Effects of fungal air pollution on human health

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ABSTRACT

The microclimate of a room has an impact on human well-being, physical and mental health, on work productivity and the preservation of good health. Several dozen species of bacteria can live in buildings and more than 400 species of fungi (mainly *Aspergillus, Cladosporium, Penicillium, Fusarium* genus). The presented results are studies from different health department suggesting the desirability of systematic microbiological testing, evaluation of fungal pathogens, and involving staff, patients, walls, floors, furniture units (hardware, underwear), and air. However the problem is a lack of unified Polish standards, the classes of microbiological indoor air and the lack of harmonization of existing rules for air sampling to assess air fungal pollution in the health care setting.

Key words: indoor air, fungi, buildings, human health

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INTRODUCTION

A microclimate of a room is *"a set of physical and chemical parameters, variable in time and space, affecting every living organism. The condition of human well-being, in terms of ability to work and regenerate and maintain proper health, is to ensure a proper comfortable microclimatee"*[cited from 1].

Microclimate parameters can be divided into two groups:

- hygrothermal conditions affecting the heat balance and thermal sensations associated with environmental effects on the human body;
- hygiene and health conditions, including indoor air quality, impact of partitions and furnishings, lighting, the color of the interiors, the noise level, the intensity of electrostatic and electromagnetic fields, etc. [2,3]

All components of the microclimate have an impact on human well-being, physical and mental dexterity, on work productivity and the preservation of good health. The microclimate also affects the body's thermal management [4,5].

In the literature [4,5], it is emphasized that every person has an innate ability to assess the microclimatic conditions, and therefore, more often subjective sensing of temperature (actual and wind chill factor temperature) is considered a measure of thermal comfort, dependent upon immunity, health status, age and habits. The most important parameters of the microclimate are interdependent and closely linked to the energy balance of the room or building [4,5].

An evaluation of hygrothermal conditions, according to Grzegorczyk [2] and Przydrożny [3], on premises intended for permanent human habitation is subordinated to the first criterion for thermal comfort - the body's state of satisfaction with the environment. This state by its very nature is a personal and subjective feeling, conditioned by many physiological and psychosomatic factors. It also results from the customs and habits of a given population and sometimes even wealth. These factors make it difficult to clarify recommendations for the required level of microclimate parameters and out of necessity force the use of a fairly broad range. Studies conducted on different populations of people define the "main" physical parameters of the air which affect the feeling of comfort in a room [2,3] which are: the air temperature in a room, the temperature of partitions, the speed of air movement in the occupied zone and the relative humidity [2,3].

Different types of premises (office, industrial, school, hospital, etc.) have different recommendations or standards describing the values of particular parameters. According to Pacholski [5] and Kania [6], all the currently applicable microclimate standards are solely based on physical parameters. Determining the optimal and acceptable values for those parameters is performed on the basis of study results of the comprehensive impact of all the parameters of the microclimate on the physiological functions of the human body. A distinction is made between standards describing the following conditions: optimal, acceptable and marginally acceptable [5,6].

Microclimate conditions that are regarded optimal are those which guarantee a maintained equilibrium of body heat balance. Any deviation from the optimal conditions results in feelings of disturbance, reduces the efficiency of physiological functions and an increase in the number of errors and accidents at work is observed [5,6].

Conditions determined to be acceptable are those which admittedly do not provide a human with thermal comfort, but do not cause physiological dysfunction and damage to health, and in which the thermoregulatory mechanisms of the body are active (excessive sweating, tachypnea, dilation of the blood vessels) [5,6].

Marginally acceptable standards describe the border values of microclimate parameters which, if exceeded, may cause severe disorders of body function and impairment of health status. [5,6].

In the opinion of Pacholski [5], the condition for normal functioning of the body as a whole is to maintain the thermal balance and body temperature within 36.5-37.5^{0}C. The author [5] emphasizes that the human body must continuously transfer heat to the environment, because the body's metabolic processes are a source of constant heat generation. He also notes that about 90% of the total energy contained in ingested food is converted into heat as a result of metabolic processes A consequence of excreting the body heat generated in the organism by metabolic processes is evaporation [5]. The human body posses some capacity for thermoregulation - at high temperatures, perspiration and blood flow in the skin increase (to facilitate the exchange of heat), at low temperatures - the opposite. When bad weather conditions exceed the possibilities of the body to adopt, there is a restriction of the manual and mental labor abilities, and resistance to other adverse environmental factors and pathogens decreases [5].

In the literature [4,7-11], it is emphasized that the temperature range in which a person feels well is very diverse and individually-dependent on the type of clothing worn, nutrition, the season, age and sex. The comfortable temperature for people who are seated, dressed normally, is usually considered to be 22°C in the winter and 22-24°C in the summer [2-5]. It is also stressed that the vertical distribution of temperature in living quarters is usually small, because they are not high. The recommended room temperature at 50% humidity with still air is in the case of mental labor: 21-23^{0}C, light manual labor: 18-19^{0}C, heavy manual labor: 17^{0}C , and very heavy manual labor: 16^{0}C [2-5].

Grandejan [4] and Pacholski [5] consider that, from a medical point of view, the problem of the humidity in the air is more important than the effect of relative humidity on well-being. If the room air temperature is within the comfortable limits, a person does not feel the changes in relative humidity within the range of 30-70% [2,3].

At low relative humidity - clothes, carpets and furniture dry up quickly, resulting in the creation and dispersion of dust. Low relative humidity also causes dryness of the mucous membranes, reducing the body's resistance to infection and the effects of allergenic factors. Plastic items can easily become charged with static electricity, and therefore attract and store dust from the air on its surface [2,3].

In the literature [2,3] it is noted that, for example, completely saturated outdoor air (with a relative humidity of 100%) at a temperature of 5° C heated to a temperature of 22° C will have a relative humidity of 23%, and at an initial temperature of -12° C heated to a temperature of 22° C, just 8%. Therefore, there is a need for humidification of indoor air in the winter. It is worth mentioning that while in living quarters, people, plants and kitchens are an important source of moisture, in public buildings, especially in large office spaces, air conditioning is required [2,3].

The circulation of air indoors is achieved by a difference in air pressure caused by natural forces or an electric fan [2,3]. In the first case, it is natural ventilation and in the second, mechanical [2,3].

Grzegorczyk [2] and Przydrożny [3] note the phenomenon of *infiltration* - consisting of an automatic inflow of air through leaks in doors and windows and through pores in the structure of building partitions, *exfiltration* - the reverse phenomenon, namely the outflow of air from inside the house and *ventilation* - by using the pressure difference on both sides of exterior walls, one can increase the intensity of air circulation by opening windows or other openings intended and implemented for this purpose [2,3].

Automatic air circulation can be intensefied through natural ventilation, by furnishing the rooms (of a building) with vertical exhaust ducts where air flow is caused by a natural draft [2,3]. This type of ventilation can work effectively if an influx of air into the room is made possible [2,3]

Structured air circulation occurs through specifically made for this purpose ventilation openings furnished with devices for regulating air flow, which is generally only used in industrial buildings with very large heat gains [2,3].

Natural ventilation is most intensive when there are large differences in temperature between the room and its surroundings, with simultaneous strong winds, which usually occur during the cold season (autumn, winter and spring) [2,3].

Mechanical ventilation, based on the appropriate design of ventilation or air conditioning, is an integral part of a building's design [1,2,3].

Kania [6] stresses that during the cold seasons, air currents, often with high speeds and low temperatures (through open windows, doors), reach the human body and cause discomfort and sometimes even colds. Therefore, recommendations are formulated to reduce the velocity of air flow, especially at the level of the employee's head, and to reduce the speed of air movement through various methods involving directing air streams up or dividing them into smaller streams dispersing concentrically [6].

Air microbiology

In the opinion of Krzysztofik [9], the air in residential houses and industrial spaces that are properly utilized and kept clean is not much different from clean outside air.

In the literature [12-26], it is emphasized that all construction buildings create excellent conditions for the settlement, growth and reproduction of numerous and varied organisms.

It is estimated that several dozen species of bacteria can live in buildings (mainly Gram negatives), more than 400 species of fungi (mainly *Aspergillus, Cladosporium, Penicillium, Fusarium* genus), several species of fungi causing decay processes of wood and wood-based materials, many species of algae, bryophytes , lichens, plant seeds, including decorative (e.g., *Ficus benjamina, abutilon*), and over 30 species of mites (mainly in house dust), over 300 species of insects (posing parasitological and sanitation threats and destroying the structural wood of houses), several species of rodents, several species of birds (living on the roofs and external walls of buildings) and several species of bats [13-26].

In air-conditioned buildings and rooms with carpeting, fungi find favorable conditions for development (e.g. sufficient amounts of food in the form of food crumbs, shed skin, hair, fur, secretions of various animals, plants, flowers, bits of wood, cloth, dust mite and insect feces, as well as the appropriate humidity of above 20% and a temperature of 5-30°C) [15,26-29]. Fungi developpment can cause the destruction of buildings, their internal and external finishes as well as the materials used for construction [26-29].

At this point, it is worth noting that atmospheric air unfortunately has limited selfcleaning capacity and is a major component of the environment. Therefore, the problem of air contamination is of particular importance in the contemporary world, and the bacterial and viral particles which occur in the atmospheric air can penetrate into a building from the outside [28] and cause aerogenous (airborne) infections [30].

Sources of air pollution can be divided into natural or artificial (anthropogenic) [30]. Air pollution can be divided into:

- *dust* (particulate solids dispersed into the air, with a particularly high concentration of particles smaller than 5 microns, which adversely affect the functioning of the respiratory system in humans as well as animals and cause the development of pneumoconiosis)
- *gas* (sulfur dioxide, nitrogen dioxide, carbon dioxide)
- *biological* (i.e. bioaerosol - viruses, bacteria, fungi, mites, and non-living particles of biological origin, as well as plant cells, pet dander, and plant pollen) [31,32,33].

Yang et al. [cited in 34] claim that on average, people spend 87% of their time in closed buildings and about 6% in means of transportation, therefore potential sources of pollutants and their concentrations in indoor air have become an important factor in the personal exposure of most people. In the case of children and the elderly, this amount of time is even longer.

According to the World Health Organization, more than three billion people suffer from diseases caused by indoor air pollution [cited in 34].

The following indoor air pollutants are considered primary: bioaerosols, which are complex particles consisting of diverse biological materials (viruses, protozoa, bacterial cells, cell fragments, fragments of mycelium and spores of fungi), products of microbial metabolism (endotoxins, enterotoxins, enzymes and mycotoxins) as well as pollen, plant remains, animal dander and particles derived from the exfoliation of the skin in humans and animals, and constitute about 5-34% of indoor air pollution [cited in 34]. Bioaerosol molecules tend to have a diameter of 0.3-100 μm. Individual bacterial cells - size 0.5-2.0 μm, e.g., *Bacillus, Pseudomonas, Xanthomonas* or *Arthrobacter*. Many fungal spores are characterized by sizes larger than 2.5-3.0 μm, such as *Aspergillus fumigatus* (3.5-5.0 um), *Aspergillus niger* (3.0-4.5 μm), *Penicillium brevicompactum* (7 - 17 μm), *Cladosporium macrocarpum* (5-8 μm), *Epicoccum nigrum* (15.0-25 μm), or *Trichoderma harizanum* (2.8-3.2 μm) [34].

In the literature [citing the 34], it is emphasized that in air-conditioned buildings and rooms with carpeting, fungi find favorable conditions for development, e.g. sufficient amounts of food in the form of food crumbs, shed skin, hair, fur, secretions of various animals, plants, flowers, bits of wood, cloth, dust mite and insect feces, as well as the appropriate humidity of above 20% and a temperature of 5-30° C [34]. Fungi development can cause the destruction of buildings, their internal and external finishes as well as the materials used for construction [34].

Potential internal sources of pollution also include such household activities as: cooking, smoking, vacuum cleaning and sweeping [34].

According to Jo and Kang [34], food, potted plants, dust, carpets, wooden materials and furniture can release fungi spores such as: *Alternaria, Aspergillus, Botrytis, Cladosporium, Pencillium* and *Scopulariopsis,* which are constituents of bioaerosols.

The solidification of fungi in the air may also be increased by the presence of plants at home, e.g. in the soil of potted plants there are often spores of *Aspergillus* [34].

According to Brooks as well as Kędzierska et al. [citing the 34], the main source of formaldehyde, VOC(*volatile organic compounds*), and VOCs (*semivolatile organic compounds*) are furniture, wallpaper, carpeting and the detergents used to clean them.

Photographic equipment, paper, photocopiers and fax machines emit ozone, acetic acid, ammonia, and nitrogen dioxide [citing the 34].

Building refurbishments [citing the 34] intensify concentrations of VOC and VOCs as well as fungal spores of the genus *Penicillium* and *Aspergillus.*

According to Szosta-Kot [34], such fungi as *Cladosporium, Alternaria, Trichoderma, Penicillium* and *Aspergillus* grow on the surface of PVC.

Glass fibers from old, leaky insulation are broken down and released into rooms by the mold vegetating on them, and surfaces insulated with cotton wool foster the development of fungi of the *Alternaria* genus, and cement surfaces - of the *Cladosporium* genus [27].

Stoiska [citing the 34] reports that damp walls, ceilings and floors are the main cause of intensive development of different species of fungi on the surface of wallpaper, and include fungi of the *Acremonium, Alternaria, Aspergillus, Aureobasidium, Chaetomium, Cladosporium, Fusarium, Paecilomyces, Penicillium, Stachybotrys, Trichoderma, Trichurus,* and *Ulocladium* genus. It has been shown that with a relative humidity of 96-98%, the time needed for complete development of fungi on wallpaper is from 8 to 10 days [34].

According to Stoiska [cited in34], finished paper products, available in every room, easily yield to microbiological corrosion and the following fungi take part in their degradation process: *Aspergillus, Penicillium* and *Mucor* genus, which easily use the components of paper and then activate the *Chaetomium, Stachybotrys* and *Alternaria* strains, which hydrolyze the resistant cellulose fibers. The author also points out that yeast-like fungi such as *Aureobasidium pullulans, Geotrichum candidum, Trichosporum cutaneum, Candida melinii,, Lipomyces starkey* also have similar properties [34].

Szostak-Kot [cited in34] points out that in the room microenvironment, an important role is played by fungi that degrade: cellulose (*Chaetomium, Myrothecium, Memmoniella, Stachybotrys, Curvularia, Trichocladium, Botryodiplodia, Acrothecium, Cephalosporium, Alternaria, Stemphylium, Trichoderma, Penicillium, Aspergillus*), cotton (*Chaetomium, Myrothecium, Sordaria*), linen (*Aspergillus, Penicillium, Chaetomium, Trichoderma*) , wool (*Chrysoporum, Aspergillus, Penicillium*), silk (*Chaetomium, Cladosporium, Penicillium, Rhizopus*) and synthetic fibers (*Aspergillus, Alternaria, Culvularia, Fusarium, Aureobasidium, Stemphylium, Paecilomyces, Penicillium, Chaetomium, Trichoderma, Stachybotrys*). From fabrics generally found in rooms, various authors have isolated dermatophytes such as *Microsporum gypseum* [34].

According to Zysk [cited in34], up to 20 species of bacteria and fungi (dermatophytes, yeast and molds) can be isolated from leather shoes. The microflora isolated from painting materials and coatings is very complex. Polymer emulsions can be colonized by fungi such as *Alternaria, Aspergillus, Candida, Cladosporium, Fusarium, Geotrichum, Penicillium, Rhodotorula, Saccharomyces, Torulopsis* [cited in34].

From water-based paints, growths of *Aspergillus, Cephalosporium, Fusarium, Geotrichum, Penicillium,* as well as *Candida, Rhodotorula* and *Saccharomyces* have been obtained [34].

Zysk [cited in34] believes that the state of the air microenvironment is also affected by construction stones along with the microflora inhabiting them. The author considers them to be very complex ecosystems that develop in different ways, depending on environmental conditions and their physicochemical properties. Stone biocenosis includes photolitoautotrophic organisms (cyanobacteria, algae, mosses, higher plants), chemolitoautotrophic (e.g., nitrifying bacteria, sulfur-oxidizing bacteria) and chemoorganic microbes (bacteria, fungi, including for example *Aspergillus, Cladosporium, Curvularia, Penicllium, Trichoderma, Alternaria)*.

According to Cwalina [cited in34], the following fungi are involved in the corrosion processes of metals and alloys: *Alternaria, Aspergillus, Cladosporium, Fusarium, Penicillium,* and *Trichoderma.*

At this point it is worth noting that, in accordance with the requirements of the European Union, the number of microorganisms in 1m^3 of indoor air should not exceed 500 cells [34].

On the basis of the available literature and data on indoor air quality in Europe, Górny and Dutkiewicz [cited in34] proposed more housing indicators for fungi, bacteria and bacterial endotoxins: 5 x10^3 CFU/m^3, 5 x10^3 CFU (m^3 and 5 ng)/m^3, respectively.

The presence of pathogenic fungi has been deemed unacceptable in all concentrations [34].

In the opinion of Wittczak [cited in34], construction buildings generate a unique microclimate (ecological niches), whose elements, which affect health, are the inhabitants themselves, the furnishings, equipment, plants and building components.

The characteristics of buildings that determine indoor air quality also include: the land on which the building stands, the external conditions around it, the age of the building, and "tight building" syndrome [34].

In its formation, the factors dependent on the number of people in the room, such as: noise, stress, tobacco smoke, odors (such as cosmetics, detergents used for cleaning clothes), infections of human communities (Rubella, Legionella, influenza, chicken pox) and the type of construction material used, method of preservation, type of ventilation systems, furnishings, as well as the type of heating and/or cooling are taken into account [34].

Effects of air on health

In 1982, the term *"Sick Building Syndrome"* (SBS) was introduced, which denotes a variety of ailments that arise as a result of prolonged time spent inside buildings, whose construction and furnishing may have harmful effects on human health [34].

In 1987, the WHO established a list of symptoms and diseases which may arise in "sick buildings" according to the prevalence of such features as: irritation or damage to the mucous membranes (eyes, nose, throat), skin dryness and irritation, neurotoxic symptoms (headaches, fatigue, irritability, impaired concentration), bronchial asthma and asthma-like symptoms (chest tightness, dyspnea), air-conditioner fever and damage to lung tissue [34].

The WHO also divided the nonspecific symptoms associated with being inside buildings into: neurotoxic disorders (headaches, fatigue, irritability, difficulty concentrating, dizziness), irritation of the mucous membranes of the conjunctiva and the nasopharyngeal cavity, asthma-like symptoms (chest tightness, wheezing), skin irritation, nose bleeds and bad smells [34].

In subsequent years, the term *SBS* was changed to *BRI "building - related illness"* - "a condition causally related to spending time inside a building" and within it two groups of disorders have been distinguished: specific (conditions of allergic, immune and infectious origin) and non-specific (of heterogeneous symptoms - irritation of the skin and the mucous membranes, headaches, fatigue, impaired concentration) [34].

Some researchers, such as Brooks [cited in34], further extended the scope of diseases characterized by BRI by: infections (Legionella, influenza, Rubella, recurrent respiratory infections, chronic inflammation of the sinuses), allergic diseases (mainly bronchial asthma, perennial allergic rhinitis and conjunctivitis), air-conditioner fever, allergic alveolitis, dryness and redness of the skin, especially the face, itching, hives, worsening of chronic skin diseases (e.g. atopic eczema, contact dermatitis), eye irritation and chronic conjunctivitis, drying of the conjunctiva, recurrent chronic otitis media and externa, symptoms of neurotoxicity, asthma-like and flu-like symptoms, CFS - Chronic Fatigue Syndrome, and neoplasms [34].

Air pollution in selected health care units

Studies performed by Łukaszuk et al. [35] at the oncological departments in Białystok and Lublin showed that air and walls at the department in Lublin had a higher number of fungal colonies compared to Białystok. The air in the department of oncology in Lublin, was characterized by a greater diversity of mycological flora. It was found that nearly twice the number of fungal colonies were found in the air outside the hospital building in Lublin, compared to Bialystok. From air samples collected from rooms of the oncology department in Bialystok a total of 1723 fungal colonies were recovered. Most pathogens were cultured from air samples of the bathroom (1034) and patient's rooms (235). There were no fungi isolated from the room were cytostatics are administered. From the air samples collected from rooms of the oncology department in Lublin a total of 5234 fungal colonies were isolated [35]. Most pathogens grew from samples of air from the bathroom (1823), corridors (1470), the health center (79), and treatment room (98). The walls in the rooms of the Bialystok department grew of total of 67 fungal colonies.. Most colonies were isolated from the walls of the corridor (24), ward (13) and in the procedure room (12). In the Lublin department 123 colonies in total were isolated from the walls, most from the treatment room (30), dirty room (14) and cytostatic room (10). Only 3 colonies from patient rooms and 8 from bathrooms were detected. From the walls of the rooms in the oncology department in Bialystok five different fungal species , and from the walls in Lublin - seven species were isolated [35].

In other studies Łukaszuk et al. [36] isolated a total of 1160 fungal colonies form air samples at the neonatal departments in Białystok and Lublin. In all, 760 colonies of fungi were isolated from patient rooms. The lowest number of fungal colonies was cultured from the air of nursing rooms (60 colonies). A total of 1380 fungal colonies were isolated from air samples of the neonatal department in Lublin. The highest number of fungi (300 colonies) were found in the physician room, corridor and newborn rooms. A total of 600 fungal colonies were collected from the air of the neonatal rooms. No significant differences between CFU of fungi in both departments were found. Outdoors, there were twice as many fungi collected in Lublin compared to Białystok [36]. One hundred and sixteen fungal colonies were isolated from the walls of the department in Białystok. Furthermore, the highest number of airborne fungi were isolated from the walls of the corridor, and the lowest number of fungi were recovered from newborn and nursing rooms. In contrast, in similar rooms in Lublin 152 fungal colonies were detected . Twenty-five fungal colonies were isolated from the walls of the neonatal department in Białystok and 37 from the department walls in Lublin. Five fungal species were isolated from the newborn rooms in Białystok, and seven in Lublin. No significant differences were recorded between the occurrence of fungal pathogens (number and species) although the number of fungal colonies in the air of patients rooms exceeded the standards recommended in the literature [36].

Krajewska et al. [37] evaluated fungal contamination in the obstetrics-gynecology departments. The total fungal count varied from 0 to 506 colonies forming units (CFU). In the patient rooms, no -9(?) mean count was 560 CFU/ m^3 of air, at the room no-1 (330 CFU/ m^3), and at the corridor (360 CFU/ m^3). No fungi were isolated from the air of the septic room and medical surgery operation theater. The highest concentration of *Aspergillus* species and *Penicillium* species were detected outside the building. A total of 160 fungal colonies was isolated from the hospital rooms. The following fungal pathogens isolated from air were: *Candida albicans*, non-*Candida albicans*, *Penicillium* species and *Cladosporium* species. The most common fungal pathogen was *Candida albicans* (82.5%) [37]. No significant correlation (r=0.09, p=0.73), between CFU of fungi in air and temperature and humidity was noted. This study showed a similar distribution of the molds and yeasts species. The obtained results showed that the number of colonies of fungi varied depending on the hospital rooms [37].

Makarowski et al. [38] collected air samples for mycological examination at radiological laboratories at three points in Bialystok, the studios, corridors and outside the building. Between March and December (during spring, summer, autumn and winter) air sampling was performed in the internal atmosphere of the radiological laboratories. The tests were performed in the morning, before start of work and the afternoon, after work ending. Monitoring of airborne fungi was done using a SAS SUPER 100 (pbi-international, Italy). Air samplings were carried out at the USG rooms, X-ray rooms and dental radiology laboratories. Results showed that fungal counts in all studied radiology laboratories were the highest during summer. The CFU values were higher during winter and autumn in the afternoon, and the vice versa during spring. In the summer, time of the day had no effect on CFU counts. In the case of measurements made in the morning, spring humidity was a factor stimulating the growth of fungi, and in autumn, the situation was reversed. During winter, the most dominant pathogen was *Candida albicans* whereas in other periods it was *Aspergillus* species. In contrast, during spring the number of fungal colonies was higher compared to other seasons. The following fungal pathogens dominated: *Penicillium* species, *Candida albicans* and non-*Candida albicans*, which accounted for more than 90% of all colonies. In the morning, more *Penicillium* species were isolated, while the afternoon *Candida albicans* and non-*Candida albicans.* Distribution of airborne fungi was different during summer. The structure of fungi in the autumn appears to be similar to that of the spring period, except that two fungal species of the genera *Acremonium* and *Aspergillus* had a slightly larger share. The authors concluded that the main pathogen isolated from indoor air of the X-ray laboratories was *Candida albicans*, and from the outdoor environment *Aspergillus* species. They showed that the temperature and humidity in the studied areas provided favorable conditions for fungal growth [38].

In another report, Makarowski et al. [30] assessed the incidence of pathogenic fungi in the air of the radiological rooms. During autumn, the highest CFU values were found in the afternoon. During spring number of fungi was greater and differentiated, both between rooms and times. In summer the population structure of fungi was more varied, and *Candida albicans* was the dominating species. In autumn, *Acremonium* species and *Aspergillus* species occurred more but otherwise it was similar to the spring season.. In winter in all tested buildings, *Candida albicans* was the dominating strain [39].

Rolka et al. [40] collected air samples from doctors washrooms and washing tools, central sterilization, medical surgery operation theatres, corridors, and the entrance to the hospital. The total fungal count varied from 0 to 110 CFU/ m^3 at11 medical surgery operation theatres before start of the surgery programme in the morning. And in the afternoon after surgeries the total fungal count varied from 0 to 30 CFU/m^3. Only in one operating room no fungi were isolated in both the morning and afternoon. The highest number of fungi were collected from the atmosphere from the corridor at the entrance into the operation theatre (140 CFU/m^3) [40]. A lower level of CFU were noted before and after the surgery. The most common species isolated from outside the building were *Candida albicans*, non-*Candida albicans*, *Mucor* species, *Penicillium* species and *Aspergillus* species. In the morning, the highest temperature was recorded in the central sterilization room (23.5 ^{0}C),operating room and the washroom of doctors (21.5 ^{0}C). The highest humidity was found in the operating rooms and the corridor of the operation theatre in the afternoon. No significant correlation between CFU and temperature and humidity was found. The authors noted a tendency of decreasing numbers of fungal pathogens in the operating rooms after the surgical programme [40].

Krajewska-Kulak et al. [41] evaluated air samples from rooms, corridors, and outside the Department of Pediatric Rehabilitation. Mycological contamination of the air was evaluated using AIR IDEAL – BioMerieux. During the study, swabs were taken from the surface of the walls, swimming pool, whirlpool bathtubs, mats and benches [41]. The highest concentrations of fungal colonies were isolated from the air of treatment room (560 CFU/m^3), gym (360 CFU/m^3) and corridor (34 CFU/m^3). The lowest levels of airborne fungi were detected in the paraffin room and cloakroom of patients. Mean number of fungi colonies isolated from air was 170.6 ±177.3 CFU/m^3. The highest temperature was detected at the patients cloakroom (23.8 ^{0}C), and the lowest at the corridor (21.4 ^{0}C). The highest humidity was found in the corridor (31.6%) and the lowest in the gym (20.1%). A significant correlation between humidity and number of CFU of fungi in air was found. The largest numbers of fungal colonies were isolated from samples collected from the surface exercise mats, benches, the walls in the office of physical therapy and the walls of the bath. The organisms most commonly isolated from the air samples were *Penicillium* species. The most commonly isolated species from the tested surfaces was *Candida albicans*. They concluded that temperature and humidity in the investigated rooms were favorable factors for fungal growth [41].

In another study, Krajewska-Kułak et al. [42], assessed the incidence of pathogenic fungi in the air of the Department of Long-Term care. Air was sampled at the entrance to the building, corridor and selected rooms. The highest number of fungi was isolated from (mean 235 ± 24.8 CFU/m^3 of air), at the corridor on the ground floor of (535 CFU/m^3), in the bathroom (320 CFU/m^3), and dirty room (120 CFU/m^3). The highest temperature was noted in on ground floor (24.2 ± 0.1), and humidity at patient rooms on the first floor (42.1 ± 1.98). Outside the building 200 CFU/m^3 were isolated. From the air in the patient rooms the most oftenisolated fungi were *Penicillium* sp., Cladosporium *herbarum* and sterile mycelia. [42]. At the corridors were isolated *Mycelia sterilia* and *Penicillium* sp., from the walls of patient rooms *Stachybotrys* sp., sterile mycelia, *Penicillium* sp., and *Mucor,* and outside the building *Penicillium* sp., and *Cladosporium herbarum.* Only in rooms with the highest number of fungi patients reported the following complaints: skin cracks of hands, ardor, hands blushing, itching of skin hands, nose dryness, cough, limbs to tingle, edema of eyelids, eyes itching and necessity of rest during the bath or wearing. Complaints were reported during the exposition to dust and cold. The patients from rooms with the highest values of fungi reported more complaints compared to patients from other rooms [42].

Makarowski et al [43] evaluated the exposition of radiology workers for hazardous factors in the environmental air of the workplace. Data were collected by two valided questionnaires: Indoor Environmental Quality - Medical Screening Questionnaire and Indoor Air Quality Health and Safety Guide. In responders opinion on quality of air effects mainly air condition (95.1%), temperature (81.2%), smells (65.3%) and caustic substances (63.4%). In the air at workplace respondents specified the following hazardous factors: microorganisms (63.4%), tobacco smoke (33.7%), paints (23.8%) and asbestos (15.8%). At their homes, responders detected presence of humidifiers (21.8%), stains on the walls (11.9%), mould (9.9%), stains on the ceiling (8.9%), and traces of water (7.9%). Almost 83.1% of the respondents reported fatigue, episodes of nervo-usness (51.5%), troubles with concentration/ memory, tingling sensation of legs (37.6%) vertigo and drowsiness (29.7%). In the opinion of respondents the environment had negative effect on their health. Responders reported the presence of many characteristic symptoms for SBS (*sick buildings syndrome*) and BRI (*building - related illness)*.[43].

The results presented suggest the desirability of systematic microbiological testing, evaluation of fungal pathogens, and involving staff, patients, walls, floors, furniture units (hardware, underwear), and air. The problem in evaluating this work, however, is a lack of unified Polish standards, and the lack of harmonization of existing rules for air sampling to assess fungal are pollution in the health care setting.

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