POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 30(3): 259–273, Y. 2015

MICROBIAL AIR CONTAMINATION IN THE CENTER AND IN THE FORDON DISTRICT OF BYDGOSZCZ

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Key words: microbial air contamination, mold fungi, heterotrophic bacteria, actinomycetes.

Abstract

Air sampling by impaction was conducted at eight sampling sites in a seasonal cycle (sites I–IV located in the center of Bydgoszcz, sites V–VIII located in the Fordon district). The results indicate the dominance of mold fungi (77%). Heterotrophic mesophilic bacteria were the second most numerous (22%) while actinomycetes accounted for a small percentage of the total number of microorganisms (1%). The following genera contributed to the population of mold fungi: *Cladosporium* (84%), *Alternaria* (5%), *Penicillium* (3%), *Fusarium* (3%), *Aspergillus* (1%). According to Polish Standard air contamination with microorganisms belonging to all investigated groups did not exceed limit values. The number of the investigated microorganisms varied seasonally and depended on the sampling site. The highest numbers were typically recorded in summer and autumn, while the lowest, in winter. Fungi and actinomycetes were the most numerous in the Old Market Place in the Fordon District and heterotrophic bacteria, in the center of Bydgoszcz at ul. Gdańska.

MIKROBIOLOGICZNA JAKOŚĆ POWIETRZA W CENTRUM I DZIELNICY FORDON MIASTA BYDGOSZCZY

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Słowa kluczowe: zanieczyszczenie powietrza, grzyby pleśniowe, bakterie heterotroficzne, promieniowce.

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Abstrakt

Badanie mikroorganizmów występujących w powietrzu prowadzono na ośmiu stanowiskach badawczych (I–IV w centrum Bydgoszczy i V–VIII w dzielnicy Fordon), w cyklu sezonowym, przy użyciu metody zderzeniowej. Analizy wykazały, że wśród drobnoustrojów powietrza dominowały grzyby pleśniowe (77%), nieco mniejszą grupę stanowiły heterotroficzne bakterie mezofilne (22%), zaś promieniowce, stanowiły niewielki procent wśród ogółu mikroflory (1%). Wśród grzybów pleśniowych stwierdzono obecność grzybów z rodzaju: *Cladosporium* (84%), *Alternaria* (5%), *Penicillium* (3%), *Fusarium* (3%), *Aspergillus* (1%). Stopień skażenia powietrza poszczególnymi grupami mikroorganizmów zgodnie z Polską Normą przeważnie nie przekraczał dopuszczalnych wartości. Liczebność badanych drobnoustrojów była zróżnicowana i zmieniała się sezonowo oraz w zależności od miejsca poboru prób. Maksimum liczebności badanych grup drobnoustrojów stwierdzono zazwyczaj latem i jesienią, natomiast zimą notowano spadek ich liczby. Grzyby i promieniowce dominowały na Starym Rynku w Fordonie, natomiast bakterie heterotroficzne najliczniej występowały na stanowisku zlokalizowanym w centrum Bydgoszczy przy ul. Gdańskiej.

Introduction

The air is a mixture of gases which does not constitute an adequate environment for microorganisms as it fails to provide nutrients and good physico-chemical conditions. Failing to provide nutrients and good physico-chemical conditions, the air, a mixture of gases, does not constitute an adequate environment for microorganisms. However, microorganisms suspended in the air in the form of bioaerosol significantly affect air quality. Bioaerosol is a collection of biological particles dispersed in the air or the gas phase. It consists of single spores, pollen, bacterial cells and viruses, agregates of spores, cells, and other biological material, products or fragments of mycelium, fungal spores and bacterial cells (endotoxins and mytotoxins), biological material lifted from the ground on its own accord or carried by bigger non-biological particles (CHMIEL et al. 2015). Biological particles get into the atmosphere in many ways: removed from the surface of soil and plants, carried by the wind or lifted by means of thermal convection, released (either spontaneously or by rainfall) from natural bodies of water, and as a result of storing and processing solid and liquid waste (KULKARNI et al. 2011).

Qualitative and quantitative composition of bioaerosol depends on time and location.

Constituting 70% of the microbial population, filamentous fungi (*Cladosporium, Alternaria, Penicillium, Aspergillus, Mucor, Rhizopus*) are typically the main component of bioaerosols (D'AMATAGO et al. 2000). Saprophytic bacteria belonging to the genera *Micrococcus* and *Bacillus* constitute another numerous group. In contrast, actinomycetes and yeast (belonging to the genera *Torulopsis, Rhodotorula, Candida, Saccharomyces*) represent only 5% of the microorganisms isolated from the air.

Epidemiologial studies show that high concentration of microorganisms in the air can be allergenic. Sometimes, however, even very low concentrations of particular microorganisms can cause serious diseases (STRYJKOWSKA-SEKULSKA et al. 2007).

Fungal allergens may trigger symptoms of respiratory disorders and skin diseases in susceptible patients (TWAROCH et al. 2015). Exposure to molds may have multiple health effects: it can cause allergies in the form of rhinitis and bronchial asthma, allergic aveolitis, and in people with poor resistance can result in severe opportunistic infections (WISZNIEWSKA et al. 2004).

Fungal conidia present in the air contain extremely high amounts of mycotoxins (KARWOWSKA 2005). They cause skin infections and toxemias characterized by headaches, diarrhea, changes to immunological mechanisms and damage to the liver, kidneys and central nervous system, and they can also be carcinogenic (GOLOFIT-SZYMCZAK and SKOWRON 2005).

For the above reasons, it is important to monitor air quality in places of increased risk of biological contamination (hospitals and particularly isolation wards), in storage premises where food items are stored, in places where people spend time every day, like dwelling places, public utility buildings and atmospheric air in the streets of towns with heavy traffic (DONDERSKI et al. 2005).

This study is aimed at evaluating air quality in two crucially different parts of the town of Bydgoszcz, i.e. the centre and the Fordon district located in the east. The areas differ in terms of population, urban development, traffic density and number of tourists.

Materials and Methods

Sampling sites

We evaluated microbial air quality in the center of Bydgoszcz and in the Fordon district (Figure 1).

Bydgoszcz has an area of 176 km^2 and a population of 358 337 (CSO 2014). Due to unique natural values, 35% of its territory is located within the protected landscape area while 9% is covered by the Vistula Landscape Park (in the north and north-east of the city). Bydgoszcz can boast having a large number of parks (31 parks with an area of more than 2 ha) which cover the area of 879 hectares. It is known for well-developed tourist traffic (390 499 tourists in 2013), services and industries including food, chemical, (rolling stock and tram production), and information technology industries.

Fordon is a district located in the east of Bydgoszcz, in the Fordon Valley on the Vistula. It has a surface area of 3063 hectares and a population of 72 160.

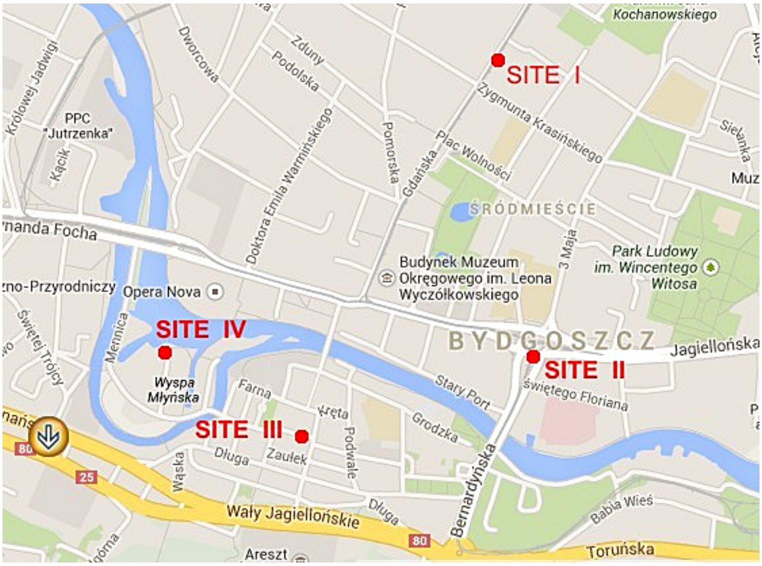

Fig. 1. The location of sites (Bydgoszcz)

Fig. 2. The location of sites (Fordon district)

Although green areas cover one third of its surface, it is principally a residential district comprising 20 housing estates, filled mainly with apartment blocks and single-family houses.

Sampling sites were located in the areas of both compact and scattered development.

Sampling sites were located in the center of Bydgoszcz: sampling site I – in ul. Gdańska, sampling site II – Rondo Jagiellonów, sampling site III – Wyspa Młyńska (historic river island within the Old Town district, famous for a wide range of cultural and recreational facilities, surrounded by boulevards and hydro facilities: canals, dams, bridges), sampling site IV – Old Market Place (Figure 1), and in the Fordon district: sampling site V – UTP Campus in ul. Fordońska, sampling site VI – Fordońska Dolina Śmierci (Fordon Death Valley – the site of mass killing and a mass grave of 1,200 – 1,400 Poles and Jews murdered between October and November 1939 by Nazi Germans), sampling site VII – Białe Marketplace (Tatra housing estate), sampling site VIII – Marketplace in Stary Fordon (Figure 2).

Sampling

The research was conducted in a seasonal cycle (spring, summer, autumn, winter), by the impaction method using Merck MAS – 100 air sampler.

The amount of 50–100 liters of air (depending on the expected contamination level) was filtered in the sampler's chamber containing a Petri dish filled with a suitable nutrient medium. The microflora from the air stream was sucked in by the air sampler and deposited on the surface of the medium. At all sampling sites sampling was conducted in three parallel repeats. The air samples were transported to the laboratory, placed in a thermostat and incubated for a specific time at an appropriate temperature. After the incubation grown colonies were counted and the number was expressed as colony forming units per cubic meter of air (CFU/1 m^3).

Air temperature, relative humidity and wind velocity were measured during sampling using Nielsen-Kellerman anemometer, Kestrel 3500 (Table 1).

Table 1

Meteorological parameters during sample collection

Date of sampling	Temperature (°C)	Humidity (%)	Wind speed (km/h)	Wind direction
13.05.2011	14	49	11	W
01.07.2011	33	30	7	SE
03.10.2011	18	56	8.5	S
18.02.2012	–1.4	83	5	N

Microbial Research

The microbial research was aimed at determining the following: 1) the total number of heterotrophic bacteria, 2) the number of mannitol-positive bacteria of S*taphylococcus* genus, 3) the number of *Pseudomonas fluorescens*, 3) the number of actinomycetes, 4) the number of mold fungi and their identification.

The total number of heterotrophic bacteria was determined using TSA agar medium. The bacteria were incubated at 37°C for 48 hours, then grown colonies were counted and their number was expressed as colony forming units per cubic meter of air (CFU/1 m^3).

The presence of mannitol-positive staphylococci was detected according to Polish Standard PN 89/Z-04111/02 using Chapman's nutrient medium. Bacterial cultures were incubated at 37°C for 48 hours, then grown colonies were counted. Bright yellow zones around a grown colony indicated a positive result. Additionally, the strains were Gram stained and identified under a microscope.

The number of *Pseudomonas fluorescens* was determined in accordance with Polish Standard PN 89/Z-04111/02 using Kinga's B nutrient medium. The bacterial cultures were incubated at 26°C for 5 days.

The number of actinomycetes and mold fungi was determined using Pochon's and Sabouraud's nutrient mediums accordingly. The microorganisms were incubated at 26°C for 5 days, after which time grown colonies were counted and their number was expressed as colony forming units per cubic meter of air (CFU/1 m^3). Mold fungi were identified on the basis of their macro- and microscopic features using the SAMSON et al. (2000) key.

Microbial air quality in Bydgoszcz was evaluated in accordance with Polish Standards PN 89/Z-04111/02 and PN-89/Z-04111/03. The results were analyzed in STATISTICA 6.0. Statistical analysis was based on Kruskal-Wallis test (one-way ANOVA on ranks), which assesses statistically significant differences between groups of data.

Results

The number of microorganisms belonging to all investigated microbial groups are presented in Tables 2 and 3 and Figure 3 and 4. The results indicate that the highest average number of heterotrophic bacteria was identified at sampling site I located in the center of Bydgoszcz in ul. Gdańska (467 CFU/m^3 of mesophilic bacteria). In the Fordon District, the highest average number of heterotrophic bacteria was identified at sampling site VII (Białe Marketplace). A slightly lower number was recorded at sampling sites II (Rondo Jagiellonów) – 165 CFU/m^3 and III (Wyspa Młyńska) – 161 CFU/m^3. The remaining sampling sites (i.e. IV- Old Market Place, V – UTP Campus, VI – Fordońska Dolina Śmierci (Fordon Death Valley), VIII – Market Place in Stary Fordon) were characterized by the lowest average number of heterotrophic bacteria (under 70 CFU/m^3). According to Polish Standards N-89/Z-04111/02 and 03 all sampling sites can be regarded as uncontaminated. We observed seasonal fluctuations in the number of heterotrophic bacteria with the highest numbers recorded in the summer, and lower and similar in the remaining seasons, both in the center of Bydgoszcz and the Fordon District (Table 2).

Table 2

The number of microorganisms and level of microbial air contamination at different sampling sites in the center of Bydgoszcz and in the Fordon district according to Polish Standards PN-89/Z-04111/02 and PN-89/Z-04111/03

Sampling site	Number of microorganisms in 1 m^3 of air				
	Heterorophic *bacteria*	*Staphylococci*	*Pseudomonas fluorescens*	*Actinomycetes*	Mold fungi
I	467 *	7 **	6 **	13 **	705 *
II	165 *	11 **	2 **	7 *	523 *
III	161 *	4 **	1 **	17 **	543 *
IV	60 *	1 **	4 **	6 *	511 *
V	58 *	3 **	6 **	4 *	562 *
VI	56 *	2 **	4 **	6 *	685 *
VII	193 *	4 **	21 **	8 *	721 *
VIII	69 *	0 *	4 **	21 **	748 *
Polish Norm No pollution * Medium pollution** Heavy pollution ***	<1000 1000–3000 >3000	No < 25 > 25	No < 50 50	10 10–100 > 100	3000–5000 5000–10000 > 10000

Table 3

An average number of microorganisms in 1 m^3 of air in the center of Bydgoszcz and in the Fordon district, depending on the season

Date of sampling	Heterorophic *bacteria*	*Staphylococci*	*Pseudomonas fluorescens*	*Actinomycetes*	Mold fungi
	[CFU · m^{-3}]				
13.05.2011	121* 0-668**	1* 0-6**	3* 0-10**	3* 0-10**	694* 213-1526**
1.07.2011	259* 90-600**	5* 0-23**	16* 0-80**	9* 0-20**	997* 88-1610**
3.10.2011	109* 30-240**	8* 0-23**	6* 0-15**	24* 3-60**	709* 413-1230**
18.02.2012	114* 0-668**	0,5* 0-4**	0* 0-0**	1* 0-2**	99* 34-228**

Explanations: * mean, ** range

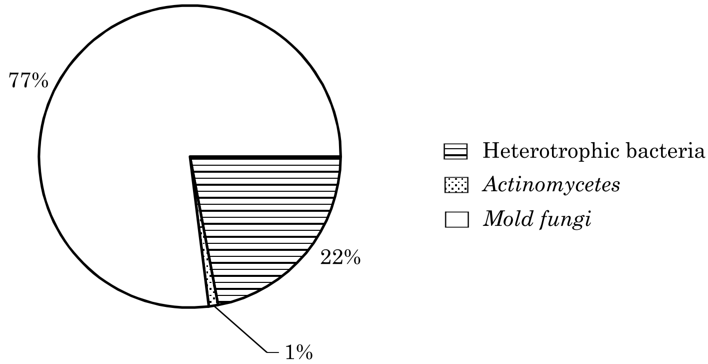

Fig. 3. Percentage fraction of microorganisms in the air

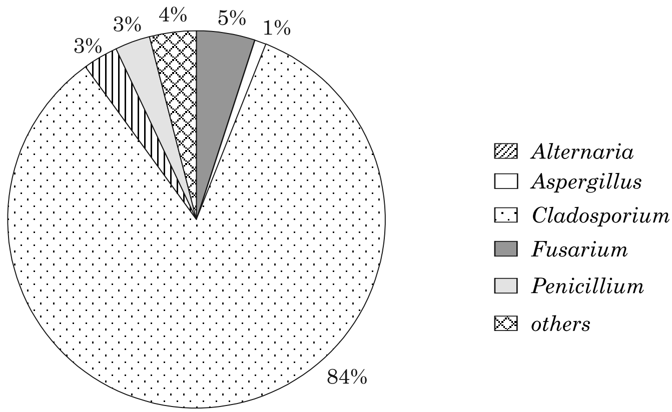

Fig. 4. Dominant genera of mold fungi

The results show that mannitol-positive *Staphylococci* were not identified only at sampling site VIII (Market Place in Stary Fordon) thereby indicating that the air was not contaminated. The remaining sites were moderately contaminated with *Staphylococci* whose number did not exceed 11 CFU/m^3 (Table 1). The most numerous in the summer and the fall, *Staphylococci* were sparse in the winter and the spring (Table 2).

The results indicate moderate air contamination with *Pseudomonas fluorescens* in Bydgoszcz. The highest average number of these microorganisms (21 CFU/m^3) was recorded in the Fordon District at sampling site VII (Białe Marketplace). They were identified from spring to fall but they were not identified in the winter (Table 3).

Actinomycetes were the most numerous at the following sampling sites: I (in ul. Gdańska) – 13 CFU/m^3, III (Wyspa Młyńska) – 17 CFU/m^3 and VIII

(Market Place in Stary Fordon) – 21 CFU/m^3, which, according to Polish Standards, indicates their moderate contamination with these microorganisms. At the remaining sites the air was classified as uncontaminated with actinomycetes (Table 2). Actinomycetes had the highest percent contribution to the microbial community in summer and fall and significantly lower in spring and winter (Table 3).

Similarly to other microorganisms, mold fungi were the least numerous in the winter (Table 3). According to Polish Standards the air in the center of Bydgoszcz and in the Fordon District was uncontaminated with these microorganisms. Their average highest number (over 700 CFU/m^3) was recorded at sampling sites I (in ul. Gdańska), VII (Białe Marketplace, and VIII (Market Place in Stary Fordon). At the remaining sites the average number of mold fungi was lower (Table 2).

The following genera contributed to the population of mold fungi: *Cladosporium* (84%), *Alternaria* (5%), *Penicillium* (3%), *Fusarium* (3%), *Aspergillus* (1%) (Figure 4).

Statistical analysis did not indicate statistically significant differences between the numbers of investigated microorganisms and sampling sites. Statistically significant differences were found only between the number of staphylococci, actinomycetes and fungi during some research seasons (Table 4).

Table 4. Statistical differences between the numbers of identified groups of microorganisms in different research seasons

Microorganisms		13.05.2011	1.07.2011	3.10.2011	18.02.2012
Heterotrophic bacteria	13.05.2011	–	ns	ns	ns
	01.07.2011	ns	–	ns	ns
	03.10.2011	ns	ns	–	ns
	18.02.2012	ns	ns	ns	–
Pseudomonas flourescens	13.05.2011	–	ns	ns	ns
	01.07.2011	ns	–	ns	ns
	03.10.2011	ns	ns	–	ns
	18.02.2012	ns	ns	ns	–
Staphylococci	13.05.2011	–	ns	ns	ns
	01.07.2011	ns	–	ns	ns
	03.10.2011	ns	ns	–	*
	18.02.2012	ns	ns	*	–
Actinomycetes	13.05.2011	–	ns	*	ns
	01.07.2011	ns	–	ns	ns
	03.10.2011	*	ns	–	**
	18.02.2012	ns	ns	**	–
Mold fungi	03.05.2011	–	ns	ns	*
	01.07.2011	ns	–	ns	***
	03.10.2011	ns	ns	–	**
	18.02.2012	*	***	**	–

Explanations: ns – differences statistically non-significant, * $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

Discussion

Air pollution is an important problem facing the world. Rapid industrial and transport development together with aggressive urban expansion lead to the menacing concentration of the air pollutant emission sources within relatively small areas. The atmosphere must absorb substantial amounts of harmful contaminants including different powders, organic compounds, non-organic compounds of nitrogen, sulphur, coal and other compounds as well as various microorganisms including bacteria, viruses, fungal spores etc. Since the air's ability to self-clean is vastly limited, it is necessary to supervise its quality and take measures which would protect it from excessive pollution (MICHAŁKIEWICZ 2002).

However, the results presented in this study should be regarded as temporary values, valid only at the time of the measurement. The physico-chemical parameters of the air as well as its contamination level can change dramatically within minutes (COX 1987). Hence, the results provide merely an approximate estimation, allowing the evaluation of the microbial number at a given moment.

When evaluating microbial air quality one should take into account a range of factors that affect the composition of microflora and therefore the results of the research: the type of emission sources, intensity of microbial emission, meteorological conditions (temperature, wind force, humidity, precipitation, sunlight, UV radiation) and the season of the year (CHMIEL 2015, KRZYSZTOFIK 1992, BREZEA-BORUTA 2010).

High temperatures and lack of precipitation foster their growth, which explains why we usually recorded a higher number of bacteria and fungi in the summer than in the winter, when weather conditions are unfavorable for microbial growth. Similarly to other cities including Toruń in Poland (DONDERSKI et al. 2005) and Castilla La-Mancha (SABARIEGO et al. 2012) and Cartagena (ELVIRA-RENDULES et al. 2013) in Spain, at a landfill site (MIAŚKIEWICZ-PĘSKA et al. 2015), the number of bacteria and fungi in the investigated air varied seasonally, reaching their maximum in summer.

Fluctuations of the total number of microorganisms depend largely on ground conditions, such as the availability of nutrients, and the intensity of microbial growth in soil and in water as well as on garbage, plant and animal remains (KRZYSZTOFIK 1992).

The results indicate that traffic, that raising dust which contains microorganisms, has a great impact on their number in the air. After some time, floating aerosol settles and accumulates on the surface of soil, water, plants, and buildings, constituting a potential source of secondary emission that can be triggered by wind or traffic (KOŁWZAN et al. 2012). Hence we believe that heavy road traffic pedestrian traffic contributed to the increased number of heterotrophic bacteria and mold fungi in the air along the main street in the center of Bydgoszcz (ul. Gdańska) and in the Białe Marketplace as well as to the increased number of mold fungi in the the Old Market Place in Fordon.

In addition, the air at sampling sites located in the center of Bydgoszcz generally contained a higher number of microorganisms than at sites located far from the center, i.e. the Fordon district. Mold fungi were the only microorganisms whose number was similar at all sampling sites. The same pattern was also noted by DONDERSKI et al. (2005) who recorded higher numbers of bacteria in the Old Town in Toruń than at Rubinkowo housing estate. Similarly, BURKOWSKA et al. (2012) recorded maxima of mesophilic bacteria, molds, mannitol-positive staphylococci and hemolytic bacteria in the urbanized part of Ciechocinek and their minima around the graduation towers.

The microbial population in the air in the center of Bydgoszcz and in the Fordon district was dominated by mold fungi. Heterotrophic mesophilic bacteria were the second most numerous while actinomycetes accounted for a small percentage of the microbial population. Similar results were obtained at the municipal landfill site Żółwin-Wypaleniska (MAŁECKA-ADAMOWICZ 2007) and the sewage treatment plant Kapuściska (MAŁECKA-ADAMOWICZ 2011) in Bydgoszcz.

According to Polish Standards PN-89/Z-04111/02 and 03 the air in the center of Bydgoszcz and the Fordon district can be considered uncontaminated with heterotrophic bacteria. Similar number of heterotrophic bacteria (ranging from 111 CFU/m^3 to 189 CFU/m^3) was recorded in the Old Town in Toruń (DONDERSKI et al. 2005). Other authors including BUGAJNY et.al. (2005) recorded 10-fold higher number of mesophilic bacteria (i.e. 13,000 CFU/m^3) in large urban areas such as Poznań. FANG et al. (2007) during the research conducted in Beijing in areas with high level of traffic and human activity, recorded even 22,000 CFU/m^3).

Regarded as air quality indicators, *Staphylococci* species indicate possible air contamination with pathogenic microorganisms (AKERMAN et al. 2003). Even without producing spores, they have the ability to remain in the air for long periods of time. This quality is of great importance as it indicates that infections can easily spread by airborne transmission (PILLAI and RICKE 2002). High sensitivity of pathogenic organisms to negative meteorological factors combined with the absence of emission sources may be responsible for their low number in the air (DONDERSKI et al. 2005). The low number of mannitol-positive staphylococci in the air in the center of Bydgoszcz (1–11 CFU/m^3) and Fordon (0–4 CFU/m^3) district seems to confirm this observation, indicating moderate air pollution. Similar results were obtained by MAŁECKA-ADAMOWICZ et al. (2011) in the Forest Recreation Park in Myślęcinek, where the air was moderately contaminated with these microorganisms at all sampling sites (5–25 CFU/m^3).

The presence of *Pseudomaonas fluorescens* in the air indicates its contamination with bioaerosols originating from water bodies. The air in the center of Bydgoszcz and the Fordon district was moderately contaminated with these microorganisms, which may be related to the fact that River Brda cuts through Bydgoszcz and flows into River Vistula in the Fordon district and both rivers can constitute emission sources of of these bacteria.

Actinomycetes, air quality indicators originating from soil, are always present in the air, both in urban areas and in the vicinity of municipal facilities (KALISZ 1994). The air in the center of Bydgoszcz and in the Fordon district contained small numbers of actinomycetes, i.e. from 4 to 21 CFU/m^3. Similar results were obtained in urban parts of Ciechocinek (BURKOWSKA and DONDERSKI 2007). In contrast, a large number of actinomycetes was recorded in the vicinity of the Kapuściska sewage treatment plant (MAŁECKA-ADAMOWICZ et al. 2011) and in the municipal landfill site in Żółwin-Wypaleniska (MAŁECKA-ADAMOWICZ et al. 2007).

In considering the presence of actinomycetes in the air, it should be emphasized that KAZIMIERCZUK et al. (2004) found these bacteria to be common organisms in atmospheric aerosols, which therefore cannot be treated as valuable indicators of air quality. However, GRZYB and FRĄCZEK (2013) maintain that actinomycetes are one of the most important components of bioaerosols and that they may pose a health risk as even very low concentrations may trigger allergies.

The microbial community in the air in the center of Bydgoszcz and in the Fordon district was dominated by mold fungi, which confirms the thesis that they are well-adapted to spreading in the air. However, although they can survive in almost all environments, they thrive indoors affecting health and well-being of residents (KRZYSZTOFIK 1968). The surface of soil and plants as well as building facades also provide habitat for these microorganisms. Mold fungi produce large numbers of spores, transmitted over thousands of kilometers and found even in stratosphere.

Mold fungi have also been isolated from the air in caves, from cave rocks, sediments and biota present in caves (BASTIAN et al. 2010, JURADO et al. 2010, WANG et al. 2010, OGÓREK et al. 2013). More than 600 CFU/m3 of mold fungi were isolated from the air outside Niedźwiedzia Cave (OGÓREK et al. 2014).

The microbial air quality is influenced not only by the number of molds in the air, but also by the species composition of the fungal community.

The following fungal genera were identified in the air in the center of Bydgoszcz and the Fordon district: *Cladosporium* (84%), *Alternaria* (5%), *Penicillium* (3%), *Fusarium* (3%), *Aspergillus* (1%). A similar composition was noted in the center of Polish cities: Ciechocinek (BURKOWSKA and DONDERSKI

2008), Poznań (Bugajny et al. 2005) and in the southern Iraq in Basrah (Muhsin and Adlan 2012). In the atmosphere of EL – Beida City (Libya), *Alternaria, Aspergillus, Cladosporium, Fusarium* and *Penicilium* were recorded in all months of the year (El-Gali and Abdullrahman 2014).

Cladosporium species have a world-wide distribution and are amongst the most common air-borne mold fungi. As has been confirmed by earlier findings, *Cladosporium* species prevail in the outdoor air, constituting between 50 and 90% of the fungal population (Bugajny et al. 2005), (Elvira-Rendueles 2013). Some species are commonly found on living and dead plant material, some parasitize other fungi (Dolińska et al. 2011).

Microbial air contaminants may emit secondary metabolites including mycotoxins, endotoxins, enterotoxins, and enzymes affecting human health. Molds of the genera *Aspergillus*, *Candida* and *Alternaria* which enter the body through the respiratory tract with spore-infected air also pose a threat to human health including allergy risk (Gołofit-Szymczak and Skowron 2005). Sensitivity to fungi is not only typically diagnosed in patients suffering from asthma but may also represent a risk factor for developing this disease (Jo et. al. 2014). Regular monitoring of microbial air quality is therefore necessary.

The information on the airbone fungi in an area would be useful to determine geographical patterns of asthma and hay fever **(**Adhikari et al. 2004**).** Daily monitoring of the number of molds in the air seems a practical solution. It is also recommended that researchers determine health effects caused by fungi and establish exposure thresholds and guidelines for the medical community (Portnoy 2004).

Conclusions

Microbial community in the center of Bydgoszcz and the Fordon district was dominated by mold fungi, followed by heterotrophic mesophilic bacteria. The number of the investigated microorganisms varied over time and depended on the sampling site. According to Polish Standards (PN-89/Z-04111/02 and PN-89/Z-04111/03) air contamination with all microbial groups in the center of Bydgoszcz and Fordon District did not exceed limit values.

Translated by Dorota Sobierajska

Accepted for print 15.07.2015

References

Adhikari A., Sen M.M., Gupta-Bhattacharya S., Chanda S. 2004. *Airbone viable, non-iable, and allergenic fungi in a rural agricultural area of India: a 2-year study at five outdoor sampling stations*. Sci. Total Environ., 326: 123–141.

BASTIAN F., JURADO V., NOVÁKOWÁ A., ALABOUVETTE C., SAIZ-JIMENEZ C. 2010. *The microbiology of Lascaux Cave*. Microbiology, 156: 644–652. http://dx.doi.org/10.1099/mic.0.036160-0

BREZA-BORUTA B. 2010. *Ocena mikrobiologicznego zanieczyszczenia powietrza na terenie oczyszczalni ścieków*. Woda-Środowisko-Obszary Wiejskie, 3(31): 49–57.

BUGAJNY A., KNOPKIEWICZ M., PIOTRASZEWSKA-PAJAK A., SEKULSKA-STRYJKOWSKA M., STACH A., FILIPIAK M. 2005. *On the microbiological quality of the outdoor air in Poznań, Poland*. Pol. J. Environ. Stud., 14: 287–293.

BURKOWSKA A., DONDERSKI W. 2007. *Bacterial pollution of air in health resort Ciechocinek*. Pol. J. Natur. Sc., 22 (4): 633–644.

BURKOWSKA A., DONDERSKI W. 2008. *Airbone molds in the air of Ciechocinek SPA*. Pol. J. Natur. Sc., 23 (4): 790–800.

BURKOWSKA A., KALWASIŃSKA A., WALCZAK M. 2012. *Airbone mesophilic bacteria at the Ciechocinek Health Resort*. Pol. J. Environ. Stud., 2: 307–312.

CHMIEL M.J., FRĄZCEK K., GRZYB J. 2015. *The problems of microbiological air contamination monitoring*. Water-Environment-Rural Areas, (I–III). T.15. Z.1(49): 17–27

COX C.S. 1987. *The aerobiological pathway of microorganisms*. Ed: John Wiley&Sons, Chichester.

D'AMATAGO G., LICCARDI G., RUSSSO M., D'AMATAGO M. 2000. *On the interrelationshop beetwen outdoor air polution and respiratory allergy*. Aerobiologia, 16: 1.

DOLIŃSKA T.M., BARTKOWSKA A., SCHOLLENBERGER M. 2011. *Light and canning microscope observations of Cladosporium uredinicola growth on rust fungi*. Phytopathologia, 61: 37–44.

DONDERSKI W., WALCZK M., PIETRZAK M. 2005. *Microbiological contamination of air within the city of Toruń*. Pol. J. Environ. Stud., 14: 223–230.

EL-GALI Z. I., ABDULLRAHMAN E. M. 2014. *Distribution of some molds in the atmospheric air of El-Beida city, Libya*. International Journal of Innovative and Applied Research, 6: 1–7.

ELVIRA-RENDUELES B., MORENO J., GARCIA-SANCZEZ A., VERGARA N., MARTINEZ-GARCIA M.J., MORENO-GRAU S. 2013. *Air-spore in Cartagena, Spain: Viable and non-viable sampling methods*. Ann. Agric. Environ. Med., 4: 664–671.

FANG Z., OUYANG Z., ZHENG H., WANG X., HU L. 2007. *Culturable Airbone Bacteria in Outdoor Environments in Beijing, China*. Microb. Ecol., 54: 487.

GRAJEWSKI J., TWARUŻEK M. 2004. *Zdrowotne aspekty oddziaływania grzybów pleśniowych i mykotoksyn*. Alergia, 3 (21): 45–49.

GOŁOFIT-SZYMCZAK M., SKOWRON J. 2005. *Zagrożenia mikrobiologiczne w pomieszczeniach biurowych*. Bezpieczeństwo pracy, 3: 29–31.

GRZYB J., FRĄCZEK K. 2013. *Bioaerosol- forming actinomycetes at the selected sites of Kraków*. Ecological Chemistry Engineering. A. 20 (4–5): 443–452.

Główny Urząd Statystyczny 2014 [http://www.bydgoszcz.pl/binary/Bydgoszcz_2014_tcm29-185916.pdf Bydgoszcz w liczbach 2014]

JO E.J., KIM M.Y., LEE S.Y., KIM M.H., SONG W.J. et. al. 2014. *Eosinophilic Airways inflammation and Airways hyperresponsiveness according to aeroallergen sensitization pattern in patients with lower airway symptoms*. Allergy Asthma Immunol Res., 6: 39–46.

JURADO V., LAIZ L., RODRIGUEZ-NAVA V., BOIRON P., HERMOSIN B., SANCZEZ-MORALS S., SAIZ-JIMENEZ C. 2010. *Pathogenic and opportunistic microorganisms in caves*. Int. J. Speleol., 39: 15–24. http://dx.doi.org/10.5038/1827-806X.39.1.2

KALISZ M., SAŁBUT J., KAŹIMIERCZUK M. 1994. *Ocena oddziaływania obiektów komunalnych na mikrobiologiczną jakość powietrza oraz rozprzestrzeniania się odorów*. Ochr. Środ. Zasob. Natur., 9 s. 125–142.

KARWOWSKA E. 2005. *Microbiological air contamination in farming environment*. Pol. J. Environ. Stud., 14: 445–449.

KAŹIMIERCZUK M., KAKISZ M., SAŁBUT J. 2004. *Mi Mikrobiologiczne zanieczyszczenie powietrza w otoczeniu obiektów gospodarki komunalnej*. (Monografia) Instytut Ochrony Środowiska, Dział Wydawnictw IOŚ, Warszawa.

KOŁWZAN B., JADCZYK P., PASTERNAK G., GŁUSZCZAK J., PAWLIK M., KRAWCZYŃSKA M., KLEIN J., RYBAK J. 2012. *Ocena stanu sanitarnego powietrza w otoczeniu wybranej oczyszczalni ścieków*. Ochrona środowiska, 34(2): 9–14.

KRZYSZTOFIK B. 1968. *Aerozole biologiczne jako element zanieczyszczenia powietrza atmosferycznego oraz powietrza pomieszczeń*. Konferencja Naukowo-Techniczna, NOT-PZITS, Warszawa.

KRZYSZTOFIK B. 1992. *Mikrobiologia powietrza*. PWN, Warszawa.
KULKARNI P., BARON P.A., WILLEKE K. (red.). 2011, *Aerosol measurement: principles, techniques, and applications*. John Willey and Sons, Inc. New York.
MAŁECKA-ADAMOWICZ M., DONDERSKI W., DOKLADNA W. 2011. *Microflora of Air in the Sewage Treatment Plant of Kapuściska in Bydgoszcz*. Pol. J. Environ. Stud., 5: 1235–1242.
MAŁECKA-ADAMOWICZ M., DONDERSKI W., KACZANOWSKA J. 2007. *The Impact of a Landfill Site in Żółwin – Wypaleniska on the Microbiological Quality of the Air*. Pol. J. Environ. Stud., 1: 101–107.
MAŁECKA-ADAMOWICZ M., DONDERSKI W., OKONIEWSKAIA A. 2010. *Evaluation of Microbial Air Quality In a Forest Recreation Park in Myślęcinek*. Pol. J. Environ. Stud., 1: 107–113.
MIAŚKIEWICZ-PĘSKA E., SZYŁAK-SZYDLOWSKI M. 2015. *Air pollution in landfill of wastes other than hazardous or inert*. Archives of Environmental Protection, 41(2): 41–46
MICHAŁKIEWICZ M. 2002. *Ocena stopnia mikrobiologicznego zanieczyszczenia powietrza wokół Grupowej Oczyszczalni Ścieków i Kompostowni Odpadów w Milanówku* (etap IV). http://www.rakstop.engo.pl/www/milanoce.htm
MUHSIN T.M, ADLAN M.M. 2012. *Seasonal distribution pattern of outdoor airborne fungi in Basrah city, southern Iraq*. Journal of Basrah Researches (Sciences), 38: 90–98.
OGÓREK R., LEJMAN A., MATKOWSKI K. 2013. *Fungi isolated from Niedźwiedzia Cave In Kletno (Lower Silesia, Poland)*. Int. J. Speleol., 42: 161–166.
OGÓREK R., LEJMAN A., MATKOWSKI K. 2014. *Influence of the external environment on airbone fungi isolated from a cave*. Pol. J. Environ. Stud., 2: 435–440.
PILLAI S., RICKE SC. 2002. *Bioaerosols from municipal and animal wastes: background and contemporary*. Can. J. Microbial., 48: 681–696.
Polish Norm (PN-89/Z-04111/02). *Ochrona czystości powietrza. Badania mikrobiologiczne. Oznaczanie liczby bakterii w powietrzu atmosferycznym (imisja) przy pobieraniu próbek metodą aspiracyjną i sedymentacyjną*.
Polish Norm (PN-89/Z-04111/03). *Ochrona czystości powietrza. Badania mikrobiologiczne. Oznaczanie liczby grzybów mikroskopowych w powietrzu atmosferycznym (imisja) przy pobieraniu próbek metodą aspiracyjną i sedymentacyjną*.
PORTNOY J.M., BARNES CH. S., KENNEDY K. 2004. *Sampling for indoor fungi*. J. Allergy Clin. Immunol., 113: 189–198.
SABARIEGO S., BOUSO V., PERÉZ-BADIA. 2012. *Comparative study of airbone Alternaria conidia levels in two cities in Castilla-La Mancha (central Spain), and correlations with weather-related variables.* Ann. Agric. Environ. Med., 2: 227–232.
SAMSON R.A, HOEKSTRA E.S. 2000. *Introduction to food- and airborne fungi*. Published and distributed by Centraalbureau voor Schimmelcultures, P.O.Box 85167, 3508 AD Utrecht, The Netherlands.
STRYJKOWSKA-SEKULSKA M., PIOTRASZEWSKA-PAJĄK A., SZYSZKA A., NOWICKI M., FILIPIAK M. 2007. *Microbiological quality of indoor air in university rooms*. Pol. J. Environ. Stud., 4: 623–632.
TWAROCH T.E., CURIN M., VALENTA R., SWOBODA I. 2015, *Mold allergens In respiratory allergy: from structure to therapy*. Allergy Asthma Immunol. Res. 7(3): 205–220.
WANG W., MA X., MA Y., MAO L., WU F., MA X., AN L., FENG H. 2010. *Seasonal dynamice of airbone fungi in different caves of the Mogao Grottoes, Dunhuang, China*. Int. Biodeter. Biodegr., 64: 461–466 http://dx.doi.org/10.1016/j.ibiod.2010.05.005
WISZNIEWSKA M., WALUSIAK J., GUTAROWSKA B., ŻAKOWSKA Z., PAŁCZYŃSKI C. 2004. *Mold in the communal environment and the workplace – a significant health risk*. Med Pr., 55(3): 257–266.