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Mycological monitoring of different workplaces in Lithuania

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Mycological monitoring of some workplaces (a paper mill, a fur mill, a shoe factory, a secondary school, a kindergarten, a hospital and two cafes) in Lithuania was carried out over a period of 5 years between 1993 and 1997. The aim of the study was to investigate the concentrations and species composition of airborne fungi in the different premises as one of the most important criteria for evaluating their sanitary state. A "Krotov 818" slit-to-agar single-stage impactor (cut-off 0.5 μm) was used for sampling of total propagules, the volume of the samples being 0.05 m^3 at a flow rate of 0.025 m^3/min. It was found that there were considerable differences in the numbers of airborne fungal propagules between the different workplaces investigated as well as between different areas of the same workplace. The data showed that some fungal species were cosmopolitan. People working for a long time in places involving production processes with the same sort of natural material are at risk of catching a respiratory, allergic or sometimes even mycotic disease as a result of certain fungal species adapting themselves to the environment. Distinctive species were isolated from the fur mill: *Aspergillus* genus fungi were abundant in those shops with constant high temperature and humidity; *Chrysosporium*, *Arthroderma*, *Microsporum*, *Trichophyton* and *Candida* species genus were found in the fur cutting–assembling and sewing shops.

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Bioaerosols, which are mainly propagules of fungi, are almost always present in the indoor air of industrial premises. The concentrations and origin of these pollutants depend on different factors, such as the types of activities and processes carried out in the premises and the technical status of the building. These factors can predetermine microclimatic conditions favorable for the development of fungi. Materials used in building construction, i.e. cellulose-based materials, plastics, coatings and paints, as well as raw materials, serve as nutrient substrata for fungal growth (Pasanen et al. 1992, Lugauskas 1997). Furthermore, processing and handling of plants, wood and other organic materials is usually associated with the generation of fungal propagules. Persistent exposure to propagules of *Aspergillus*, *Penicillium* and some other genera is known to cause respiratory and allergic disorders in humans, such as allergic asthma, allergic rhinitis and allergic alveolitis. When propagules of opportunistic pathogens penetrate into the lungs, they increase the risk of bronchopulmonary aspergilloses and aspergilloma in the immunocompromised subjects. It has been found that considerable concentrations of mycotoxins are located inside, as well as on the surface of the spores of some toxigenic fungi, and therefore a risk of chronic inhalative mycoses can occur in heavily polluted premises (Lacey & Crook 1988, Frisvad & Gravesen 1994, Lacey & Dutkiewicz 1994, Blanco et al. 1997, Singh & Singh 1999). It must be stated that comprehensive investigations of the mycological state of different industrial environments have not been carried out until now in Lithuania. Furthermore, there are no available data on the concentrations and species composition of fungi occurring in industrial environments such as fur mills, shoe factories, etc.

The aim of this study was to investigate the concentrations and species composition of airborne fungi in different industrial premises and non-industrial environments as one of the most important criteria for evaluating their sanitary state.

MATERIAL AND METHODS

Four industrial enterprises were chosen for the airborne fungi studies: (i) the paper mill "Naujieji Verkiai", where various sorts of paper and paper products are produced from paper waste and cellulose; (ii) the fur mill "Vilniaus kailiai", where the pelts of mink, foxes and rabbits, as well as sheepskins, are dressed, leathered and dyed and garments are sewn; (iii) the shoe factory "Vilniaus Viktorija", where women's footwear and sports shoes are produced from natural and synthetic raw materials; and (iv) the cheese-making factory "Belvederis", where the fermented cheese "Liliputas" is produced (some species of *Penicillium* Link genus fungi are used in this process). In addition, a secondary school, a kindergarten, a hospital and two cafes were investigated. All the selected premises, with the exception of the cheese-producing factory, are situated in Vilnius district and normal working activities were taking place during the sampling period.

A "Krotov 818" slit-to-agar single-stage impactor (cut-off 0.5 μm) was used for sampling of total propagules, the volume of the samples being 0.05 m^3 at a flow rate of 0.025 m^3/min. Simultaneously, the settle-plates method for direct fungi isolation was applied (Volpe & Kucherenko 1970, Wanner et al. 1993). All samples were obtained

in triplicate; Petri dishes containing malt extract agar (Difco) and Sabouraud dextrose agar (BBL) media were used for fungi isolation and cultivation. The plates were incubated at 26±1°C and the developed colonies were counted after 3, 5 and 7 days. The viable propagule levels in the air were expressed as colony-forming units (cfu)/m^3. The prevailing fungal species were estimated according to the species detection frequencies in all the environmental samples (Mirkin et al. 1989). Identification of fungal monocultures was performed according to different manuals (Raper et al. 1965, Ellis 1971, 1976, Domsch et al. 1980, Ramirez 1982, Lugauskas et al. 1987, Larone 1993, St-Germain & Summerbell 1996, Zabawski & Baran 1998).

The software package Microsoft Excel 8.0 was used for data processing and for graphical presentation of the results.

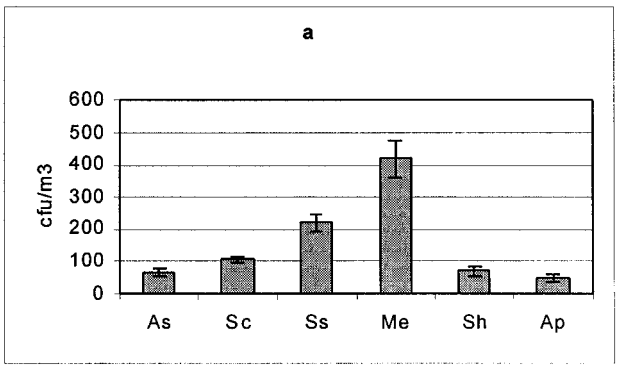
RESULTS

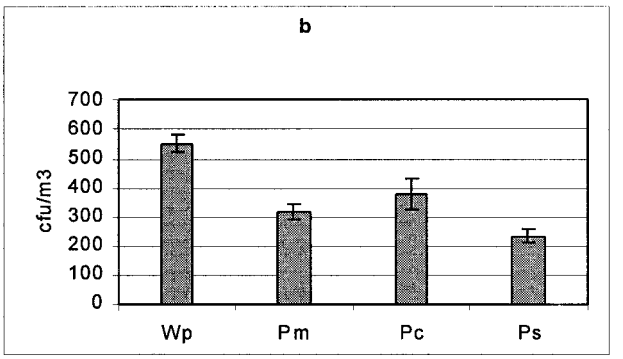
Quantitative evaluation of air contamination

The most distinct air contamination dependence on environmental factors was noticed in the industrial premises. The concentrations of fungal propagules per cubic meter of air and the numbers of identified fungal species in the studied premises differed (Fig. 1). There were considerable differences in the numbers of airborne fungal propagules between the different workplaces investigated as well as between different areas of the same workplace. The concentrations of fungal propagules ranged from 40 to 2180 cfu/m^3. The lowest concentrations were determined at the shoe factory. The air in the assembling plant, stole-casting shops, storehouse and administration premises was least polluted by fungi, with concentrations not exceeding 100 cfu/m^3. Comparatively higher levels of fungal propagules were detected in the mechanical and sewing–stretching shops (420 and 220 cfu/m^3, respectively).

The air in the paper mill was also not heavily contaminated with fungi, with concentrations not exceeding 600 cfu/m^3. The lowest concentrations were detected in the production storehouse (233 cfu/m^3) and the highest concentrations occurred in the waste paper storehouse (553 cfu/m^3).

Extreme variations in fungal concentrations (200–2180 cfu/m^3) were characteristic of the air in the fur mill. The highest concentration was found in the round-rolling shop (2160 cfu/m^3), where softening of pelts is carried out. Comparatively high air contamination by fungal propagules was observed in the fur matching shop (1365 cfu/m^3). Moderate concentrations, not exceeding 1000 cfu/m^3, were revealed in the air of the cutting–assembling and soaking off–tanning shops (920 and 800 cfu/m^3, respectively). Minimal counts were detected in the air of the sewing shop and administration building (220 and 313 cfu/m^3, respectively).





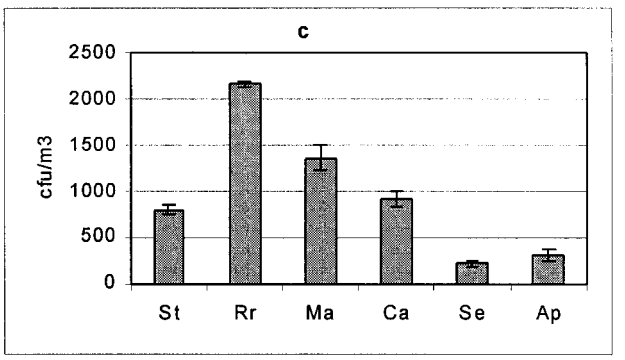


Fig. 1. Numbers of airborne fungal propagules in the investigated premises. (a) Shoe factory. As = assembling shop; Sc = stole-casting shop; Ss = sewing–stretching shop; Me = mechanical shop; Sh = storehouse; Ap = administration premises. (b) Paper mill. Wp = waste paper storehouse; Pm = paper manufacture shop; Pc = paper commodities manufacture shop; Ps = production storehouse. (c) Fur mill. St = soaking off–tanning shop; Rr = round-rolling shop; Ma = matching shop; Ca = cutting–assembling shop; Se = sewing shop; Ap = administration premises.

Airborne fungal species

Many microorganism species are brought into the paper mill shops or departments with the raw materials. These raw materials are often kept in humid conditions where active lignin–cellulose complex destroyers such as *Aspergillus fumigatus*, *Scopulariopsis brevicaulis* (Sacc.) Bainier (Fig. 2A), *Paecilomyces puntonii* (Vuill.) Nann. (Fig. 2B), *Geniculisporum serpens* Chesters et Greenh. (Fig. 2C), *Fusarium sambucinum* Fuckel, *Wallemia sebi* (Fr.) Arx and many others begin to develop. A great number of their propagules die during technological processes as a result of temperature and other environmental factors. However, some conidia of *Aspergillus fumigatus*, known as opportunistic pathogens (Table I), may survive because of their resistance to high temperatures and later develop on the finished product if it becomes damp. Various other species were isolated from various substrata at the paper mill and could cause human respiratory diseases in cases of constant exposure. *Aspergillus penicillioides* Speg., *A. niger*, *Cladosporium*

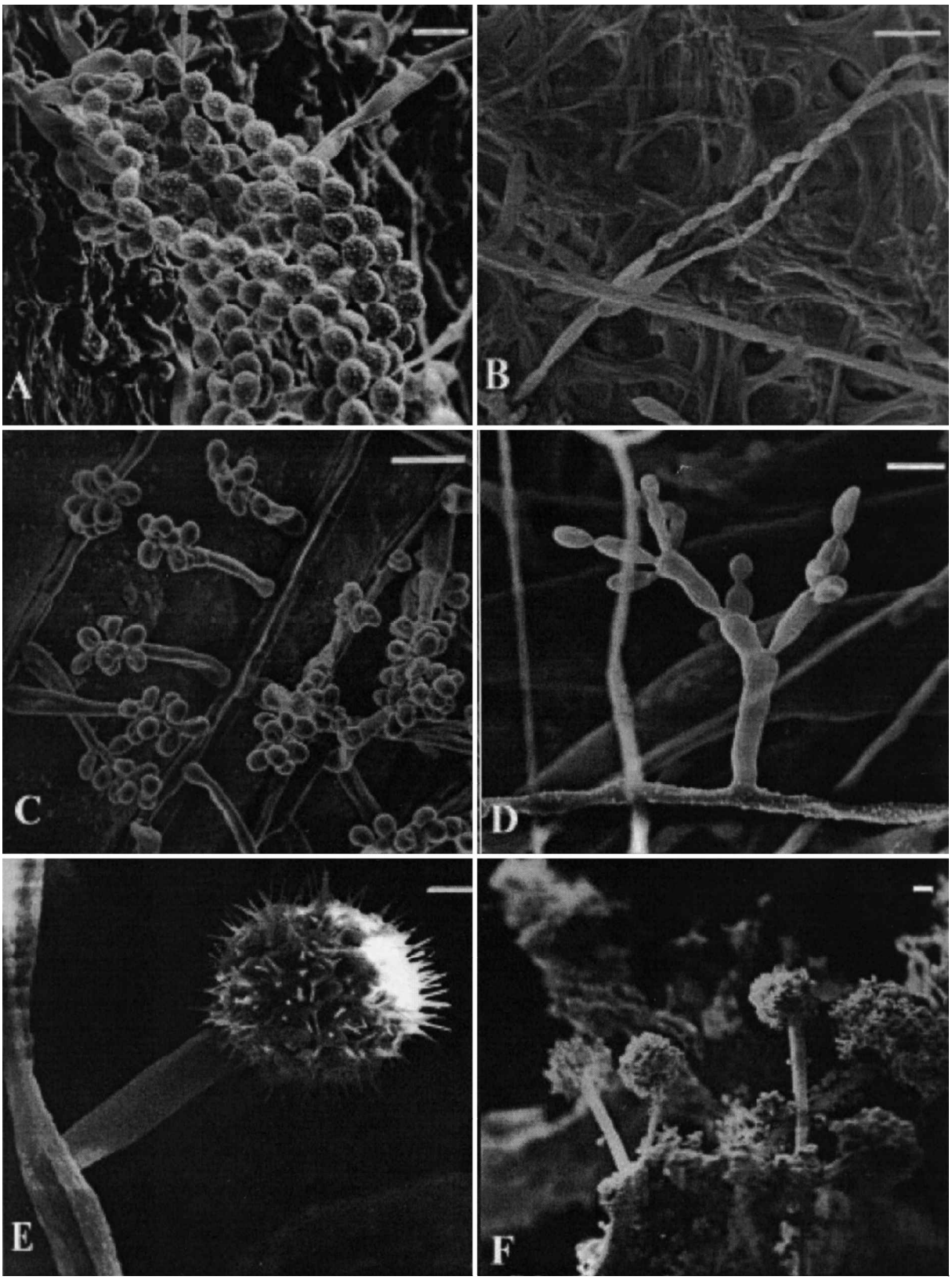


Fig. 2. Scanning electron micrographs of the fruit-bodies of fungi. (A) *Scopulariopsis brevicaulis.* Original magnification ×1500. (B) *Paecilomyces puntonii.* Original magnification ×1800. (C) *Geniculisporum serpens.* Original magnification ×2000. (D) *Cladosporium herbarum.* Original magnification ×1500. (E) *Rhizopus stolonifer.* Original magnification ×1400. (F) *Eurotium herbariorum.* Original magnification ×500. Scale bars = 10 μm.

cladosporioides, *Cladosporium herbarum* (Fig. 2D), *Geotrichum candidum* Link ex Pers., *Aureobasidium pullulans* and *Penicillium funiculosum* Thom. were especially widespread in the production rooms of the paper mill.

Some more examples of pathogens and opportunistic pathogens important to human health according to Larone (1993), St-Germain & Summerbell (1996) and Zabawski & Baran (1998) are presented in Table I.

The fungal species composition varied quite widely between the buildings of the fur mill. Some species were encountered frequently in all the buildings: *Penicillium expansum*, *P. viridicatum* Westling, *Cladosporium herbarum* and *C. sphaerospermum* (Table II) all had detection frequencies >40%. Fungal species found less frequently were considered as accidental because they were isolated only from single samples. In particular, many pathogens and opportunistic pathogens were isolated from the sewing shop: *Trichophyton rubrum*, *Zymonema dermatitidis*, *Candida albicans*, *Rhizopus stolonifer* (Fig. 2E), *Penicillium expansum*, *Rhizomucor pusillus*, *Aspergillus niger*, *A. candidus*, *Cladosporium herbarum*, *Arthroderma unicinatum* Dawson et Gentles and others (Table I).

Some fungal species were the same in the fur cutting–assembling shop: *Candida albicans*, *Rhizopus stolonifer*, *Aspergillus candidus*, *Rhizomucor pusillus* and *Alternaria alternata*. Although technological processes were not being carried out during sampling and people were not working in the fur round-rolling shop, fungi of the *Aspergillus* genus, such as *A. candidus*, *A. oryzae* (Ahlb.) Cohn, *A. caesiellus* Saito, *A. repens* de Bary = *Eurotium herbariorum* (Fig. 2F), *A. citrisporus* (Höhn) Raper, Fennell and Tresnen and *A. melleus* Yukowa, were found in this workplace. The pathogenic fungal species *Candida albicans*, *Microsporum fulvum*, *Trichophyton violaceum* and *Rhodotorula rubra* were isolated from the air of the round-rolling shop. *C. albicans*, *Trichophyton rubrum*, *Zymonema dermatitidis* and *Aspergillus flavus* Link were abundant in the air of the effluent cleaning shop. Yeast-like fungi dominated in the air of the soaking off–tanning section of the fur dressing shop; the pathogenic strains *Candida albicans*, *Microsporum nanum* and *Trichophyton rubrum*, together with *Aspergillus fumigatus*, *Alternaria alternata*, *Cladosporium cladosporioides*, *Rhizopus stolonifer* and other opportunistic pathogens, were found there.

Fungal species possessing the ability to destroy keratin were detected in some shops. Based on the data obtained it can be affirmed that working conditions are unfavorable in those shops. Constant mycological control and determination of the composition of fungi in the surrounding air is necessary.

The air was not heavily contaminated by fungal propagules in the shoe factory but species undesirable for human health

Table I. *Pathogens and opportunistic pathogens isolated from industrial premises.*

Fungal species	Paper mill				Fur mill							Shoe factory					
	Wp	Pm	Pc	Ps	St	Rr	Ma	Ca	Se	Ap	Ec	As	Sc	Ss	Me	Sh	Ap
Pathogens																	
Candida albicans (Robin) Berkhout.					+	+		+	+		+						
Microsporum fulvum Uriburi						+											
Microsporum nanum Fuentes					+												
Trichophyton mentagrophytes (Robin) Blanchard													+				
Trichophyton rubrum (Castellani) Sabouraud					+		+		+		+						
Trichophyton tonsurans Malmstem																	
Trichophyton violaceum Sabouraud						+											
Zymonema dermatitidis (Gilchrist et Stokes) Dodge									+		+						
Rhodotorula rubra (Demme) Lodder						+											
Opportunistic pathogens																	
Absidia corymbifera (Cohn) Sacc. et Trott							+		+			+					
Acremonium strictum W. Gams													+				
Aspergillus fumigatus Fresen.		+			+							+	+	+	+		+
Aspergillus niger Tiegh	+	+		+					+				+	+	+		
Aspergillus versicolor (Vuill.) Tirab.							+					+	+				
Chaetomium globosum Kunze						+											
Cladosporium cladosporioides (Fresen.) G. A. de Vries		+	+	+	+											+	
Curvularia lunata (Wekker) Boedijn						+											
Penicillium expansum Link					+	+	+		+			+		+			
Rhizomucor pusillus Lindt								+	+								
Rhizopus stolonifer (Ehrenb. ex Fr.) Vuill					+			+	+							+	

Paper mill: waste paper storehouse = Wp; paper manufacture shop = Pm; paper commodities manufacture shop = Pc; production storehouse = Ps. Fur mill: soaking off–tanning shop = St; round-rolling shop = Rr; matching shop = Ma; cutting–assembling shop = Ca; sewing shop = Se; administration premises = Ap; effluents cleaning shop = Ec. Shoe factory: assembling shop = As; stole-casting shop = Sc; sewing–stretching shop = Ss; mechanical shop = Me; storehouse = Sh; administration premises = Ap.

Table II. *Prevailing fungal species in the air samples of the investigated industrial premises.*

Fungal species	Species detection frequency (%)		
	Paper mill	Fur mill	Shoe factory
Alternaria alternata (Fr.) Keissl.	16.6	33.3	16.6
Aspergillus candidus Link	8.3	23.8	5.5
Aspergillus cervinus (Massee) Neill	–	–	33.3
Aspergillus fumigatus Fresen.	8.3	5.5	50.0
Aspergillus niger Tiegh.	25.0	11.1	22.2
Aureobasidium pullulans (de Bary) G. Arnaud	33.3	5.5	16.6
Cladosporium cladosporioides (Fresen.) G. A. de Vries	50.0	11.1	5.5
Cladosporium herbarum (Pers.) Link ex Gray	16.6	52.4	5.5
Cladosporium sphaerospermum Penz.	8.3	61.9	11.1
Eurotium herbariorum (Wiggers) Link ex Gray	–	16.6	22.2
Mortierella longicollis Dixon-Stew.	25.0	–	–
Penicillium chrysogenum Thom	–	28.6	11.1
Penicillium decumbens Thom	16.6	33.3	5.5
Penicillium expansum Link	–	47.6	33.3
Penicillium oxalicum Currie et Thom	8.3	27.7	27.7
Penicillium viridicatum Westling	8.3	42.9	5.5
Rhizopus stolonifer (Ehrenb. ex Fr.) Vuill.	–	23.8	11.1

were revealed: *A. fumigatus*, *A. niger*, *Trichophyton mentagrophytes*, *P. expansum* and others. Great numbers of the following pathogens and opportunistic pathogens were isolated from the air of the shop, where people worked in three shifts: *Microsporum gypseum* (Bodin) Guiard et Grigorakis, *M. ferugineum* Ota, *Alternaria alternata*, *Absidia corymbifera*, *Geotrichum candidum* (Fig. 3A), *Aureobasidium pullulans* and others. Spots of fungal origin were observed on certain pieces of leather in the shoe factory (Fig. 3B).

It is not possible to make a judgment, on the basis of detected fungus concentrations, regarding contamination of the cheese-producing shop because microorganisms can be distributed in the air by the workers during the production process. We have ascertained that *Penicillium* genus fungi from the *Asymmetrica-Funiculosa* section were isolated most often from the ripening cheese. The yeast-like fungus *Geotrichum fermentans* (Diddens et Lodder) v. Arx, *G. candidum* and *Dipodascus* genus species should also be mentioned. These species may play two types of role in cheese-producing premises. Some *Penicillium* Link species from the *Asymmetrica-Velutina* section were also encountered frequently on the cheeses. The milk reception room is the main source via which microbial infection enters cheese shops.

The data obtained showed that a great number of fungal species could be observed which entered the rooms by different means: *Phoma eupyrena* Sacc., *Ph. herbarum* Westend., *Cladosporium herbarum, C. cladosporioides*, *Penicillium claviforme* Bainier and others. The propagules of the above-mentioned and unmentioned fungal species are brought in from outdoors and become the cause of defective cheese production and air pollution. According to the data obtained the *Rhodotorula rubra* yeast-like fungus and some *Aspergillus* genus species ought to be included among such fungi. The building materials in such rooms need to be resistant to the influence of microorganisms, because they can consolidate on surfaces and become a source of surrounding pollution (Fig. 3C, 3D). The following fungal species which are unfavorable for cheese production and undesirable for the workers in the shop were isolated from the air, walls, ceilings, partitions and other surfaces in the cheese-processing rooms: *Mortierella lignicola* (Martin) Gams et Moreau, *Penicillium olivino-viride* Biourge, *P. variabile* Sopp, *Cladosporium cladosporioides*, *C. herbarum, Chrysosporium* spp. and *Mycelia sterilia* (Fig. 3E).

One of the non-industrial premises investigated was a secondary school, where considerable physical activity takes place, much dust can be found and where, in certain cases, high humidity and propagules of various fungal species are observed. Various fungal species from the *Penicillium* genus dominated in the air and on various surfaces of these premises, which were often covered with dust. We found plenty of propagules of *Aspergillus fumigatus*, *A. niger*, *Penicillium cyclopium*, *P. expansum* and *Chrysosporium merdarium* (Link ex Grev.) J. W. Carmich. (Fig. 3F) and especially of *Candida albicans*, *Circinella circinans* (Bainier) Milko (Fig. 4A), *Mortierella polycephala* Coem. and *M. candelabrum* Tiegh. et Le Monn. species.

The fungal species composition of the school air can be considered as unstable, casual and very variable, although the isolation of *Trichophyton rubrum* and *T. tonsurans* Malmsten shows that the infection nidus can occur as a result of favorable environmental conditions in schools, accounting for some pupils' ailments.

Twenty-seven fungal species were isolated from the air and from dust on various surfaces at kindergarten N26 in the city of Vilnius. The following species of the *Penicillium* genus dominated: *P. cyclopium*, *P. chermesinum* Biourge, *P. decumbens*, *P. purpurogenum* Stoll, *P. expansum*, and other species frequently encountered were *Alternaria alternata*, *Aspergillus fumigatus*, *A. niger*, *Rhizopus stolonifer*, *Fusarium moniliforme* J. Sheld. (Fig. 4B), *Aureobasidium pullulans*, *Trichophyton rubrum* and *Thermomyces longinosus* Tsikl. High air humidity, bad ventilation and a shortage of heating were responsible for the favorable mycological conditions. Mycological control of kindergartens should be carried out constantly because children are particularly sensitive to external irritants. There is a direct relation between the incidence of respiratory and allergic diseases and the increased concentrations of propagules of the mentioned species in the room air and settled dust of the kindergarten.

The mycological state of two small cafes located in old buildings, with constantly wet walls, was investigated. The fungal species encountered were found to be the same as in the other investigated premises, namely *Alternaria alternata*, *Cladosporium herbarum*, *Aspergillus niger*, *A. fumigatus* and *Rhizopus stolonifer*. In addition to these species, which are cosmopolitan and found in the air and on walls, ceilings, household surfaces and stored products, the following fungal species were isolated: *Aureobasidium pullulans*, *Myrothecium roridum* Tode ex Fr. (Fig. 4C), *Penicillium capsulatum*, *P. chrysogenum*, *P. expansum*, *P. palitans*, *Piptocephalis microcephala* Tiegh., *Trichosporiella cerebriformis* (G. A. de Vries

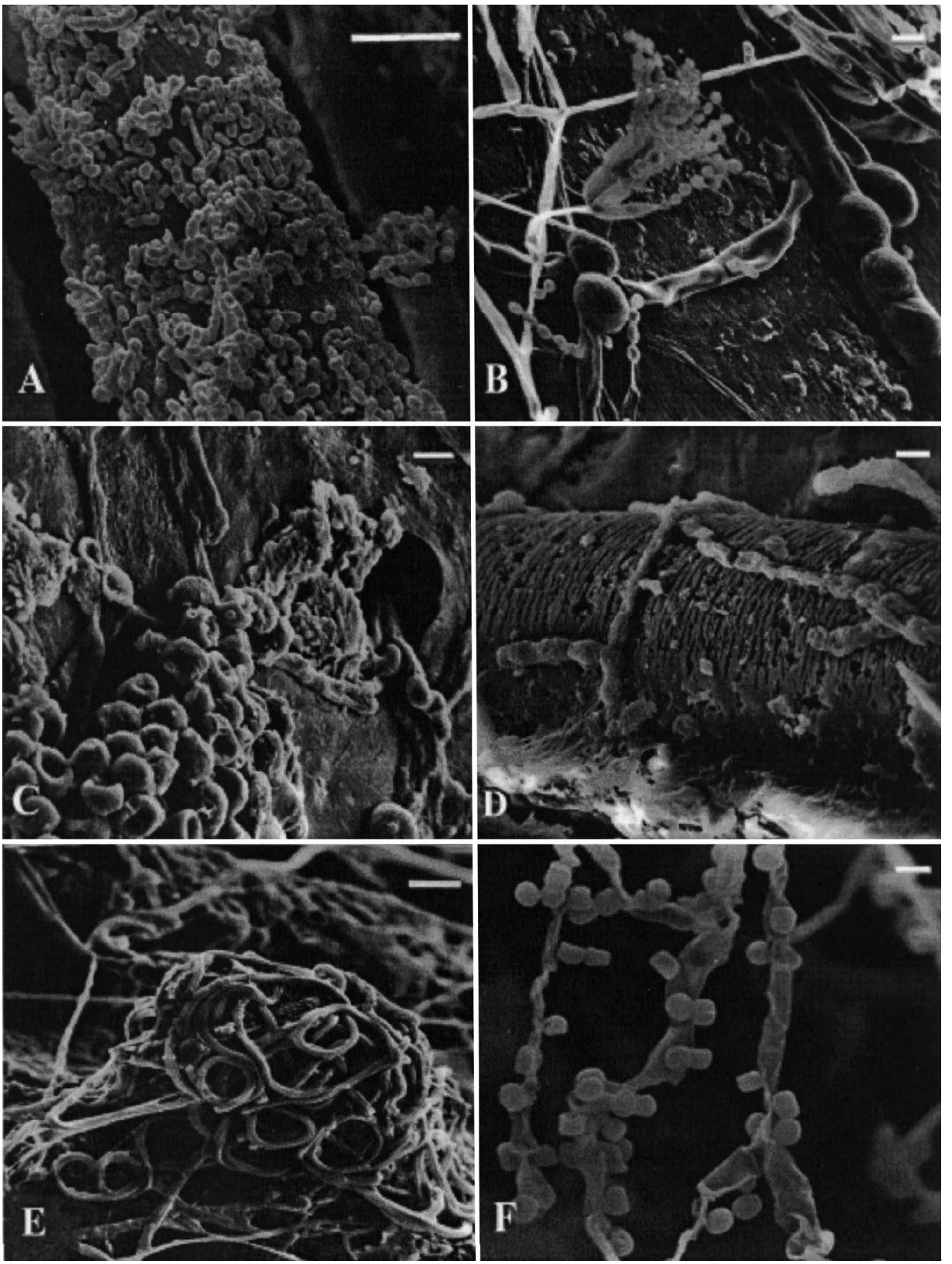


Fig. 3. Scanning electron micrographs of the materials damaged by fungi. (A) Threads damaged by *Geotrichum candidum*. Original magnification ×3000. (B) Natural leather saturated with antipyrenes. Original magnification ×1000. (C) Old polyethylene film. Original magnification ×1000. (D) Glass textile made of bakelite resin and polyvinyl-formaldehyde. Original magnification ×1000. (E) Shelves damaged by *Mycelia sterilia*. Original magnification ×1400. (F) Fruit-bodies of *Chrysosporium merdarium*. Original magnification ×900. Scale bars = 10 μm.

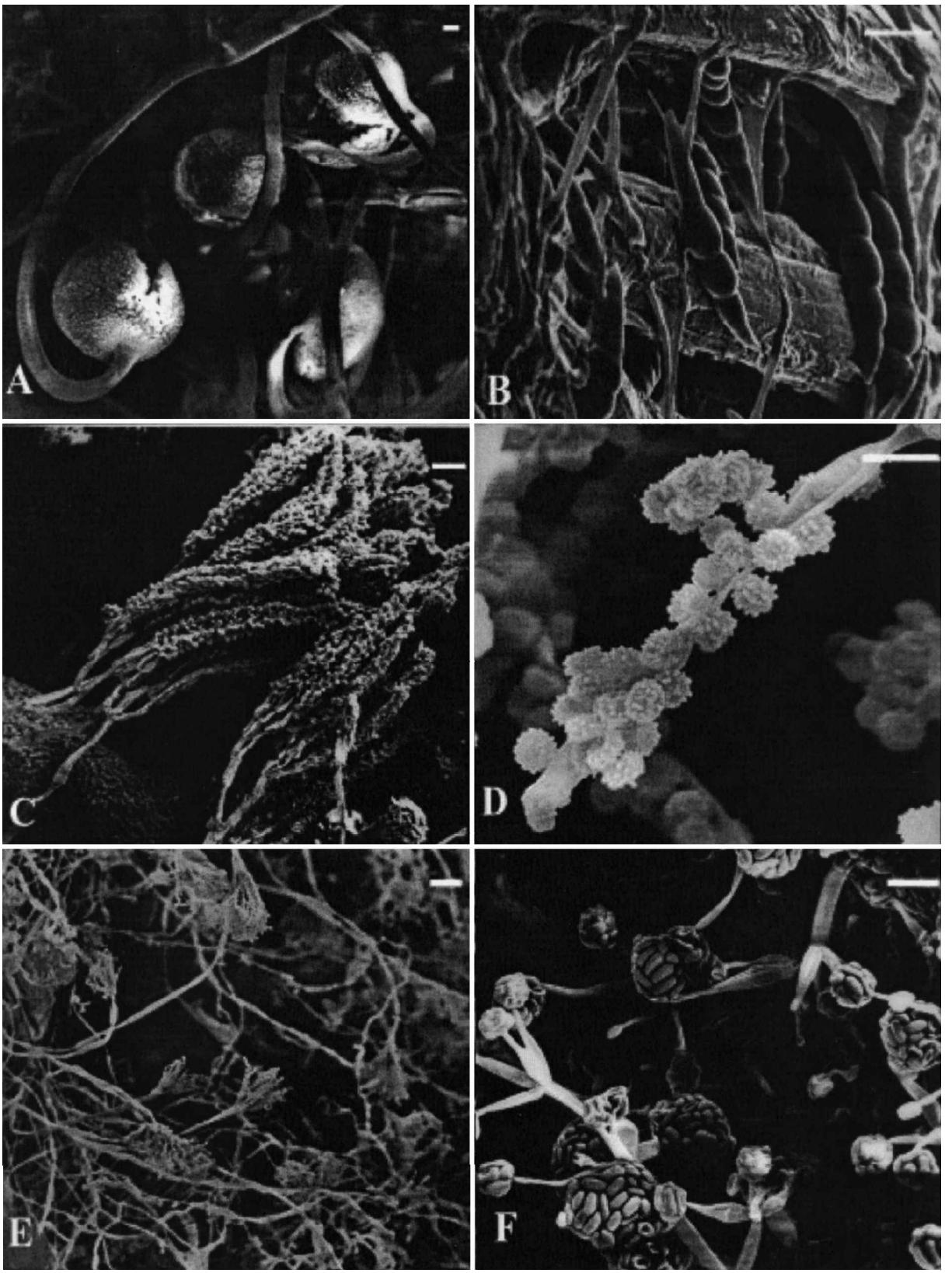


Fig. 4. Scanning electron micrographs of the fruit-bodies of fungi. (A) *Circinella circinans.* Original magnification ×500. (B) Macroconidia of *Fusarium moniliforme.* Original magnification ×2000. (C) *Myrothecium roridum.* Original magnification ×1000. (D) *Periconia lateralis.* Original magnification ×2300. (E) *Penicillium clavigerum.* Original magnification ×800. (F) *Verticillium tenerum.* Original magnification ×1400. Scale bars = 10 μm.

et Kleine-Natrop) W. Gams, *Myceliophtora lutea* Cost. and others. *Periconia lateralis* Ellis et Everh. (Fig. 4D), *Phialophora verrucosa* Medlar and *Bipolaris sorakiniana* (Sacc.) Shoem. were detected on packages in one of the food stores. This demonstrates that products stored in unfit rooms can be damaged by various fungi. In this case the food product packages were infected by fungi producing toxic matter. Some of the mentioned species strains may be pathogenic to humans and animals. Therefore, food products with packaging damaged by fungi ought not to be used for human consumption.

The wards and other rooms at the St. Jokubas traumatologic hospital in Vilnius are a special case because they are part of a very old building. The hospital is constantly overcrowded with patients. After studying the rooms, fungi of the *Penicillium* genus were found to be predominant. The following species were isolated: *Penicillium chrysogenum*, *P. clavigerum* Demelius (Fig. 4E), *P. expansum*, *P. decumbens*, *P. oxalicum*, *P. lanosum* Westling, *P. implicatum* Biourge, *P. aurantio-virens* Biourge, *P. stoloniferum* Thom and *P. variabile* Sopp. The predominant species of the *Aspergillus* genus were: *A. niger*, *A. fumigatus*, *A. silvaticus* Fennell et Raper, *A. restrictus* G. Sm. and *Eurotium herbariorum*. *Paecilomyces* genus fungi were quite often encountered and mostly belonged to *Paecilomyces niveus* Stolk et Samson and *P. inflatus* (Burniside) J. W. Carmich. species. *Mucor hiemalis*, *Phoma fimeti*, *Rhizopus cohnii* Berl. et De Toni, *Chaetomium globosum*, *Dipodascus armilareae*, *Verticillium tenerum* (Nees ex Pers.) Link (Fig. 4F) species should be considered as casual because they were isolated only in solitary cases. The increased number of fungal propagules observed at the hospital is alarming and demands immediate action as it creates very unfavorable conditions for the treatment of patients with open wounds.

DISCUSSION

The results of our investigation revealed that the air in both industrial and non-industrial premises can be heavily contaminated by fungal propagules. According to the data obtained it can be asserted that several factors can predetermine such microbiological contamination of the environment. One of these is a source or sources of fungal development within the building. Organic remnants remaining after processing of raw materials serve as nutrient substrata for fungal growth.

Sufficient water activity of the substrata is the basic factor predetermining germination and development of fungal propagules (Onions & Kelley 1986). Humidity and optimal temperatures created excellent conditions for fungal development in the round-rolling shop at the fur mill. Huge piles of unsorted, and in some areas water-damaged, paper in the waste paper storehouse were associated with the highest numbers of airborne fungi observed in the paper mill. Air currents caused by specific industrial processes and as a result of handling moldy raw materials are associated with the appearance of airborne particles, of which fungal propagules comprise a considerable fraction. These specific conditions were found in the matching and cutting–assembling shops at the fur mill. The concentrations of airborne fungi found in the premises investigated in this study are relatively low compared with those in industrial buildings, where agricultural products, wood or plants are processed ($2.4 \times 10^4/m^3$ according to Lacey & Crook 1988).

We assume that the extremely low concentrations of fungal propagules in the assembling and stole-casting shops and the storehouse at the shoe factory were the result of tidiness and the absence of indrafts of external air. As can be seen from the data presented in Table II, there were differences in the compositions of fungal species observed at the different premises. *Aspergillus* spp. prevailed in the shoe factory, while the detection frequency in samples from the other investigated premises was significantly lower.

Fungal growth and metabolism could be related to the specificity of the available nutritive substratum, such as leather, because *Aspergillus* spp. possess extremely well-developed enzymatic systems, allowing them to colonize proteins and keratin-containing substrata (Bilaj & Koval 1988, Gravesen et al. 1994). It is noteworthy that *A. cervinus* was abundant in the round-rolling, matching, cutting–assembling and sewing shops. This fungus is regarded as an opportunistic pathogen and contact with its propagules can be dangerous for humans.

The abundance of suitable nutrient substrata and the existence of favorable microclimatic conditions predetermined the abundance of *Penicillium* spp. at the fur mill. Fungi belonging to this group possess not only well-developed enzymatic systems but are also known as producers of a wide range of secondary metabolites, some of which are regarded as mycotoxins and are hazardous to human health. Entering the lungs with inhaled air, these substances can cause acute or chronic mycotoxicoses. Furthermore, *Penicillium*, *Aspergillus*, *Cladosporium* and *Alternaria* species are allergenic and represent a risk of allergic rhinitis, asthma and allergic alveolitis in immunocompromised hosts. Moreover, *A. fumigatus* and *A. niger* species can cause superficial or pulmonary aspergilloses (Gravesen et al. 1994, Zabawski & Baran 1998). Contact with fungi of the genera *Microsporum* and *Trichophyton* represents a potential danger of dermatophytoses for workers involved in technological processes where increased humidity is necessary (e.g. in the soaking off–tanning and round-rolling shops at the fur mill).

As a result of the data obtained we can state that air in some industrial premises is polluted by fungi, causing health problems for the workers. In order to reduce exposure to airborne fungi, preventive measures such as sufficiently intensive ventilation, if possible, or natural ventilation should be introduced. Any remnants left after processing of raw materials serve as nutrient substrata for fungi and therefore cleaning and tidying are simple and effective measures. In some industrial premises, where constant cleanliness is difficult to achieve, the main task remains the use of a complex of measures against microbial pollution.

The data presented herein enable us to affirm that a constant skilled estimation of the mycological state is necessary in the majority of workplaces. The main criteria of such estimations ought to be the distribution of fungal propagules and the compositions of species.

REFERENCES

Bilaj, V. I. & Koval, E. Z. 1988. Aspergilli. – Naukova dumka, Kiev (in Russian).

Blanco, J. L., Garcia, M. E. & Kurup, V. P. 1997. Immunoreactivity of antigens extracts of *Aspergillus fumigatus* isolated from different sources. – Revista Iberoamericana de Micologia 14: 60–62.

Domsch, K. H., Gams, W. & Anderson, T. H. 1980. Compendium of soil fungi. Vol. 1. – Academic Press, London.

Ellis, M. B. 1971. Dematiaceous Hyphomycetes. – Commonwealth Mycological Institute, Kew, London.

Ellis, M. B. 1976. More dematiaceous Hyphomycetes. – Commonwealth Mycological Institute, Kew, London.

Frisvad, J. C. & Gravesen, S. 1994. *Penicillium* and *Aspergillus* from Danish homes and working places with indoor air problems: identification and mycotoxin determination. – In: Health Implications of Fungi in Indoor Environments (ed. R. A. Samson), pp. 281–290. – Elsevier, Amsterdam.

Gravesen, S., Frisvad, J. C., & Samson, R. A. 1994. Microfungi. – High Tech PrePress, Munksgaard, Copenhagen.

Lacey, J. & Dutkiewicz, J. 1994. Bioaerosols and occupational lung disease. – J Aerosol Sci 25(8): 1371–1404.

Lacey, J. & Crook, B. 1988. Fungal and actinomycetes spores as pollutants of the workplace and occupational allergens. – Ann Occup Hyg 32: 515–533.

Larone, D. H. 1993. Medically important fungi. A guide to identification. – USDA, Washington, D. C.

Lugauskas, A. (Ed.) 1997. Microbiological deterioration of materials. – UAB Valstiečių laikraštis, Vilnius (in Lithuanian).

Lugauskas, A., Mikulskienė, A., & Šliaužienė, D. 1987. Catalogue of fungi deteriorating polymeric materials. – Nauka, Moscow (in Russian).

Mirkin, B. I., Rozenberg, G. S., & Naumova, L. G. 1989. Dictionary of concepts and terms of modern phytocoenology. – Nauka, Moscow (in Russian).

Northolt, M. D. & Soentoro, P. S. S. 1988. Fungal growth on foodstuffs related to mycotoxin contamination. – In: Introduction to food-borne fungi (ed. R. A. Samson & E. S. van Reener-Hoekstra), pp. 231–238. – Centralbureu voor Schimmelcultures, Baarn, Delft, The Netherlands.

Onions, A. H. S. & Kelley, J. 1986. Microfungi in buildings. – University of Warwick, Warwick, UK.

Pasanen, A.-L., Juutinen, T., Jantunen, M. J., & Kalliokoski, P. 1992. Occurrence and moisture requirements of microbial growth in building materials. – Int Biodeterioration 30: 273–283.

Ramirez, C. 1982. Manual and atlas of the Penicillia. – Elsevier, Amsterdam.

Raper, K. B., Fennel, J., & Austwick, P. K. C. 1965. The genus *Aspergillus*. – Williams & Wilkins Co., Baltimore, MD.

Singh, A. & Singh, A. B. 1999. *Aspergillus* spp. as an important occupational risk factor among susceptible individuals. – Aerobiologia 15: 233–240.

St-Germain G. & Summerbell R. 1996. Identifying filamentous fungi. A clinical laboratory handbook. – Star Publishing Co., Belmont, NY.

Volpe, I. M. & Kucherenko, V. D. 1970. Practical guidance of hygienic microbiology. – Moscow State University, Moscow (in Russian).

Wanner, H. U., Verhoeff, A., Colombi, A., Flannigan, B., Gravesen, S., Mouilleseaux, A., Nevalainen, A., Papadakis, J., & Seidel, K. (Eds.) 1993. Biological Particles in Indoor Environments. – Report No. 12. Commission of the European Community, Brussels.

Zabawski, J. & Baran, E. 1998. Characteristics of the pathogenic, common fungi and the opportunistic fungi of the class: Zygomycotina, Ascomycotina and Deuteromycotina – In: Textbook of the medical mycology, Vol. 4 (ed. E. Baran), pp. 37–254. – Volumed, Wroclaw, Poland (in Polish).