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An Overview of The Effects of Indoor Fungi on Human Health

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ABSTRACT: According to estimates, concerns about the quality of indoor air may be present in as many as 30% of buildings globally. Both organic and inorganic particles are potential air pollution sources. This article focuses on biological air pollutants originating from living and non-living organisms, particularly those related to fungi. Domestic house indoor air contains fungi that, to a significant extent, share the same species composition as those outside the building. When rooms are ventilated or through other openings, microorganisms enter buildings where they can grow on the surfaces of a variety of materials. Intensely grows in stuffy, humid, poorly ventilated areas. For this reason, residents may experience more discomfort from exposure to interior air pollution than they would from exposure to outside air contaminants. Due to their propensity to produce mycotoxins, allergic reactions, volatile organic chemicals, and even fungal illnesses, fungi can be extremely dangerous when found in residential buildings.

KEYWORDS: Indoor fungi, Allergies, Volatile Compounds, Mycotoxins.

INTRODUCTION

The majority of people spend around 90% of their free time indoors, therefore despite the strange perception, being exposed to interior air pollution may be worse than being exposed to outdoor air pollutants[1]. Only between 1978 and 2016 were fourteen international conferences solely devoted to indoor air quality-related topics, the condition of the air inside buildings may give rise to complaints about up to 30% of structures worldwide, according to a 1984 WHO (World Health Organization)[2]. As per the latest WHO assessment on indoor air quality, mold, and moisture, this issue has not lessened or even gotten worse over the previous few years, according to estimates, indoor wetness affects between 10 and 50 percent of interior spaces in Europe and other advanced industrialized countries[3]. There are more and more complaints of respiratory illnesses linked to residing in houses where there are problems with humidity and when various building components have bacteria on them[4]. The quality of the air is determined by the quantity and kind of impurities suspended in it, both organic and inorganic particles are potential contributors to air pollution, and the natural contaminants found in biological sources, both extant and living, are the subject of this article, microbes are worthy of consideration when considering biological aspects, although microorganisms enter a building from the outside, it's important to note that the interior contains important development sources[5, 6]. As so-called bioaerosol, indoor microorganisms can be found in the air and settle on a variety of surfaces, including walls, windows, food remnants, under carpets, and other wet materials, they can also form layers of condensed steam on these surfaces, home dust is an environment that is particularly favorable for the growth of numerous microorganisms[7,8]. The air filters in air conditioning systems frequently become colonized by a variety of microorganisms, including fungi, which will then be the primary cause of air pollution, hospitals were also found to have incidents of mold colonizing air filters[9]. It makes sense, then, that at least half of the fungal species isolated from the interior air are the same as those isolated from other materials, dust, or the wall surfaces of these rooms[10]. There are several ways for spores, conidia, and other fungus structures to enter the human body: through the mouth, the nose, or the skin[11].

REACTIONS TO FUNGI AND ALLERGIES

The presence of fungi in homes is frequently linked to allergy reactions, and their capacity to trigger inflammatory responses is greatly influenced by their environment of growth, particularly the type of substrate[12]. Asthma, rhinitis, conjunctivitis, urticaria, and atopic dermatitis are just a few of the symptoms of a fungus allergy. each of the four types of hypersensitivity reactions can be brought on by fungi, depending on the species[13]. Among the various types of allergic reactions to fungi that have been described, type I immediate reaction hypersensitivity is the most prevalent, The clinical manifestations of this immunological response, commonly referred to as anaphylaxis, include asthma, rhinitis, sinusitis, urticaria, enlarged blood vessels, and bronchial occlusion, in this situation, fungus-related irritants cause the synthesis of IgE, which opsonizes mast cells and basophils[14,15]. Typically,

symptoms start to show up 10 to 30 minutes after allergen interaction, reactions of type II occur less frequently, mannan, a fungus antigen that can cause this kind of reaction, is most frequently found in *Aspergillus* and *Candida* species' cell walls [16]. These are cytotoxic responses that are primarily mediated by IgG and IgM antibodies or cytotoxic lymphocyte-producing cells, natural killer (NK) cells, also known as activated macrophages, that are targeted against an antigen present in blood cells or that are part of the cell membrane[17]. When it comes to allergic bronchopulmonary aspergillosis (ABPA), also known as allergic broncho alveolitis, we encounter type III sensitization to fungal antigens[18]. Immune complexes made up of antibodies and fungal antigens are typically linked to this kind of allergic reaction, when a person is repeatedly exposed to tiny conidia such as those produced by *Aspergillus fumigatus*, which only reach a size of 2-3.5 microns, they can develop these complexes, this is the case with APBA[19,20]. Hypersensitivity responses' clinical signs and symptoms Type III reactions occur 4-6 hours after exposure to the allergen, and a type IV hypersensitive reaction follows after 24 to 48 hours of contact between Th1 (CD4+) sensitized lymphocytes and antigen, the antigen may be some fungus-produced haptens or cellular structures, or as was recently described, it may be related to a species of archaea[21]. Insignificant amounts of fungal spores naturally exist in both outdoor and indoor air, however, they could result in some allergic reactions in those who are vulnerable[22]. The summer is when mold is most prevalent, also, from September to November, the problem progressively gets better, with high quantities of spores from the *Cladosporium* and *Alternaria* species. during the late summer are the causes of severe bronchial asthma exacerbations during this season[23]. However, the season may have little effect on the number of various fungi's spores or conidia in indoor air, In this instance, the fungal species *Serpula lacrymans* is involved, which fully developed basidiocarps constantly discharge a massive quantity of basidiospores, the high concentrations of many volatile chemical compounds present in this fungus make it dangerous, it secretes both at the moment of its fruiting bodies' demise and throughout periods of active growth, however, this fungus is harmful to construction materials because of its potent ligninolytic and cellulosic characteristics[24]. Since fungus spores make up a sizable portion of household dust, it has been demonstrated that in most cases, fungal spores are the only cause of seasonal hay fever and so-called dust allergies. consequently, household dust acts as a major mold reservoir, and most of the dust-associated fungal flora is a reflection of the room airborne mycobiota, there are enough nutrients in the dust for fungus to flourish if there is enough dampness, and house dust typically contains a lot of organic stuff and frequently has a pH that is ideal for fungal[25]. Each day, the average person inhales about 10,000 liters of air, the amount of bacteria, fungus, and other microscopic organic particles that can be found in one liter of clean outdoor air can range up to twenty, as a result, the respiratory system is highly exposed to a variety of allergens[26]. Allergic reactions brought on by mold frequently resemble influenza-related ones, the distinction between molds classified as non-pathogenic and pathogenic is irrelevant, and both organizations pose a threat to human health[27]. Common symptoms of exposure to mold allergens include runny nose, cough, conjunctivitis, chest pain, and hives, in general, fungal species are often pathogenic and cause nonallergic mycosis, when exposed to allergenic fungi, individuals with atopic dermatitis, atopic alveolitis, or bronchopneumonia (ABPA) may have an aggravation of symptoms [28].

FUNGI AS VOLATILE COMPOUNDS PRODUCERS

It is generally known that fungi can produce a significant number of volatile organic molecules, they represent only one of their major or secondary metabolism's many byproducts, these chemical substances' secretion is also closely associated with a sick building, it is referred to as sick building syndrome (SBS), extracellular polysaccharides (EPS) are produced in enormous quantities, and volatile compounds are secreted when mold grows in enclosed spaces that are inadequately ventilated and have a high relative humidity[29,30]. Since it is well known that fungi are more active metabolically in environments with higher relative humidity, the symptoms of fungi VOC secretion are typically soreness, headaches, eye pain, pharyngitis, lightheadedness, fuzzy vision, and trouble focusing, sensitivity to smell, fatigue, apathy, or even a greater propensity for colds, a greater amount of bioaerosol in the air indoors exacerbates this primarily neurotoxic effects[31]. Such hazardous conditions may only exist in the entire flat, in a single room, or even the entire building, particularly if the latter was built using materials that were insufficient for the local climate, volatile organic molecules and carbon dioxide are always released when fungus develop in certain environments, the substances that fungus secrete fall into various categories, including alcohols, ketones, aldehydes, and esters[32]. Among alcohols, we often find 1-octanol, 2-octanol, methylbutanol, apart from alcohol, other frequently generated compounds by fungi include terpenes and ketones, including 2-pentanone, 2-hexanone, 2-heptanone, 3-octanone, α-pinene, β-pinene, camphene, limonene, or methylfurans[33]. In addition to the fungus species, the type of MVOC produced is also influenced by the substrate that the fungus grows on, furthermore, there are differences amongst strains of the same species, In indoor air, *Aspergillus* species, *Penicillium* species, *Cladosporium* species, and *Fusarium* species are the most prevalent and often isolated, and are capable of producing a variety of volatile chemicals, it was established that these species could secrete nonanal, acrolein, 2-pentanone, 2-hexanone[34]. Additionally, formaldehyde and -glucans, which are generated by many different species of fungi, have been demonstrated to have a severe irritant effect on mucosal membranes, some molecules, among other things, certain carpets, furnishings, and building things can produce monoterpenes, these compounds can also be created by bacteria and actinobacteria[35].

MYCOTOXINS AS RESULTS OF SECONDARY METABOLISM

Mycotoxins are a well-known issue that has detrimental effects on both human and animal health, demonstrating the detrimental effects of fungi that are directly in contact with humans and making it hard to overlook their toxic consequences on the human body[36]. The fact that virulent strains of the fungus population have been identified and may produce more mycotoxins is concerning, this phenomenon might be connected to the growing usage of plant protection chemicals, such as fungicides and insecticides, whose well-known mutagenesis effects[37]. Mycotoxins, which are toxic byproducts of mold's secondary metabolism, are thought to be necessary for fungi in their natural habitat because the majority of them are created in opposition to other microorganisms, including other fungal species, in a fight for environmental niches[38]. Over 400 distinct mycotoxins have been identified to date, mycotoxins can cause acute as well as chronic diseases in humans, as well as one (mg) for every (kg) of body weight. is required to cause acute intoxication, which frequently results in death[39]. Food that has been infected with mycotoxins is typically the source of mycotoxin poisoning, primary mycotoxicosis, however, can also result from inhaling spores, conidia, or mycelium fragments, given that mycotoxins can concentrate in various mycelium structures and permeate into the culture medium, particularly throughout the time of sporulation, *A. flavus*, and *A. parasiticus*, two other species, produce mycotoxins that accumulate in conidia and sclerotia, *Stachybotrys chartarum*, for instance, produce mycotoxins that are concentrated in conidia, phialides, and conidiophores[40,41]. Studies reveal that even 25% of the homes are damp, and additional calculations suggest that up to 24% of the occupants may be exposed to allergens and mycotoxins released by fungus, these findings link long-term exposure to mycotoxins to the noticeably higher rate of cancer in humans who live in moldy rooms[42]. Aflatoxin, Fumonisins, Zearalenone, Ochratoxin A, and Trichothecenes are some of the most significant and frequently found mycotoxins in the environment, neoplastic alterations, especially cancer of the liver or kidney, are believed to be caused by chronic low-dose exposure to these substances[43]. Due to the carcinogenic qualities of the benzofuran ring, the first listed substance looks to be especially toxic to humans and animals, several species of *Aspergillus* have been isolated from materials containing cellulose or collagen, and they are makers of hazardous mycotoxins in the environment[44]. The production of mycotoxin and the degree to which it is produced is determined by the fungal strain, its genotype, developmental stage, temperature, relative humidity, and the fungus's growth substrate's chemical composition, about the latter, the type of nitrogen source is particularly significant for the production of toxic compounds[45]. For instance, the optimal temperature at which aflatoxin production occurs is 33 °C, mycotoxins are created intensely in warmer weather and with greater relative humidity, especially within houses with inadequate ventilation, additionally, it has been discovered that the formation of this toxin is prevented by certain amounts of phosphates and inorganic nitrogen as well as by oxygen deprivation and increased carbon dioxide[46]. Since *Aspergillus ochraceus* is so common in the environment, the majority of mycotoxins must have specific organ and tissue affinity, Trichothecenes, which seem to have a preference for the digestive system, and Zearalenone, which significantly harms the reproductive system, are also very dangerous, Ochratoxin A is predilection for the kidneys and liver appears to be particularly hazardous[47]. Apart from the deleterious consequences of mycotoxins, allergies, and the volatile organic molecules that fungi produce, these microorganisms can also result in hazardous infections, which can be superficial, cutaneous, or subcutaneous, notably, the *Aspergillus* species which is frequently found in household air, being opportunistic pathogens, especially in prone people, can induce lung aspergillosis, keratitis, or otitis[48,49]. House dust, as previously mentioned, can serve as a significant reservoir for mold and dermatophytes as well as other fungal spores or propagules, particularly within humid dwellings issues, the latter are more common in apartments inhabited by people with a variety of household animals that shed animal dander or corneous epidermis, this condition can lead to the emergence of diseases caused by dermatophytes, which have zoophilic dermatophytes as their etiological factors, such as *M. canis* and *T. mentagrophytes*[50]. In conclusion, depending on a person's sensitivity, mold growth in homes is always associated with certain health issues, given that fungus spores are exposed every day in approximately every fourth pole, the issue of the prevalence of fungi in apartments and public buildings as it is discussed in this article becomes more pressing, spores of bacteria and fungi are frequently found in structures and can readily settle into any void left by their presence, provided that the substrate has a minimal quantity of water and a suitable relative humidity, the first ones can grow under lower substrate humidity conditions and at much lower relative humidity levels, it should be emphasized[51].

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