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REVIEW ARTICLE

Allergenic potential of moulds isolated from buildings

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Abstract

Introduction: Moulds are the one of the known biological factors that have a negative impact on human health. Moulds are commonly present in residential and work environments. Materials plentiful in organic compounds, such as building materials or paints, are a splendid substrate for the development of moulds. The first documented mention of a study describing the harmful effects caused by moulds in buildings emerged in the early nineteenth century. In Copenhagen and then in Padua, moulds of the genus *Penicillium, Cladosporium* and *Mucor* were found in buildings.
Objective: To present the current state of the allergic properties and other negative health effects caused by moulds isolated from buildings.
Brief description of the state of knowledge: The literature and own research clearly shows that moulds and their secondary metabolites can evoke toxic effects on human and animal health, and cause symptoms similar to allergic diseases. These allergens have been noted in spores as well as other fungal fragments; however, most allergens are located in germinating spores, in the hyphal tips and in mycelia. Fungal allergy can express in different ways: asthma, rhinitis, conjunctivitis, urticaria and atopic dermatitis. Fungal allergy antigen is bound to IgE-dependent reactions but also to reactions independent of IgE.
Conclusions: Moulds are a significant but difficult to detect etiologic agent of different allergic diseases. Prevention of this diseases is important for patients with suspected connection between common allergic symptoms and affinity with moulds.

Key words
allergy, mould, building mycology

INTRODUCTION

Moulds (fungi) are eukaryotic organisms with cell walls, without chlorophyll (they do not have the ability to synthesize organic compounds from inorganic substances), propagating sexually or asexually (by spores). Moulds are considered as parasites if the sources of organic substances are living organisms, or to saprophytes, where they derive compounds from the lifeless, damp, organic materials or substrates, such as wood, paper, paint, dust, food scraps and leather. The share of moulds in the biomass of the earth is estimated at about 25%. All fungi acquire oxygen from the air or from oxygen dissolved in water. Among moulds there is no absolute anaerobes. The result of studies conducted by Smith and Nadim in 1983 shows that moulds have the ability to develop within 2 – 3 weeks, even on a clean glass surface where fingerprints were left. They have a minimal need for growth and development, which allows them to colonize niches extremely poor in organic substances. However, materials rich in organic compounds, such as building materials or paint, are an excellent substrate for the development of moulds. Mould are commonly present in residential and work environments, and according to the literature, inside residential buildings there occur more than 400 species of fungi [1]. Therefore, indoor air is often excessively contaminated with the spores of moulds [2, 3].

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About 8 million people living in Poland (in approximately 2.7 million houses) are at risk of mycotoxins and allergens secreted by moulds. Deterioration of health is more frequently observed in people residing in an enclosed space, e.g. flats, offices, healthcare institutions, dining places, and all other locations providing an enclosed space construction [4]. Spores of microscopic fungi are important aeroallergens included in air pollution. More than 80 species among 120,000 of described species of fungi may be associated with respiratory allergy [3]. Exposure to moulds may have multiple health effects: it can cause allergies in the form of rhinitis and bronchial asthma, allergic alveolitis, and in people with poor resistance can result in severe opportunistic infections [5].

OBJECTIVE

The aim of this study is to present the current state of the allergic properties and other negative health effects caused by moulds isolated from buildings.

DESCRIPTION OF THE STATE OF KNOWLEDGE

Characteristics of moulds. The optimal condition for development of moulds is high humidity of the air and fungal medium, although many xerophylic species of the genus *Aspergillus* and *Penicillium* have the ability to survive in very dry environments. Mould spores and conidia are resistant to lack of water and drought, under which conditions they are able to survive for even a year. Mould, due to the fact that they are aerobic microorganisms, commonly grow on the surface. The source of carbon for these organisms may be different compounds and the rich enzymatic apparatus allows the use of substances very poor in nutrients, even plastics. The temperature range in which moulds are able to grow is from 18 – 32°C, but they can survive even within the limits of 6 – 60°C [3]. Particularly encouraging for growth and development are positive temperature and relative humidity reaching above 60%, when it can be produced on the damp layer of walls and windows [3, 6]. The most negative factor for the existence of fungi is a draft of air, which can be used in antifungal prevention in apartments and residential buildings. However, in order to effectively eliminate mould, other methods and means must be used, both in the construction of building and with chemicals.

Moulds produce a huge amount of spores, which can be transmitted over thousands of kilometers, and appear even in the stratosphere. The very small size (3–10 microns) of spores also allows them to penetrate deeply into the bronchial tract, which can be the beginning of mould allergy [7]. The process of spore release depends of the type of fungus as well as weather conditions. The concentration of spores in the home environment increases with the rising number in the external environment. Some spores are released when the air is dry, and their concentration in the air increases with extended wind and decreased humidity, during high insolation of, for example, fungi spores of the genera: *Alternaria, Cladosporium, Helminthosporium*. The 'moist' spores produced by fungi of class *Ascomycetes* are released into the atmosphere in rain, often at night [8]. The abundance of fungi spores exceeds the number of grains of pollen which are the other environmental allergen. Many studies show a significant association between increased levels of fungal spores and antigens, and the presence of allergy symptoms [9, 10, 11]. As studies show that the most allergenic are the spores which accumulate as a fundamental part of the secondary metabolites of mycelium – mycotoxins. Water droplets on the surface of the mycelium are the source of the highest concentrations of pathogenic metabolites. Some moulds produce several toxins and some toxins are produced by more than one species of fungus [12]. The main toxin is aflatoxin (AF), ochratoxin A (OT), zearalenone (ZEN), trichothecenes and fumonisins (F) [5, 13]. Mycotoxins are characterized by multidirectional activity: mutagenic, neurotoxic, immunosuppressive and carcinogenic. The greatest risk for human and animal health are filamentous fungi of the genera *Aspergillus, Penicillium, Fusarium, Stachybotrys, Alternaria i Cladosporium* [14, 15, 16]. Currently, the minimum concentration of mycotoxins and minimum exposure time required to produce adverse effects on human health remains unknown [3, 17].

Moulds and buildings. In 1965, for the first time, van der Plas Hueck in the Netherlands estimated the global losses in technical materials caused by microorganisms worldwide. He found that 2% per annum of materials undergo microbial decomposition. In 1996, Zyska (after van der Plas Hueck), presented the results of this test applied to Poland. Zyska took selected materials into account: fabric, leather, wood products, pulp and paper, petroleum refinery products, paints and coatings, fibres and plastics, gum, machinery, electrical equipment, herbal, pharmaceutical and cosmetic medication. The total value of losses caused by destruction of materials by microorganisms in 1996 amounted to approximately 1,084 million PLN. Currently, it is expected that these values are much higher than expected, reaching about 5% of GDP (10,907 million PLN). However, in estimating these costs, there was no accounting, for example, of monuments, museum collections, threats to health and life [18]. The content of microorganisms in the air is conditioned by many factors, Krajewska-Kułak et al. [19] report that the most important are: the geographical area, season, type of room (open, closed, staff room, factory, health care institution). Moreover Krzysztofik [20] reports that residential buildings and offices create a specific microclimate in which the microbiological air purity was also disrupted by the presence of people, building materials, furnishings, appliances, air temperature and humidity, and the type of ventilation. A large group of microorganisms, particularly moulds, often colonize air-conditioning filters which are the direct cause of air pollution. Cases of colonization of air filters by moulds have typically been found even in hospitals [21]. According to the World Health Organization (WHO), more than 3 billion people suffer from diseases caused by indoor air pollution [22].

The presence of pathogenic fungi indoors (especially *Stachybotrys chartarum*) in building materials is considered an important risk factor for contamination of the microclimate. The adverse health effects for humans and animals are associated with intense exposure to *S. chartarum* and other fungi of the genus *Aspergillus, Penicillium, Fusarium, Trichoderma*. It is estimated that 25% of all Polish buildings are contaminated with mycotoxins and allergens secreted by moulds colonizing construction materials [1]. For comparison, in the UK and in Scandinavian countries, mould growth occurs in 10% of buildings. Most often, the reservoir of dangerous moulds are watered plants, pets, wallpaper, dusty mattresses, plush toys, contaminated ventilation and air conditioning [7]. In indoor air, the levels of fungal spore sometimes exceed even 1,000/m^3 [2, 7]. The types of fungi most commonly found in homes are *Aspergillus, Penicillium, Mucor, Rhizopus, Aureobasidium* and *Cladosporium*. According to research, moulds produce spores throughout the year and their growth is dependent on the relative humidity, which depends on ventilation, air conditioning and the presence of thermal insulation of the building [23]. The most common in the holding rooms are the species: *Cladosporium sphaerospermum* (isolated from the surface of building materials in bathrooms, kitchens), *Cladosporium cladosporioides, Cladosporium herbarum* (isolated from the air where the number of spores may be as high as 10,000 cfu/m). The last two species are characterized by the presence of similar allergic proteins [24].

In residential buildings, the development process of moulds requires several conditions: the presence of oxygen and nutrients that can always get in the built environment, the source of which is primarily small amounts of organic material, emulsion paints, glue, wallpaper and dust settled on a daily basis. A suitable medium for moulds is wood. Fungi attack solid wood, processed in the form of plates, where the particles are composed of wood or materials such as lignin-cellulose (chipboard or straw) [18]. The commonest and possibly the most destructive wood decay fungus found in buildings in temperate regions, including Australia, Europe and Japan, is the dry-rot fungus *Serpula lacrymans* (previously known as *Merulius lacrymans*). This fungus can grow quickly and may spread throughout a building from one timber to another, potentially causing devastating effects in the whole building. There are many other dry and wet-rot fungi that can cause wood decay and subsequent damage to the building environment [25]. They have also been implicated in causing hypersensitivity pneumonitis (extrinsic allergic alveolitis) [26].

Health problems connected with presence of the moulds in buildings. The literature and own research clearly shows that mould fungi and their secondary metabolites have toxic effects on human and animal health, and cause symptoms similar to allergic diseases. This problem has become particularly important in Europe after the occurrence of numerous floods. For healthy individuals, the inhalation of mould spores carried by air, under normal circumstances should not be a threat, due to the fact that the airways have self-cleaning mechanisms. However, longer exposure to such pathogens can evoke serious respiratory illnesses. In the case of overload or damage to the respiratory tract these defence mechanisms may fail, and the inhaled spores form mucous plugs in the bronchioles and pulmonary alveoli, germinate and form micelles. Mycelium settled in this way through the continuous antigen production in the tissue induces IgE antibodies, which leads to inflammation and tissue damage, and supports the mycelium growth. An example of this type is aspergillosis, found in young people with asthma and those with a tendency to atopy [5].

Most of the health problems associated with indoor air quality occur in areas associated with the presence of fungi; it is estimated that they provide up to 70% of all indoor air microbial contamination. This is demonstrated by the results of mycological analysis conducted on indoor air in the USA and Brazil where the results of the studies showed that the main fungi occurring are *Penicillium* spp., *Aspergillus* spp., and *Cladosporium* spp. [27]. Professional groups particularly exposed to the harmful effects of mould are employees of the agricultural-food industries, the staff of museums, libraries and archives, and art conservators. The exposed group may also include office workers when offices as the source of hazards may be contaminated with mould in ventilation and air conditioning hoses, stock, settling dust, wood shelves and barrier constructions [28].

The spores of moulds can also cause infectious diseases and especially attack the lungs of people with strong immune system deficiency (patients with cancer or AIDS). For milder symptoms after exposure to moulds belong: malaise, nausea, headaches and other psychosomatic symptoms. Unfortunately, a shortage of significant epidemiological data about diseases caused by exposure to moulds and diversity of diseases and clinical symptomatology is noted, which is why various types of reports are so valuable. In recent medical and epidemiological studies, toxic symptoms in children living in damp areas have ben reported, as well as children in contact with paper covered by moulds and who inhaled contaminated air. These effects are generally associated with protein allergens and toxic metabolites (mycotoxins) produced by various species of moulds transmitted mainly by air [5]. Many moulds produce numerous protein or glycoprotein allergens capable of causing allergic reactions in people. These allergens have been found in spores, as well as other fungal fragments [29]; however, most allergens are located in germinating spores, in the hyphal tips, and in mycelia [30, 31]. An estimated 6–10% of the general population and 15–50% of those who are genetically susceptible (atopic) are sensitized to mould allergens [32]. Allergy to spores of fungi occurs in the form of inhaled allergies, food allergy, contact allergy (skin), allergy to antibiotics, and allergic reaction in response to fungal infection in the organism. Fungal allergy can manifest in different ways: asthma, rhinitis, conjunctivitis, urticaria and atopic dermatitis. Fungal allergy antigen is bound to IgE-dependent reactions, but also to reactions independent of IgE [33]. Inhaled allergies frequently observed involve the upper and lower respiratory tract, and concerns the small size of the spores (3–10 μm) which can easily penetrate into these areas. We often have to deal with a runny nose [34]. There are contradictory views on whether the fungus can cause allergic conjunctivitis; some argue that due to their small size the spores do not stop in the conjunctiva of the eyelids, but are flushed out by tears [35]. Others believe that there is a common link between allergic conjunctivitis and the moulds inducing them [36]. Bronchial asthma is caused by early-type allergic reaction in which antibodies called reagins (IgE) participate. To the characteristic symptoms of asthma belong bronchospasm and asthmatic attack, occurring most often at rest. This disease causes many allergens or substances that alter the immune reactivity in exposed people [37, 38]. 'Mould astma' is frequently used to determine atopic asthma cases with leading allergy to fungal spores [39]. Health disorders associated with exposure to moulds are tight building syndrome, a synonym for sick building syndrome (SBS), and chronic fatigue syndrome [10, 40, 41, 42]. Improper insulation techniques or repair (exposure to glass fibres and asbestos) are also very important in the development of SBS [40]. In 40–60% of SBS, the type of ventilation system and method for heating and/or cooling spaces cause the symptoms [41]. Sick building syndrome is characterized by subjective symptoms experienced by workers in modern office buildings. In 1987, the WHO established a list of symptoms and disease entities which may arise in 'sick buildings', according to the prevalence of features such as: irritation or damage to the mucous membranes (eyes, nose, throat, bronchi), dryness and skin irritation, neurotoxic symptoms (headache, fatigue, irritability, impaired concentration), bronchial asthma, asthma-like symptoms (chest tightness chest pain, shortness of breath), and damage of pulmonary tissues [42, 43, 44]. One of the reasons which might cause these symptoms is considered with toxic volatile metabolites, often referred as 'volatile organic compounds' (VOCs) produced by moulds [10, 13]. Another word for diseases associated with being in an excessively polluted internal environment is called building-related illness (BRI). In BRI, two groups of diseases are distinguished: specific (conditions of allergic, immune or infectious origin) and non-specific (heterogeneous symptomatics – irritation of the skin and mucous membranes, headache, fatigue, loss of concentration) [43, 44].

CONCLUSIONS

We spend 90% of our lives indoors, so it is expected that the conditions in these places in particular should not be harmful to humans. However, it seems that a lot of health problems due to the negative effects of a variety of physical, chemical and biological agents are present in confined areas. [7, 10, 11, 45]. Studies conducted in recent years demonstrate that fungi can be the source of allergens in flats. It seems that the role of moulds may be much higher than previously expected. Fungi appear to be a significant, but difficult to detect, etiologic agent of different allergic diseases. This is why prevention is so important for patients with a suspected relationship between common allergic symptoms and their affinity with moulds. Prevention efforts should focus on avoiding darkened rooms that are poorly ventilated and with a relatively high humidity (kitchens, bathrooms, saunas, basements), furnished with wallpaper, and full of house dust.

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