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EXPOSURE TO AIRBORNE MICROORGANISMS IN FURNITURE FACTORIES

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Abstract: Microbiological air sampling was performed in 2 furniture factories located in eastern Poland. In one factory furniture were made from fibreboards and chipboards while in the other from beech wood. It was found that the concentration of total microorganisms (bacteria + fungi) in the air of the facility using beech wood for furniture production (mean 10.7×10^3 cfu/m^3, range $3.3–27.5 \times 10^3$ cfu/m^3) was significantly higher ($p < 0.01$) compared to microbial concentration in the facility using fibre- and chipboards (mean 3.6×10^3 cfu/m^3, range $1.9–6.2 \times 10^3$ cfu/m^3). On average, the commonest microorganisms in the air of the furniture factories were corynebacteria (*Corynebacterium* spp., *Arthrobacter* spp., *Brevibacterium* spp.) which formed 18.1-50.0% of the total airborne microflora, and fungi (mostly *Aspergillus* spp., *Penicillium* spp., *Absidia* spp. and yeasts) which formed 6.2–54.4% of the total count. The values of the respirable fraction of airborne microflora in the furniture factories varied within fairly wide limits and were between 15.0–62.4%. Altogether, 28 species or genera of bacteria and 12 species or genera of fungi were identified in the air of examined factories, of which respectively 8 and 7 species or genera were reported as having allergenic and/or immunotoxic properties. In conclusion, the workers of furniture factories are exposed to relatively low concentrations of airborne microorganisms which do not exceed the suggested occupational exposure limits. Nevertheless, the presence of allergenic and/or immunotoxic microbial species in the air of factories poses a potential risk of respiratory disease, in particular in sensitive workers.

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Key words: furniture factories, occupational exposure, wood dust, bioaerosols, bacteria, fungi.

INTRODUCTION

It was demonstrated that workers in the furniture industry show an increased risk of work-related respiratory symptoms, bronchial hyperresponsiveness and lung function impairment [3, 6, 24, 40, 46, 53, 54] which may be due to exposure to adverse biological factors (wood dust and associated microorganisms) and chemicals (dyes, varnishes, solvents) [3, 9, 23, 53]. So far, little is known about possible health effects of microorganisms associated with wood on the workers of furniture factories. It is known that bacteria and fungi may develop in timber logs stored in the forest and in lumber yards [15, 33, 45], or on chopped wood (chips, planks) stored and/or kiln dried in wood processing facilities in conditions favouring microbial growth [21, 39, 44]. During wood processing, microorganims are released into the air and high concentrations of airborne bacteria, fungi and bacterial endotoxin may occur inside sawmills [2, 10, 13, 17, 21, 36, 37], and inside factories producing wood

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pulp, fibreboards and chipboards [2, 19, 36, 37]. Airborne microorganisms were identified as a cause of occupational pulmonary disease (allergic alveolitis, asthma, organic dust toxic syndrome) in the woodworkers exposed to large quantities of wood dust [5, 14, 20, 21, 22, 30, 39, 44, 54].

Until recently, only a few studies have been conducted on the exposure of furniture industry workers to microorganisms [1, 3, 40, 56]. Al Zuhair *et al.* [3] found in 2 English furniture factories microbial concentrations averaging between 5.3×10^2–2.2×10^3 cfu/m^3, with prevalence of fungi (62% of total microbial count) in one factory and of Gram-negative bacteria (53%) in the other factory. Abdel Hameed *et al.* [1] recorded in 2 Egyptian workshops producing furniture, concentrations of bacteria, actinomycetes and fungi ranging from 3.1×10^3–3.5×10^4 cfu/m^3, 0–8.2×10^3 cfu/m^3, and 8.0×10^1–3.5×10^3 cfu/m^3, respectively. Gram-positive bacteria (cocci, spore-forming bacilli) distinctly prevailed among bacteria forming 93% of the total count. *Streptomyces* spp. dominated among actinomycetes while *Penicilium* spp., *Aspergillus* spp., *Cladosporium* spp., and yeasts were most abundant among fungi. A number of bacterial and fungal species isolated by these authors possess potential allergenic and/or immunotoxic properties.

Wilhelmsson *et al.* [56] found at 11 out of 12 measurement sites in 6 Swedish wood furniture factories, concentrations of filamentous fungi between 1.7×10^2–1.9×10^4 cfu/m^3, similar to those recorded by the above-mentioned authors. At one site, the concentration of fungi was much greater, equal to 6.5×10^5 cfu/m^3. The potentially allergenic fungi *Paecilomyces* spp. prevailed in the air of the examined factories. The concentration of airborne bacterial endotoxin inside these factories ranged from 0.0012–0.35 µg/m^3. Petretskii *et al.* [40] examined settled dust in Ukrainian furniture factories with a high prevalence of respiratory diseases among workers and found the presence of potentially pathogenic bacterial and fungal species.

The aim of the present work was to study the concentration and species composition of the microflora of air of 2 Polish furniture factories which differed in the kind of material used for furniture production.

MATERIALS AND METHODS

Examined facilities. Air sampling was performed in 2 furniture factories located in eastern Poland on the territory of Lublin Province. In the factory marked "A" furniture was made from fibreboards and chipboards, while in the factory marked "B" it was made from beech wood. Despite different materials used for making furniture, the production process in both factories was similar and comprised 4 basic departments, described as: initial processing, board processing, varnishing and assembly.

In the initial processing departments of factories "A" and "B", large fibre- and chipboards or beech planks were first sawed into battens, then into small boards which were trimmed and sanded. In the board processing department of factory "A", the boards were coated with veneer, and in both factories the boards were precisely formatted by repeated trimming, planing and sanding. The boards were then painted with polyester or nitric varnishes in the varnishing department and put together into ready furniture in the assembly department.

In furniture factory "A", the air samples were taken in the sequence of production cycle at the following 5 sites, marked A1-A5: • sawing chipboards into battens with circular saw (A1); • sawing battens into small boards with machine "Steton" (A2); • machine sanding of fibreboards (A3); • trimming of veneered chipboards with a machine (A4); • sanding of veneered chipboards with a machine (A5).

In furniture factory "B", the samples were taken at the following 5 sites, marked B1-B5: • frame sawing of beech planks into battens (B1); • trimming of beech battens with a sawing machine (B2); • four-side planing of beech battens with a machine (B3); • manual planing of beech battens (B4); • sanding of beech battens with a machine (B5).

Sites A1-A3 and B1-B3 belonged to the initial processing departments, while sites A4-A5 and B4-B5 belonged to the board processing departments. All samples were taken indoors.

Microbiological examination of the air. The examination was performed as previously described [17, 19]. Air samples were taken in furniture factories with a custom-designed particle-sizing slit sampler [11] enabling estimations of both total and respirable fractions of the microbial aerosol. Each air sample was a duplicate, taken at a flow rate of 20 l/min. It consisted of 2 parallelly exposed agar plates: one "a" sampled directly for all organisms and used for the estimation of the total concentration of cfu per m^3; and the other "b" sampled through a pre-selector for the respirable fraction. The value of respirable fraction was expressed as a percent (%) of the total count.

At each sampling site, a series of 5 double samples were taken on each of the following agar media: blood agar for total mesophilic Gram-negative and Gram-positive bacteria, half-strength tryptic soya agar for thermophilic actinomycetes, and malt agar for fungi. The blood agar plates were subsequently incubated for 1 day at 37ºC, then 3 days at 22ºC and finally 3 days at 4ºC. The malt agar plates were subsequently incubated for 4 days at 30ºC and 4 days at 22ºC [12]. The prolonged incubation at lower temperatures was aimed at isolating as wide a spectrum of bacteria and fungi as possible. The tryptic soya agar plates were incubated for 5 days at 55ºC. The grown colonies were counted and differentiated and the data reported as cfu per 1 cubic meter of air (cfu/m^3). The total concentration of microorganisms in the air was obtained by the addition of the concentrations of total

mesophilic bacteria, thermophilic actinomycetes and fungi. The percent composition of the total microflora of the air was then determined.

Bacterial isolates were identified with microscopic and biochemical methods, as recommended by Bergey's Manual [26, 50, 57] and Cowan & Steel [8]. Additionally, the selected isolates were identified with microtests: API Systems 20E and NE (bioMérieux, Marcy l'Etoile, France) and BIOLOG System (Biolog, Inc., Hayward, CA, USA). Fungi were classified by microscopic methods, according to Barron [4], Larone [32], Litvinov [34], Ramirez [42], and Raper & Fennell [43].

The study was performed in the greater part in the years 1987-1989 and continued in the years 1998-2001. Preliminary results of this work have been reported elsewhere [28].

RESULTS

The concentration of total microorganisms in the air of the facility using beech wood for furniture production (mean 10.7×10^3 cfu/m^3, range $3.3–27.5 \times 10^3$ cfu/m^3) was significantly higher ($p < 0.01$) compared to microbial concentration in the facility using fibre- and chipboards (mean 3.6×10^3 cfu/m^3, range $1.9–6.2 \times 10^3$ cfu/m^3) (Tab. 1). Significant differences between these 2 facilities were noted, also with regard to particular components of airborne microflora: mesophilic bacteria ($p < 0.01$), thermophilic actinomycetes ($p < 0.05$), and fungi ($p < 0.01$) (Tab. 1). In both factories, the largest concentrations of airborne microorganisms were noted at the beginning of the production cycle, at first sawing of boards or planks.

Corynebacteria (*Corynebacterium* spp., *Arthrobacter* spp., *Brevibacterium* spp.) were the most common microorganisms in the air of both furniture factories, forming 31.9–50.0% of the total airborne microflora in factory "A" and 18.1–41.9% of the total count in factory "B" (Fig. 1). In factory "A", they were followed by a group described as "other mesophilic bacteria" which consisted mostly of cocci (*Staphylococcus* spp., *Micrococcus* spp.) and formed 17.5–51.1% of the total count. By contrast, in factory "B" the second group to corynebacteria were fungi which constituted 16.9–54.4% of the total airborne microflora. In factory "A" fungi formed 5.8–35.9% of the total count. *Penicillium* spp., *Aspergillus* spp., *Absidia* spp., and yeasts (*Rhodotorula* spp., *Candida* spp.) were the most common fungi in the air of the examined furniture factories.

The proportion of Gram-negative bacteria was very small in factory "A" (0–6.2% of the total) and greater in factory "B" (1.8–20.6% of the total). A relatively large concentration of Gram-negative bacteria, mostly identified as *Rahnella* spp., was found at the first sawing of beech planks (5.7×10^3 cfu/m^3, 20.6% of the total airborne microflora). The proportions of spore-forming bacilli and thermophilic actinomycetes were low in both factories (Fig. 1).

Table 1. Microorganisms in the air of furniture factories "A" and "B": concentrations and respirable fractions (Rf).

Plant, sampling site	Mesophilic bacteria		Thermophilic actinomycetes		Fungi		Total microorganisms	
	Concentration (mean ± S.D., cfu/m$^3 \times 10^3$)	Rf (%)	Concentration (mean ± S.D., cfu/m$^3 \times 10^3$)	Rf (%)	Concentration (mean ± S.D., cfu/m$^3 \times 10^3$)	Rf (%)	Concentration (mean ± S.D., cfu/m$^3 \times 10^3$)	Rf (%)
Factory "A"								
A1. Sawing chipboards into battens with circular saw	2.8 ± 0.4	45.8	0.2 ± 0.1	50.0	0.6 ± 0.3	0	3.6 ± 0.7	39.8
A2. Sawing battens into small boards with machine "Steton"	3.8 ± 1.3	53.1	0.2 ± 0.3	0	2.2 ± 3.0	13.5	6.2 ± 4.3	34.8
A3. Machine sanding of fiberboards	1.8 ± 0.5	30.0	0	0	0.1 ± 0.1	0	1.9 ± 0.6	37.5
A4. Trimming of veneered chipboards with a machine	2.8 ± 1.1	23.4	0.1 ± 0.1	100	0.2 ± 0.2	0	3.1 ± 1.4	27.2
A5. Sanding of veneered chipboards with a machine	2.5 ± 1.7	14.3	0.2 ± 0.2	50.0	0.3 ± 0.2	0	3.0 ± 1.9	15.0
Mean	2.8 ± 1.3	33.3	0.2 ± 0.2	40.0	0.7 ± 1.6	2.7	3.6 ± 2.5	30.9
Factory "B"								
B1. Frame sawing of beech planks into battens	16.9 ± 7.5	35.5	0.2 ± 0.1	50.0	10.4 ± 6.8	23.7	27.5 ± 11.2	31.1
B2. Trimming of beech battens with a sawing machine	7.7 ± 1.4	60.2	0.5 ± 0.3	37.5	1.6 ± 0.6	18.5	9.8 ± 1.4	52.2
B3. Four-side planing of beech battens with a machine	3.0 ± 0.5	40.0	0.1 ± 0.1	100	0.7 ± 0.2	36.4	3.8 ± 0.7	40.8
B4. Manual planing of beech battens	3.9 ± 1.6	75.4	0.3 ± 0.2	0	4.8 ± 1.3	51.9	9.0 ± 2.8	62.4
B5. Sanding of beech battens with a machine	2.3 ± 1.1	41.1	0.2 ± 0.2	0	0.8 ± 0.3	15.4	3.3 ± 1.1	32.1
Mean	6.8 ± 6.3**	50.4	0.3 ± 0.2*	37.5	3.7 ± 4.2**	29.2	10.7 ± 9.9**	43.7

*-** concentration significantly greater than in factory "A"; *$p < 0.05$, **$p < 0.01$.

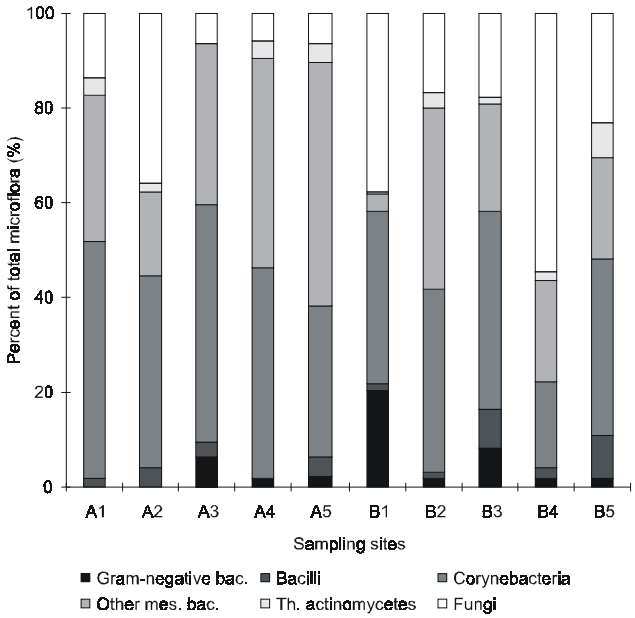

Figure 1. Composition of airborne microflora in furniture factories (total count, including mesophilic bacteria, thermophilic actinomycetes and fungi).

The values of the respirable fraction of airborne microflora in the furniture factories "A" and "B" varied within a fairly wide range, respectively between 15.0–39.8% and 31.1–62.4%. At all sampling sites, the values of respirable fraction were greater for bacteria than for fungi.

In the air samples taken in the examined furniture factories, 28 species or genera of bacteria and 12 species or genera of fungi were identified, of these, respectively 8 and 7 species or genera were reported as having allergenic and/or immunotoxic properties [14, 16, 20, 25, 29, 30, 38] (Tab. 2). These figures are certainly underestimated, as a number of bacterial and fungal strains could be identified only to the generic level.

DISCUSSION

The concentrations of airborne microorganisms in the examined furniture factories ranged from 1.9×10^3–2.75×10^4 cfu/m^3 and conformed to the values of the order 10^2–10^4 cfu/m^3, recorded in this environment by other authors [1, 3, 56]. The level of microbial pollution in furniture factories is much lower compared to sawmills and various wood processing facilities [2, 10, 13, 17, 19, 21, 36, 37]. As, so far, there are no internationally recognized Occupational Exposure Limit (OEL) values for bioaerosols, the results obtained in the present work could be compared only to the proposals raised by particular authors. The OEL value of 10×10^3 cfu/m^3 for total airborne microorganisms proposed by Malmros *et al.* [35] was exceeded at only 1 sampling site out of 10 examined, while the OEL value proposed for this component by Dutkiewicz and Jabłoński (100×10^3 cfu/m^3) [14] was never exceeded. Similarly, the concentration of Gram-negative bacteria (recovered on blood agar plates among other mesophilic bacteria) exceeded at only one site the OEL value of 1×10^3 cfu/m^3 proposed by Clark [7] and Malmros *et al.* [35], while the OEL value of 20×10^3 cfu/m^3 proposed for these bacteria by Dutkiewicz and Jabłoński [14] was never exceeded. The OEL values proposed by Dutkiewicz and Jabłoński [14] for thermophilic actinomycetes and fungi (respectively 20×10^3 cfu/m^3 and 50×10^3 cfu/m^3) were not exceeded at any site.

It is noteworthy that concentration of airborne microbes in the facility using beech wood for furniture production was significantly higher compared to the facility using fibre- and chipboards. This may be explained by the fact that beech planks were provided from a sawmill without any additional processing, while the production of fibre- and chipboards involved the use of high pressure and temperature which killed most microbes.

Table 2. List of microbial species and genera identified in samples of air from furniture factories.

Gram-negative bacteria: ***Acinetobacter calcoaceticus**+** (B2-B4), *Pseudomonas maltophilia* (B1), *Pseudomonas marginalis* (B1), *Pseudomonas (Stenotrophomonas) boreopolis* (B1), *Pseudomonas* spp. (B1, B4, B5), ***Rahnella* spp.+** (A1, A3-A5, B), *Sanguibacter keddieii* (B1).

Bacilli: *Bacillus licheniformis* (B4), ***Bacillus subtilis**** (A5, B4, B5), *Bacillus* spp. (A1-A3, A5, B).

Corynebacteria: ***Arthrobacter globiformis**** (A, B), *Arthrobacter* spp. (A, B), ***Brevibacterium linens**** (A, B2, B5), *Brevibacterium helvolum* (A1-A4, B5), *Corynebacterium xerosis* (A2, B2-B4), *Corynebacterium* spp. (B1).

Other mesophilic bacteria: *Micrococcus roseus* (A1, A2, A5), *Micrococcus luteus* (A, B2-B5), *Micrococcus* spp. (A3, A4, B), *Nocardia* spp. (A2, B4), *Rhodococcus* spp. (A2, B4), *Staphylococcus epidermidis* (A1, A2, B1-B3, B5), *Staphylococcus* spp. (A, B), *Streptococcus* spp. (A2, A4, A5, B1-B4), ***Streptomyces albus**** (A2, B4), *Streptomyces* spp. (A, B).

Thermophilic actinomycetes: ***Saccharopolyspora rectivirgula**** **(synonyms:** ***Faenia rectivirgula, Micropolyspora faeni*****)** (A2), ***Thermoactinomyces vulgaris**** (A, B).

Fungi: ***Absidia* spp.*** (B2-B5), ***Alternaria alternata**+** (A1, A5, B1), ***Aspergillus fumigatus**+** (A1, A2, A4, B2-B5)**,** *Aspergillus repens* (A2, B1, B5), ***Candida* spp.*** (A2, B1, B5), *Geotrichum candidum* (A3, B1), *Monosporium* spp. (A4, A5, B3), ***Mucor* spp.*** (A1), *Paecilomyces* spp. (B2, C4), ***Penicillium* spp.*+** (A1, A2, A5, B1, B5)**,** ***Rhizopus nigricans*** * + (B2-B4), *Rhodotorula rubra* (A2, B1, C3).

Sites of isolation are given in parentheses. Quoting only the letter attributed to a particular factory ("A" or "B", without numbers) means that the species was isolated from all sampling sites within the factory. Names of species reported as having allergenic and/or immunotoxic properties (see text) are in bold and marked as follows: * allergenic species; + immunotoxic species.

A rich and diverse microflora may develop in beech logs stored in lumber yards before processing in sawmills. Prażmo *et al.* [41] found an abundant occurrence of Gram-negative bacteria in stored beech timber and in the air of a sawmill processing beech wood, with a distinct prevalence of *Rahnella* strains which have been isolated from over 70% of the total samples. This report corroborates with the results of the present work demonstrating abundant occurrence of *Rahnella* spp. in the air of a furniture factory during initial sawing of raw beech planks. Of the Gram-negative bacteria recovered from the air of furniture factories, *Rahnella* spp. and *Acinetobacter calcoaceticus* are known to possess strong endotoxic and/or allergenic properties [18, 47, 48, 49].

So far, little is known about the potentially pathogenic properties of dust-borne corynebacteria which prevailed among microbial strains isolated from the air of the examined furniture factories. The cases of allergic alveolitis caused by *Arthrobacter globiformis* and *Brevibacterium linens* were reported [38] and the involvement of peptidoglycan produced by these bacteria in causing organic dust toxic syndrome (ODTS) cannot be excluded [31].

The concentration of fungi in the factory using beech wood for producing furniture, on average was 5 times greater compared to that using fibre- and chipboards. Although the level of fungal pollution of air in furniture factories is by 1-3 orders of magnitude lower compared to those reported from sawmills and other wood processing facilities [2, 10, 13, 17, 19, 21, 36, 37], the presence of potentially pathogenic species poses a risk to the furniture-producing workers. Of the fungi commonly occurring in the air of furniture factories, *Aspergillus fumigatus*, *Penicillium* spp. and *Absidia* spp. possess allergenic and immunotoxic properties and are known risk factors of occupational respiratory disease [20, 27, 29, 30, 39, 55]. Sorenson *et al.* have demonstrated that yeasts are common contaminants of stored wood [51] and pose a potential risk of organic dust toxic syndrome in exposed woodworkers [52].

CONCLUSIONS

The workers of furniture factories are exposed to relatively low concentrations of airborne microorganisms which do not exceed the suggested occupational exposure limits. Nevertheless, the presence of allergenic and/or immunotoxic microbial species in the air of factories poses a potential risk of respiratory disease, in particular in sensitive workers.

REFERENCES

1. Abdel Hameed AA, Khoder MI, Farag SA: Organic dust and gaseous contaminants at wood working shops. *J Environ Monit* 2000, **2**, 73-76.

2. Alwis KU, Mandryk J, Hocking AD: Exposure to biohazards in wood dust: bacteria, fungi, endotoxins, and (1→3)-beta-D-glucans. *Appl Occup Environ Hyg* 1999, **14**, 598-608.

3. Al Zuhair YS, Whitaker CJ, Cinkotai FF: Ventilatory function in workers exposed to tea and wood dust. *Br J Ind Med* 1981, **38**, 339-345.

4. Barron GL: *The Genera of Hyphomycetes from Soil.* Williams & Wilkins, Baltimore 1968.

5. Belin L: Sawmill alveolitis in Sweden. *Int Archs Allergy Appl Immunol* 1987, **82**, 440-443.

6. Bohadana AB, Massin N, Wild P, Toamain JP, Engel S, Goutet P: Symptoms, airway responsiveness, and exposure to dust in beech and oak wood workers. *Occup Environ Med* 2000, **57**, 268-273.

7. Clark CS: Workgroup report on prevention and control. Workshop on Health Effects of Organic Dusts in the Farm Environment, Skokloster, Sweden, April 23-25, 1985. *Am J Ind Med* 1986, **10**, 267-273.

8. Cowan ST, Steel KJ: *Manual for the Identification of Medical Bacteria.* University Press, Cambridge 1965.

9. Demers PA, Teschke K, Kennedy SM: What to do about softwood dust? A review of respiratory effects and recommendations regarding exposure limits. *Am J Ind Med* 1997, **31**, 385-398.

10. Duchaine C, Meriaux A, Thorne PS, Cormier Y: Assessment of particulates and bioaerosols in eastern Canadian sawmills. *Am Ind Hyg Assoc J* 2000, **61**, 727-732.

11. Dutkiewicz J, Kwapiszewski C: New sampler for microbiological examination of the air. *Ochrona Powietrza* 1975**, 9(2)**, 37-42 (in Polish).

12. Dutkiewicz J: Exposure to dust-borne bacteria in agriculture. I. Environmental studies. *Arch Environ Health* 1978, **33**, 250-259.

13. Dutkiewicz J: Bacteria, fungi and endotoxin in stored timber logs and airborne sawdust in Poland. **In:** O'Rear CE, Llewellyn GC (Eds): *Biodeterioration Research 2*, 533-547. Plenum Press, New York 1989.

14. Dutkiewicz J, Jabłoński L: *Occupational Biohazards.* PZWL, Warsaw 1989 (in Polish).

15. Dutkiewicz J, Sorenson WG, Lewis DM, Olenchock SA: Levels of bacteria, fungi and endotoxin in stored timber. *Int Biodeterioration* 1992, **30**, 29-46.

16. Dutkiewicz J, Śpiewak R, Jabłoński L: *Classification of Occupational Biohazards and the Exposed Professional Groups.* 2nd Ed. Institute of Agricultural Medicine, Lublin 1999 (in Polish).

17. Dutkiewicz J, Krysińska-Traczyk E, Prażmo Z, Skórska C, Sitkowska J: Exposure to airborne microorganisms in Polish sawmills. *Ann Agric Environ Med* 2001, **8**, 71-80.

18. Dutkiewicz J, Skórska C, Krysińska-Traczyk E, Dutkiewicz E, Matuszyk A, Sitkowska J: Response of sawmill workers to work-related airborne allergens. *Ann Agric Environ Med* 2001, **8**, 81-90.

19. Dutkiewicz J, Olenchock SA, Krysińska-Traczyk E, Skórska C, Sitkowska J, Prażmo Z: Exposure to airborne microorganisms in fiberboard and chipboard factories. *Ann Agric Environ Med* 2001, **8**, 191-199.

20. Dykewicz MS, Laufer P, Patterson R, Roberts RN, Sommers HM: Woodman's disease: Hypersensitivity pneumonitis from cutting live trees. *J Allergy Clin Immunol* 1988, **81**, 455-460.

21. Eduard W: *Assessment of Mould Spore Exposure and Relations to Symptoms in Wood Trimmers*. Thesis. Agricultural University, Wageningen, The Netherlands 1993.

22. Eduard W, Sandven P, Levy F: Serum IgG antibodies to mold spores in two Norwegian sawmill populations: relationship to respiratory and other work-related symptoms. *Am J Ind Med* 1993, **24**, 207-222.

23. Enarson DA: Wood processing. **In:** Rylander R, Jacobs RR (Eds): *Organic Dusts. Exposure, Effects and Prevention*, 233-246. Lewis Publishers, Boca Raton, FL 1994.

24. Goldsmith DF, Shy CM: Respiratory health effects from occupational exposure to wood dust. *Scand J Work Environ Health* 1988, **14**, 1-15.

25. Johnson CE, Bernstein L, Gallagher JS, Bonventre PF, Brooks SM: Familial hypersensitivity pneumonitis induced by *Bacillus subtilis*. *Am Rev Respir Dis* 1980, **122**, 339-348.

26. Krieg NR, Holt JG (Eds): *Bergey's Manual of Systematic Bacteriology. Vol. 1*. Williams & Wilkins, Baltimore 1984.

27. Krysińska-Traczyk E: Moulds *Aspergillus fumigatus* as a cause of respiratory diseases of occupational origin. *Med Wiejska* 1973, **8**, 275-284 (in Polish).

28. Krysińska-Traczyk E, Skórska C, Milanowski J, Cholewa G, Sitkowska J, Dutkiewicz J, Fąfrowicz B: Microflora of the air in furniture factories as a potential occupational hazard: concentration and

composition of the microflora and imunological reactivity of the workers to microbial aeroallergens. *Pneumonol Alergol Pol* 1996, **64 (Suppl. 1)**, 38-44 (in Polish).

29. Lacey J, Crook B: Review: Fungal and actinomycete spores as pollutants of the workplace and occupational allergens. *Ann Occup Hyg* 1988, **32**, 515-533.

30. Lacey J, Dutkiewicz J: Bioaerosols and occupational lung disease. *J Aerosol Sci* 1994, **25**, 1371-1404.

31. Laitinen S, Kangas J, Husman K, Susitaval P: Evaluation of exposure to airborne bacterial endotoxins and peptidoglycans in selected work environments. *Ann Agric Environ Med* 2001, **8**, 213-219.

32. Larone DH: *Medically Important Fungi: A Guide to Identification.* American Society for Microbiology, Washington, D.C. 1993.

33. Levy JF: Colonisation of wood by fungi. **In:** Liese W (Ed): *Biological Transformation of Wood by Microorganisms*, 16-23. Springer-Verlag, Berlin 1975.

34. Litvinov MA: *Guide for Determination of the Microscopic Soil Fungi.* Izd. Nauka, Leningrad 1967 (in Russian).

35. Malmros P, Sigsgaard T, Bach B: Occupational health problems due to garbage sorting. *Waste Manag Res* 1992, **10**, 227-234.

36. Mandryk J, Alwis KU, Hocking AD: Work-related symptoms and dose-response relationships for personal exposures and pulmonary function among woodworkers. *Am J Ind Med* 1999, **35**, 481-490.

37. Mandryk J, Alwis KU, Hocking AD: Effects of personal exposures on pulmonary function and work-related symptoms among sawmill workers. *Ann Occup Hyg* 2000, **44**, 281-289.

38. Milanowski J, Dutkiewicz J, Potoczna H, Kuś L, Urbanowicz B: Allergic alveolitis among agricultural workers in eastern Poland: A study of twenty cases. *Ann Agric Environ Med* 1998, **5**, 31-43.

39. Minárik L, Mayer M, Votrubová V, Ürgeová N, Dutkiewicz J: Allergic alveolitis due to antigens present in mouldy beech chips - description of two cases. *Studia Pneumol Phtiseol Cechoslov* 1983, **43**, 38-45 (in Slovak).

40. Petretskii VV, Kunel'skaia VI, Petretskii NV: Microbial contamination of the air in the wood-processing industry. *Gig Tr Prof Zabol* 1991, **(8),** 20-21.

41. Prażmo Z, Dutkiewicz J, Cholewa G: Gram-negative bacteria associated with timber as a potential respiratory hazard for woodworkers. *Aerobiologia* 2000, **16,** 275-279.

42. Ramirez C: *Manual and Atlas of the Penicillia.* Elsevier, Amsterdam 1982.

43. Raper KB, Fennell DI: *The Genus Aspergillus.* Williams & Wilkins, Baltimore 1965.

44. Rask-Andersen A, Land CJ, Enlund K, Lundin A: Inhalation fever and respiratory symptoms in the trimming department of Swedish sawmills. *Am J Ind Med* 1994, **25**, 65-67.

45. Rossell SE, Abbot EGM, Levy JF: Bacteria and wood. A review of the literature relating to the presence, action and interaction of bacteria in wood. *J Inst Wood Sci* 1973, **6(2)**, 28-35.

46. Schlünssen V, Schaumburg I, Taudorf E, Mikkelsen AB, Sigsgaard T: Respiratory symptoms and lung function among Danish woodworkers. *J Occup Environ Med* 2002, **44**, 82-98.

47. Skórska C: Studies on the biological activity of the endotoxins of *Acinetobacter calcoaceticus. Med Wiejska* 1988, **23**, 203-208 (in Polish).

48. Skórska C: Assessment of the effects of the inhalation exposure of experimental animals to the allergenic extract of *Acinetobacter calcoaceticus* done with immunological methods. *Med Wiejska* 1991, **26**, 140-149 (in Polish).

49. Skórska C, Sitkowska J, Burrell R, Szuster-Ciesielska A, Dutkiewicz J: Effects of repeated inhalation exposure to microvesicle-bound endotoxin. *Ann Agric Environ Med* 1996, **3**, 61-65.

50. Sneath PHA, Mair N, Sharpe ME, Holt JG (Eds): *Bergey's Manual of Systematic Bacteriology. Vol. 2.* Williams & Wilkins, Baltimore 1986.

51. Sorenson WG, Simpson J, Dutkiewicz J: Yeasts and yeast-like fungi in stored timber. *Int Biodeterioration* 1991, **27**, 373-382.

52. Sorenson WG, Shahan TA, Simpson J: Cell wall preparations from environmental yeasts: effect on alveolar macrophage function *in vitro*. *Ann Agric Environ Med* 1998, **5**, 65-71.

53. Talini D, Monteverdi A, Benvenuti A, Petrozzino M, Di Pede F, Lemmi M, Carletti A, Macchioni P, Serretti N, Viegi G, Paggiaro P: Asthma-like symptoms, atopy, and bronchial responsiveness in furniture workers. *Occup Environ Med* 1998, **55**, 786-791.

54. Tatken RL (Ed): *Health Effects of Exposure to Wood Dust: A Summary of the Literature.* U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, NIOSH, Cincinnati, OH 1987.

55. Van Assendelft AHW, Raitio M, Turkia V: Fuel chip-induced hypersensitivity pneumonitis caused by Penicillium species. *Chest* 1985, **87**, 394-396.

56. Wilhelmsson B, Jernudd Y, Ripe E, Holmberg K: Nasal hypersensitivity in wood furniture woorkers. An allergological and immunological investigation with special reference to mould and wood. *Allergy* 1984, **39**, 586-595.

57. Williams ST, Sharpe ME, Holt JG (Eds): *Bergey's Manual of Systematic Bacteriology. Vol. 4.* Williams & Wilkins, Baltimore 1989.