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HEALTH EFFECTS OF EXPOSURE TO INDOOR FUNGI
CASE STUDY – THE RESTORERS OF MURAL PAINTINGS

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Abstract

The majority of environmental problems in buildings are associated with the lack of maintenance, chronic neglect and building defects leading to water ingress, condensation and dampness in the building fabric. Deterioration of historical building materials such as in churches, monuments and buildings of historic and architectural interest are attributed to changes in the built environment. Fungi inhabit nearly all terrestrial environments. In this regard, the interiors of human dwellings and workspaces are no exception. They are among the most common microbiota in the interiors of buildings, including monuments. The principal agents of indoor fungal contamination in monuments are anamorphic (asexual) fungi mostly belonging to the phyla Ascomycota and Zygomycota, commonly known as 'moulds'. Management of biodeterioration and health problems in buildings is a complex issue and require a multi-disciplinary approach, which combines the skills of scientists, health specialists, restorers, etc.
This paper reviews the literature on health problems and the aim is to make the restorers conscious about the risks of the exposure to indoor fungi in monuments.

Keywords: health, fungi problems, restorers

1. Introduction

Indoor air quality is an important issue for occupational and public health. Fungi inhabit nearly all terrestrial environments. In this regard, the interiors of human dwellings and workspaces are no exception. There is no indoor space which is sterile and free from microbial contamination, the presence of biological contaminants in low concentrations can be treated as a 'normal'. Fungi are essential to survival of our global ecology but they may pose a significant threat to the health of occupants when they grow in our buildings. The problem of microbial contamination of indoor spaces connected with biodeterioration of materials and buildings accompanies mankind in the dawn of

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its history. Probably the first reference about the destructive influence of fungal flora on human dwellings and clothes is found in the 3rd Book of the Bible, Leviticus, chapter 14, verse 33-48.

The majority of environmental problems in buildings are associated with lack of maintenance, chronic neglect and building defects leading to water ingress, condensation and dampness in the building fabric.

Deterioration of historical building materials such as in churches, monuments and buildings of historic and architectural interest are attributed to changes in the built environment. The main environmental parameters affecting the decay of materials are water, humidity, temperature, UV light and lack of ventilation [1].

Buildings are constantly subjected to microbial exposure. During particular periods of building use, its construction elements undergo an environmental stress created by the presence of different forms of water. Each time when the water appears on the surfaces of construction materials or penetrates them through holes and cavities, it can provoke microbial contamination. Such a situation is particularly visible in the case of water damage. In buildings, this is relatively common and usually associated with mould problems. The scale of this phenomenon is confirmed by numerous studies. American investigation reveal that 27-56% of homes have problems with visible fungal contamination of surfaces, and/or bad quality of indoor air. In Europe, this percentage ranges from 12-80%. Only in Germany the costs caused by mould damage in buildings are estimated to the amount of more than 200 million Euros per year [2].

It has been estimated that approximately ¼ of the Earth's total biomass is composed of fungi. Of all the biological factors, fungi are responsible for the 80% of total building materials degradation [3].

Airborne microorganisms are ubiquitous present the various fields of indoor and outdoor environments. The potential implication of fungal contaminants in bioaerosols on occupational health is recognized as a problem in several working environments [4].

Airborne bacteria and fungi can cause various types of human health problems, including irritation, allergies, infections, toxic reactions, and inflammatory responses.

Humans are exposed to molds via ingestion, inhalation, and skin contact with mold or mold infested material. Although molds are living, multiplying organisms, they do not have to be alive to cause adverse health effects.

The fungal cell wall is composed primarily of chitin fibrils embedded in a matrix of β-(1 →3)-D-glucans. Glucan exposure may exacerbate the infectious, allergic, and toxic reactions to fungi. Exposure to mycotoxins in indoor air has become of particular concern because of the potential for both acute and chronic health effects [5].

The physiological, biochemical and morphological properties of moulds and their common occurrence make them most frequent cause of biodeterioration of buildings and its various material and serious health hazards.

Dampness and consequently fungal contamination are a result of construction of material faults, often intensified poor ventilation and improper use of buildings.

The principal agents of indoor fungal contamination are anamorphic (asexual) fungi mostly belonging to the phyla *Ascomycota* and *Zygomycota*, commonly known as 'moulds'. Molds known to potentially produce mycotoxins and which have been isolated in infestations causing adverse health effects include certain species of *Acremonium, Alternaria, Aspergillus, Chaetomium, Cladosporium, Fusarium, Paecilomyces, Penicillium, Stachybotrys,* and *Trichoderma*.

2. Case study - the restorers of mural paintings

Conservation of ancient buildings is a major issue for modern societies, both from economical and cultural viewpoints. Information about the ancient built heritage is vital to plan adequate remedial measures.

Monuments and buildings of historic and architectural interest works as spatial environmental ecosystems and provide ecological niches and pockets of microclimates in their built environment for the development of building pathology and must be understood as a whole.

The composition of fungal species indoors tends to reflect that of the outdoors. Some fungal species, most notably A*spergillus* and *Penicillium*, are often found to account for 80% of indoor spores.

The most common building health problems in monuments relates to dampness and condensation resulting in mould growth and a range of other fungal pests, aggravating respiratory problems and allergies.

Moulds and fungal spores could occur in hidden cavities and underneath the interior wall surfaces or in cavity walls in historical buildings.

Allergy in the workplace environment is a growing concern to employers and it is a complex issue, which requires a multidisciplinary integrated approach. Exposure to indoor allergens is a risk factor for the development of allergic reactions and the incidence of the problem is increasing at an alarming rate. Safety and health at work is a set of activities institutionalized aimed to ensuring the best conditions in the unfolding working process, protection of life, physical and mental health workers and other persons participating at work [6].

The legislation still in force occupational disease is defined as disease that occurs as a result of exercise a trade or profession, caused by harmful physical agents, chemical or biological characteristics of the workplace, as well as different strain organs or body systems in the work.

In this paper we present our initial work. It was prepared a questionnaire about microfungi addressed to mural paintings restorers aimed to identify symptoms caused by moulds which may be presents indoor, including monuments decorated with murals.

One of the question was: Which of the following health issues affected you during a continue period of work: (1) muscle and/or joint pain, (2) fatigue/weakness, (3) neurocognitive dysfunction, (4) sinusitis, (5) headache,

(6) gastrointestinal problems, (7) shortness of breath, (8) anxiety/depression/ irritability, (9) vision problems, (10) chest tightness, (11) insomnia, (12) dizziness, (13) numbness/tingling, (14) laryngitis, (15) nausea, (16) skin rashes, (17) tremors, (18) heart palpitations.

The other question was about signs and symptoms of allergic reactions:

1. Nose: itching, soreness, blocked, running, sneezing;
2. Eyes: dryness, itching, redness, soreness, weeping/tearing;
3. Chest: discomfort, tightness, wheezing, breathlessness and cough;
4. Skin: itching, redness, blistering, scaling, rash.

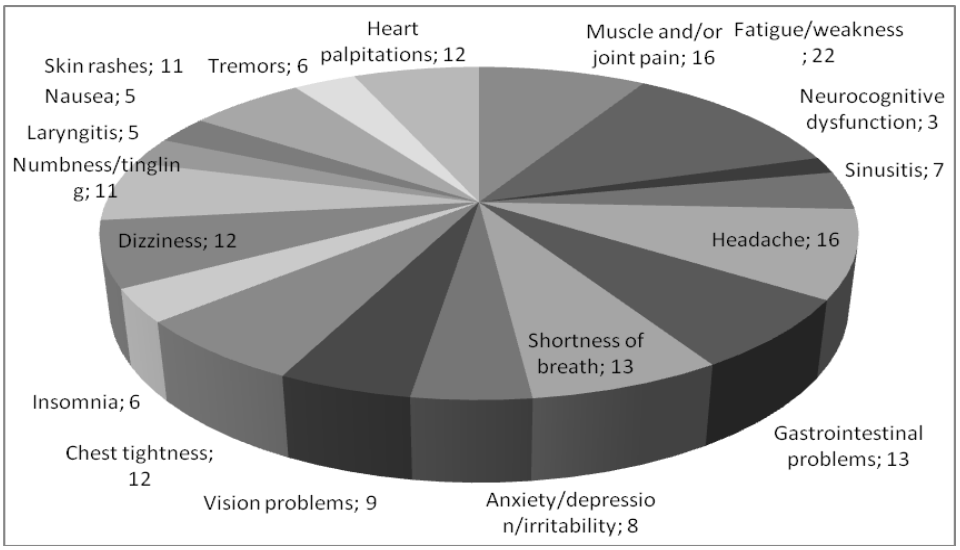

Figure 1. Frequent complains.

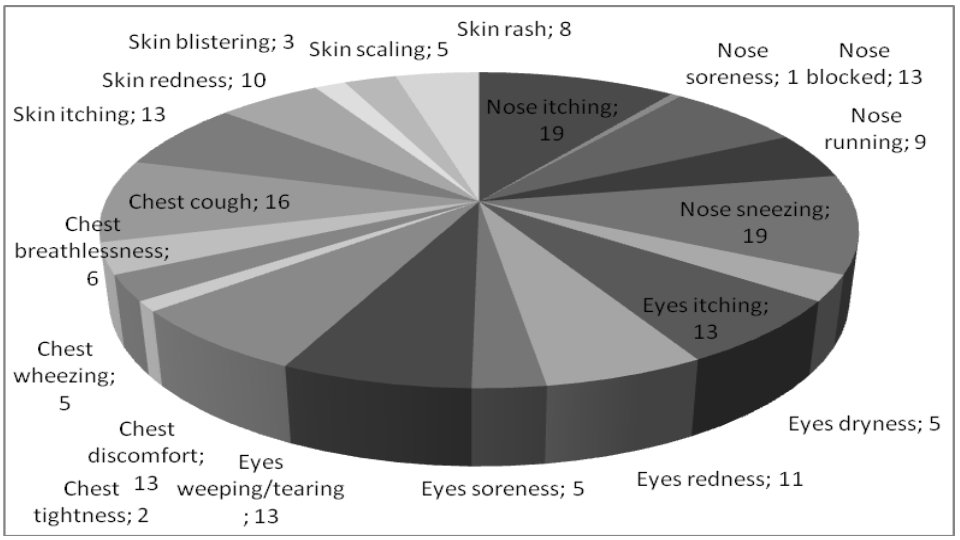

Figure 2. The occurence of allergy signs.

3. Results and discussion

The questionnaire was completed only by 25 people, 16 were restorers of mural paintings, the others were conservators or biologists working in museums. The results are presented in Figures 1 and 2.

The Government Decision 1092/16.08.2006 is to prevent and protect workers against risks to their safety and health, which results or may result from the exposure to biological agents during work. According to GD 1092/2006 biological agents are micro-organisms, including genetically modified, cell cultures that are likely to cause infection, allergy or toxicity.

We have found out that there is a lack of knowledge on biological expertise and although some restorers have allergies they do not correlate with causes. Although there is evidence that damp indoor environment and, in consequence, the growth of filamentous fungi, are strongly connected with symptoms and diseases of the human respiratory tract. The relationship between the amount of inhaled fungal particles and induction of respiratory problems, is however, still unclear and controversial. Biological aerosols can penetrate into the human body through the nose, mouth and conjunctiva epithelium, bronchi and alveoli, as well as the epidermis (mainly on hands). Our results show that itching and sneezing are reported by most of the respondents, while fatigue/weakness is the most frequent complain.

The most aggressive attack of mould on fresco in Romania is the old Orthodox Church 'Buna Vestire' from Jina, Sibiu, having a mural painting original from 1801, the deterioration degree being around 75% from the painted surface. Eight moulds were isolated from the church: four from air inside and four from the frescoes samples, three species belong to *Penicillium* genera [7].

About the fungi that attack mural paintings from our country, Boldura has made numerous researches at all the monasteries from the north of Moldavia, where microscopic species were identified as *Acremonium roseum, Penicillium chrysogenum, Phoma pigmentevora* and *Alternaria alternate* [8]. If the pigment used in murals contains much carbon in its composition the respective portions are strongly attacked.

Mycotoxins are secondary metabolites that are derived from a few precursors formed during metabolism. Mycotoxins are not volatile. It is commonly believed that not all mycotoxins have been identified yet, since more new ones are being discovered as analytic methods are developed.

Mycotoxins have four basic kinds of toxicity: acute, chronic, mutagenic and teratogenic. The most commonly described effect of acute mycotoxin poisoning is the deterioration of liver or kidney function, which in extreme cases may lead to death. However, some mycotoxins act primarily by interfering with protein synthesis, and produce effects ranging from skin sensitivity or necrosis to extreme immunodeficiency. Others are neurotoxins, which in low doses may cause sustained trembling in animals, but at only slightly higher doses cause brain damage or death. The prime chronic effect of many mycotoxins is the

induction of cancer, especially of the liver. Some toxins affect DNA replication, and hence can produce mutagenic or teratogenic effects.

The primary routes of indoor environmental exposure at mycotoxins are most likely dermal and inhalational. Significant exposures probably occur when fungal spores, fungal mycelia, and contaminated growth substrate are aerosolized, especially as a result of handling of moldy material. This is why restorers should wear masks, gloves and protective equipment.

During exponential growth, many fungi release low molecular weight, volatile organic compounds (VOCs) as products of secondary metabolism. These compounds comprise a great diversity of chemical structure, including ketones, aldehydes and alcohols as well as moderately to highly modified aromatics and aliphatics. Limited evidence suggests that exposure to low concentrations of VOCs may induce respiratory irritation independent of exposure to allergenic particulate [9]. Volatile organic compounds may also arise through indirect metabolic effects.

Microbial volatile organic compounds reportedly can diffuse through construction and may be useful in locating concealed mould growth. Mould and decay problems in buildings are used by moisture damage: water leakage, convection of damp air and moisture condensation, rising damp from the ground and moisture accumulation in the structure.

The most common species found on mural painting and in the air are *Alternaria, Cladosporium, Aspergillus* and *Penicillium.*

According to http://mycota-crcc.mnhn.fr *Alternaria Alternata* is toxic and pathogenic. The conidiophores are allergen and can cause serious allergic respiratory diseases (asthma, chronic sinusitis, and rhinitis). It can also cause coetaneous mycoses of the skin and of the scalp. Its mycotoxins are responsible for leukopenia.

Cladosporium herbarum is implicated in cases of allergies, rhinitis and asthma. It is above all toxic by releasing epicladosporic acid.

Aspergillus niger is toxic and pathogenic, it causes otomycosis (lung mycosis) in man and birds. It can cause the aspergillosis of the external auditory canal in patients with a prior lesion or an anatomitic malformation of the auditory canal.

Penicillium frequentans is implicated in cases of extrinsic allergies in some workers.

However, all molds under proper conditions are capable of eliciting a negative health response in humans through other methods such as inflammation, allergy or infection.

Although not attributed exclusively to molds, *Sick Building Syndrome (SBS)* is a term "used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building" because all other probable causes have been ruled out. Symptoms include headaches; eye, nose, and throat irritation; dry cough; dry or itchy skin; dizziness and nausea; difficulty in concentrating; fatigue; and sensitivity to odours. Sick building syndrome is attributed to inadequate ventilation, chemical

contaminants from indoor and outdoor sources, and biological contaminants such as molds, bacteria, pollens, and viruses [10].

Infectious disease occurs when a pathogenic microbe enters a susceptible host, proliferates and induces a body response.

Ancillary products of mould growth such as volatile organic metabolites (e.g. alcohols) or volatile breakdown products from extracellular processes (e.g. formaldehyde) may contribute to symptoms of illness or discomfort independent of exposure to fungal biomass [9]. The diversity in clinical scope of building-related illnesses makes their diagnosis difficult.

While around 40% of the clinical expression of an allergic disorder can be accounted by genetic factors, for these to be manifest there is an absolute requirement for interactions with environmental factors. The most characteristic feature of the human allergic tissue response is the generation of IgE directed specifically against small amino-acid sequences found on common environmental allergens derived from indoor and outdoor sources. The most important of these include dust mites, domestic animals and fungi such as *Cladosporium, Alternaria,* and *Penicillium.* Allergens derived from fungi such as *Alternaria* are more important in driving allergic responses linked to asthma.

3.1. Allergic rhinitis and sinusitis - type I allergic syndromes

A link between respiratory exposure to fungal material and seasonal allergy was first proposed in 1873 by Blackley who demonstrated the provocation of allergic respiratory symptoms by exposure to *Penicillium* spores [9, p. 10]. Microbe molecules and products can stimulate histamine responses in exposed individuals. This type of response is called an allergy. Concern regarding human exposure to mould aerosols in indoor environments is mainly related to direct mucosal irritation and elicitation of an IgE-mediated hypersensitivity response that precipitates rhinitis and upper airways irritation, eye irritation and frequently sinusitis that characterize allergic syndromes [9, p. 10]. The symptoms of allergy are not manifested until sensitisation in which an individual incurs repeated exposures to the antagonistic agent.

3.2. Hypersensitivity syndromes

Extrinsic allergic alveolitis, or hypersensitivity pneumonitis (HP) is an acute inflammatory reaction of the lower airways upon exposure to an agent to which a sensitivity has developed from prior exposure. Hypersensitivity pneumonitis involves cell-mediated immunity (Type IV allergic response), in contrast to Type I allergic syndromes that are IgE-mediated, and thus may exist independently of the latter. Numerous environmental antigens have been implicated as elicitors of HP, including fungal aerosols. The majority of case literature on fungus-mediated HP involves occupational exposures where exposures to mould aerosol exceed background by several orders of magnitude.

3.3. Asthma

Asthma is a disease characterized by reversible airway obstruction triggered by any of a number of provocation agents, including allergens, cold and exercise stress, and relieved by the inhalation of aerosolised beta-adrenergic antagonists [9, p. 12]. Asthma symptoms include wheezing, usually accompanied by dyspnea (shortness of breath) and cough, often in an episodic pattern with intermittent or extended periods of remission.

4. Conclusions

Health and safety issues relating to proliferation of toxic moulds should be an important consideration for architects, developers, building owners, etc. The lack of maintenance, chronic neglect, and building defects leading to water ingress, condensation, and dampness in the building fabrics would lead to proliferation of toxic moulds and could cause complaints of sick buildings by occupants. The major sources of toxic mould occur in buildings on damp walls, in hidden cavities and voids particularly in warm, airtight buildings.

Fungi play an essential role in our global mycology and survival on plant and animal, but can also pose a significant health risk when they are permitted to grow in buildings. Fungal colonization of interior surface occurs when biodegradable materials are chronically damp or wet. We can say that moisture of the habitat is the most important factor the growth of fungi.

Insufficient exposure to the natural sunlight can also be a factor for mould growth. Careful inspection of signs, for example, severe salt efflorescence, moisture, mould stain, blistering of finishes, and timber decay would indicate symptoms of deterioration leading to health complaints. Moisture and inadequate ventilation are the keys to biodeterioration and proliferation of moulds and mould spores in air. Once infestation has started, it will continue to propagate, if the condition is favourable until eventually the material can no longer sustain the fungal loads.

Indoor air quality management and management of biodeterioration and health problems in buildings are complex issues requiring multi-disciplinary investigations. All molds under proper conditions and concentrations are capable of adversely affecting human health. Therefore, it is clear, that reduction and prevention of mold exposure is needed to decrease the risk of damage to human health. Small amounts of mold are always present in the air, the key to decreasing adverse health affects from mold exposure is to prevent the germination and growth of mold on indoor surfaces.

The research done among restorers shows that itching and sneezing are reported by most of the respondents, while fatigue/weakness is the frequent complain but there is lack of knowledge of biological expertise and although some restorers have allergies they do not correlate with causes. Furthermore, restorers are unaware of the seriousness of exposure to moulds and sometimes unwilling to cooperate with biologists.

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