on human health, ***Air Quality, Atmosphere and Health***, **14(11)**: 1723-1736.
4. L, Bhatia, R. Vishwakarma, (2010) Hospital indoor airborne microflora in private and government owned hospitals in Sagar city, India, ***World Journal of Medical Sciences***, **5(3)**: 65-70.
5. N. Valentín, (2007) ***Microbial Contamination in Archives and Museums: Health Hazards and Preventive Strategies Using Air Ventilation Systems***, Los Angeles, California: The Getty Conservation Institute, p1-26.
6. J. M. Seguel, R. Merrill, D. Seguel, A. C. Campagna, (2017) Indoor air quality, ***American Journal of Lifestyle Medicine***, **11(4)**: 284-295.
7. N. Bruce, R. Perez-Padilla, R. Albalak, (2000) Indoor air pollution in developing countries: A major environmental and public health challenge, ***Bulletin of the World Health Organization***, **78(9)**:

1078-1092.
8. I. Annesi-Maesano, N. Baiz, S. Banerjee, P. Rudnai, S. Rive, Sinphonie Group, (2013) Indoor air quality and sources in schools and related health effects, ***Journal of Toxicology and Environmental Health, Part B***, **16(8)**: 491-550.
9. World Health Organization, (2006) ***Development of WHO Guidelines for indoor air quality: Report on a Working Group Meeting***, Bonn, Germany: World Health Organization, 23-24 October 2006 (No. WHO/EURO: 2006-4091-43850-61740). World Health Organization. Regional Office for Europe.
10. S. C. Verde, S. M. Almeida, J. Matos, D. Guerreiro, M. Meneses, T. Faria, C. Viegas, (2015) Microbiological assessment of indoor air quality at different hospital sites, ***Research in Microbiology***, **166(7)**: 557-563.
11. M. Mohammadyan, S. Keyvani, A. Bahrami, K. Yetilmezsoy, B. Heibati, K. J. G. Pollitt. (2019) Assessment of indoor air pollution exposure in urban hospital microenvironments, ***Air Quality, Atmosphere and Health***, **12(2)**: 151-159.
12. M. Frankel, G. Beko, M. Timm, S. Gustavsen, E. W. Hansen, A. M. Madsen, (2012) Seasonal variations of indoor microbial exposures and their relation to temperature, relative humidity, and air exchange rate, ***Applied and Environmental Microbiology***, **78(23)**: 8289-8297.
13. P. Kumari, C. Woo, N. Yamamoto, H. L. Choi, (2016) Variations in abundance, diversity and community composition of airborne fungi in swine houses across seasons, ***Scientific Reports***, **6:** 37929.
14. J. Park, T. Ichijo, M. Nasu, N. Yamaguchi, (2016) Investigation of bacterial effects of Asian dust events through comparison with seasonal variability in outdoor airborne bacterial community, ***Scientific Reports***, **6:** 35706.
15. C. Humbal, S. K. Joshi, U. K. Trivedi, S. Gautam, (2019) Evaluating the colonization and distribution of fungal and bacterial bio-aerosol in Rajkot, western India using multi-proxy approach, ***Air Quality, Atmosphere and Health***, **12(6)**: 693-704.
16. S. Sidra, Z. Ali, Z. A. Nasir, I. Colbeck, (2015) Seasonal variation of fine particulate matter in residential micro-environments of Lahore, Pakistan, ***Atmospheric Pollution Research***, **6(5)**: 797-804.
17. E. Brągoszewska, A. Mainka, J. S. Pastuszka, (2016) Bacterial aerosols in an urban nursery school in Gliwice, Poland: A case study, ***Aerobiologia***, **32(3)**: 469-480.
18. S. Y. Cho, J. P. Myong, W. B. Kim, C. Park, S. J. Lee, S. H. Lee, D. G. Lee, (2018) Profiles of environmental mold: Indoor and outdoor air sampling in a hematology hospital in Seoul, South Korea, ***International Journal of Environmental Research and Public Health***, **15(11)**: 2560.
19. M. Maroni, B. Seifert, T. Lindvall, T. (Eds.), (1995) ***Indoor Air Quality: A Comprehensive Reference Book***, Amsterdam, Netherlands: Elsevier.
20. J. D. Spengler, K. Sexton, (1983) Indoor air pollution: A public health perspective, ***Science***, **221(4605)**: 9-17.
21. K. R. Smith, S. Mehta, (2003) The burden of disease from indoor air pollution in developing countries: Comparison of estimates, ***International Journal of Hygiene and Environmental Health***, **206(4-5)**: 279-289.
22. E. Brągoszewska, I. Biedroń, B. Kozielska, J. S. Pastuszka, (2018) Microbiological indoor air quality in an office building in Gliwice, Poland: analysis of the case study, ***Air Quality, Atmosphere and Health***, **11(6)**: 729-740.
23. K. Reijula, C. Sundman-Digert, (2004) Assessment of indoor air problems at work with a questionnaire, ***Occupational and Environmental Medicine***, **61(1)**: 33-38.
24. P. Kumari, D. Toshniwal, (2022) Impact of lockdown measures during COVID-19 on air quality a case study of India, ***International Journal of Environmental Health Research***, **32(3)**: 503-510.
25. P. Madamarandawala, Y. Weerasinghe, D. Pathiraja, A. Ekanayake, D. Madegedara, D. Magana-Arachchi, (2019) Impact of microbial air quality in preschools on paediatric respiratory health, ***SN Applied Sciences***, **1(10)**: 1-11.
26. E. Karwowskae, (2005) Microbiological air contamination in farming environment, ***Polish Journal of Environmental Studies***, **14:** 445-449.
27. J. Karbowska-Berent, R. L. Gorny, A. B. Strzelczyk, A. Wlazło, (2011) Airborne and dust borne microorganisms in selected Polish libraries and archives, ***Building and Environment***, **46(10)**: 1872-1879.
28. G. P. Shiaka, S. E. Yakubu, (2013) Comparative analysis of airborne microbial concentrations in the indoor environment of two selected clinical laboratories, ***IOSR Journal of Pharmacy and Biological Sciences***, **8:** 4.
29. B. Flannigan, (2001) Microbial aerosols in buildings: Origins, health implications and controls. In: ***Łod´z: Proceedings of the II International´ Scientific Conference: Microbial Biodegradation and Biodeterioration of Technical Materials***, p11-27.
30. World Health Organization. ***Global Health Observatory Database***, Geneva: World Health Organization; 2009. Available from: http://www.who.int/gho/database/en [Last accessed on 2016 Apr 26].
31. World Health Organization, (2013) ***Health Care-Associated Infections Fact Sheet***, Geneva: World Health Organization. Available from: http://www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf [Last accessed on 2021 Sep 10].
32. National Nosocomial Infections Surveillance System. (2004) National Nosocomial Infections Surveillance (NNIS) system report, data summary from January 1992 through June 2004, issued October 2004, ***American Journal of Infection Control***, **32:** 470.
33. N. Menachemi, V. A. Yeager, E. Welty, B. Manzella, (2015) Are physician productivity and quality of care related, ***Journal for Healthcare Quality***, **37:** 93-101.
34. P. Kumar, A. B. Singh, R. Singh, (2021) Seasonal variation and size distribution in the airborne indoor microbial concentration of residential houses in Delhi and its impact on health, ***Aerobiologia***, **37(4)**: 719-732.
35. A. P. Jones, (1999) Indoor air quality and health, ***Atmospheric Environment***, **33(28)**: 4535-4564.
36. R. Sharma, R. Deval, V. Priyadarshi, S. N. Gaur, V. P. Singh, A. b. Singh, (2011) Indoor fungal concentration in the homes of allergic/asthmatic children in Delhi, India, ***Allergy and Rhinology***, **2(1)**: ar-2011.
37. S. F. Hayleeyesus, A. M. Manaye, (2014) Microbiological quality of indoor air in university libraries, ***Asian Pacific Journal of Tropical Biomedicine***, **4**: S312-S317.
38. P. Srikanth, S. Sudharsanam, R. Steinberg, (2008) Bio-aerosols in indoor environment: Composition, health effects and analysis, ***Indian Journal of Medical Microbiology***, **26(4)**: 302-312.
39. S. N. Baxi, J. M. Portnoy, D. Larenas-Linnemann, W. Phipatanakul, C. Barnes, S. Baxi, P. B. Williams, (2016) Exposure and health

effects of fungi on humans, ***The Journal of Allergy and Clinical Immunology: In Practice***, **4(3)**: 396-404.
40. A. H. Khan, S. M. Karuppayil, (2012) Fungal pollution of indoor environments and its management, ***Saudi Journal of Biological Sciences***, **19(4)**: 405-426.
41. T. Husman, (1996) Health effects of indoor-air microorganisms, ***Scandinavian Journal of Work, Environment and Health***, **22(1)**: 5-13.
42. S. Sarıca, A. Asan, M. T. Otkun, M. Ture, (2002) Monitoring indoor airborne fungi and bacteria in the different areas of Trakya University Hospital, Edirne, Turkey, ***Indoor and Built Environment***, **11(5)**: 285-292.
43. S. Sudharsanam, P. Srikanth, M. Sheela, R. Steinberg, (2008) Study of the indoor air quality in hospitals in South Chennai, India microbial profile, ***Indoor and Built Environment***, **17(5)**: 435-441.
44. S. Kotgire, R. Akhtar, A. Damle, S. Siddiqui, H. Padekar, U. Afreen, (2020) Bioaerosol assessment of indoor air in hospital wards from a tertiary care hospital, ***Indian Journal of Microbiology Research***, **7:** 28-34.
45. A. Baudet, E. Baurès, H. Guegan, O. Blanchard, M. Guillaso, P. Le Cann, A. Florentin, (2021) Indoor air quality in healthcare and care facilities: Chemical pollutants and microbiological contaminants, ***Atmosphere***, **12(10)**: 1337.

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