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Microbiological air quality at municipal waste sorting plant

Mikrobiologiczna jakość powietrza w zakładzie segregowania odpadów

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Abstract
Municipal waste plants can be a source of biological contamination of the environment, depending on the method of operation and the type of collected waste. The aim of this study was the quantitative characteristics of airborne microorganisms at the Barycz municipal waste sorting plant in Cracow. Bioaerosol measurements of indoor and outdoor air of the municipal waste sorting plant were performed during the summer season using a six-stage Andersen cascade impactor. The highest concentration of bacterial and fungal aerosol was observed in the medium fraction sorting room (129.02×10^3 cfu·m^{-3} and 116.21×10^3 cfu·m^{-3}, respectively). There were statistically significant differences in the concentrations of bacterial and fungal aerosol between indoor and outdoor air. The calculations showed a significant correlation between the concentration of bioaerosol and particulate matter. Based on the analysis of bioaerosol particle size distribution, it was found that the concentration of bacteria and fungi has a maximum value in the diameter range 3.3–7.0 µm. The study confirmed that the municipal waste sorting plants can be causing exposure to microbiological agents.

Streszczenie
Zakłady gospodarki odpadami, w zależności od sposobu eksploatacji i rodzaju składowanych odpadów, mogą być źródłem skażeń biologicznych otaczającego środowiska. Celem badań była ilościowa charakterystyka jakości mikrobiologicznej powietrza na terenie sortowni odpadów komunalnych Barycz w Krakowie. Pomiary bioaerozolu wykonano latem, w pomieszczeniach pracy sortowni odpadów Barycz oraz na zewnątrz zakładu, przy użyciu 6-stopniowego impaktora kaskadowego Andersena. Najwyższe stężenia aerozoli bakteryjnych i grzybowych odnotowano w pomieszczeniu kabiny sortowniczej frakcji średniej (odpowiednio 129,02×10^3 jtk·m^{-3} i 116,21×10^3 jtk·m^{-3}). Stwierdzono istotne statystycznie różnice w stężeniu aerozolu bakteryjnego i grzybowego pomiędzy badanymi pomieszczeniami i tłem zewnętrznym. Obliczenia wykazały istotną korelację pomiędzy stężeniem bioaerozolu, a zapyleniem. Na podstawie analizy rozkładu ziarnowego bioaerozolu stwierdzono, że stężenie bakterii oraz grzybów osiągało swoje maksymalne wartości w zakresie średnic 3,3-7,0 µm. Przeprowadzone badania potwierdzają, że sortownie odpadów komunalnych mogą być środowiskiem pracy związanym z narażeniem na szkodliwe czynniki mikrobiologiczne.

1. INTRODUCTION

In recent years, increasing attention is paid to increasing biological hazards associated with the collection of municipal waste in landfills and the functioning of municipal waste sorting plants. The employees working in the landfill and sorting plants are concerned mainly about the health effects due to exposure to biological agents [Breza-Boruta 2012]. In the case of municipal waste sorting plants, the risk in the workplace is primarily associated with the generation of bioaerosol and organic dust [Dutkiewicz 1997]. It was also demonstrated that exposure to harmful components of bioaerosols in the workplace can cause many adverse health effects, from simple irritation through various toxic and allergic reactions, up to the occurrence of infections and infectious diseases [Douwes et al. 2003, Zielińska-Jankiewicz and Kozajda 2003, Dutkiewicz 2004]. Biological factors are becoming a serious problem of occupational medicine and public health. Hazards caused by these factors are related to specific professions, as well as to the presence and properties of individual factors [Dutkiewicz and Górny 2002].
Due to the fact that the microbiological quality of air is a very important factor in the workplace, the aim of this study was to characterize this property of air at the municipal waste sorting plant Barycz in Cracow.

2. MATERIALS AND METHODS

The study was carried out in the summer of 2015 at the premises of the waste sorting plant Barycz. The samples of air were collected in duplicate at five measuring points (sorting cabins and control rooms) in the buffer zone and at a point situated outside the sorting plant (as the “background” 100 metres from the plant). The waste sorting plant Barycz is a comprehensive facility

designed for mechanical and manual sorting of dry fraction of municipal waste. At the outset, wastes are subjected to a process of mechanical sifting, then separation of metals and manual sorting in sorting cabins. This facility allows the recovery of secondary raw materials, which are transferred for further reuse. The air samples were collected using a six-stage Andersen cascade impactor (model 10-710, Graseby-Andersen, Inc., Atlanta, GA). The sampler was placed at a height of 1.5 m above the floor or ground (outdoor measurements) to simulate the aspiration from the human breathing zone. A 5-minute sampling period and the flow rate of 28.3 $dm^3 \cdot min^{-1}$ were applied for the collection of air samples. Bacteria were collected on tryptic soy agar (TSA LAB-AGAR™, Biocorp) and fungi were collected on malt agar (Malt Extract Agar, Biocorp) media. During sampling, the air temperature and relative humidity were measured using a hygrometer Kestrel 4000 and particulate matter was measured using a dust analyser DustTrak II (model 8530, TSI Inc., Shoreview, MN, USA). The air samples were collected during normal routine operation of waste sorting.

The TSA plates were incubated for 1 hour at 37°C, then 3 days at 22°C and another 3 days at 4°C. The MEA plates were incubated for 4 days at 30°C and then for 4 days at 22°C. The prolonged incubation of samples for culturing of bacteria or fungi enables the growth of slowly growing strains at a lower temperature range. After incubation, the bacterial and fungal colonies were counted. The concentration of bioaerosol was calculated as the number of colony forming units per cubic meter of air ($cfu \cdot m^{-3}$). The results were statistically analysed using Statistica 12 (StatSoft, Inc., Tulsa, OK, USA). The analysis of variance (ANOVA) was performed and the significance of differences between means was verified by the Tukey's test (α=0.05). The results showing the effect of microclimatic parameters (temperature and relative humidity) on the prevalence of airborne microorganisms were evaluated using the *r* coefficient of the Pearson's correlation.

3. RESULTS AND DISCUSSION

The concentrations of bacterial and fungal aerosol are presented in Table 1. The investigation showed that the highest concentration of airborne bacteria was observed in the medium fraction sorting room (129.02×10^3 $cfu \cdot m^{-3}$), and the lowest concentration was observed in the outdoor air (1.78×10^3 $cfu \cdot m^{-3}$). The analysis showed significant differences in the concentrations of bacterial aerosol between the medium fraction sorting room and other rooms of the sorting plant, a buffer zone and the outdoor air ($p<0.05$). The concentrations of bacterial aerosol were higher in the indoor air than in the outdoor air, but the differences were not statistically significant ($p>0.05$). In the air of sorting rooms, the lowest concentration of bacterial aerosol was observed in the paper sorting room (5.81×10^3 $cfu \cdot m^{-3}$) and the highest concentration was observed in the medium fraction sorting room (129.02×10^3 $cfu \cdot m^{-3}$). Only in one of the examined rooms of the waste sorting plant (medium fraction sorting room), the obtained concentrations of bacterial aerosol were higher than the reference values for bacteria in the workspaces contaminated by organic dust (100×10^3 $cfu \cdot m^{-3}$) recommended by the Panel of Experts of Biological Factors [Górny 2010]. The results of research conducted in such buildings confirmed that municipal waste sorting plants may be associated with the presence of high concentrations of bacterial aerosol, even in situations where the objects are correctly operated [Butarewicz and Kowaluk-Krupa 2004, Deacon et al. 2009, Lis et al. 1999].

The highest concentration of fungal aerosol was observed in the air of medium fraction sorting room (116.21×10^3 $cfu \cdot m^{-3}$) and the lowest concentration was observed in the outdoor air (4.35×10^3 $cfu \cdot m^{-3}$). The analysis showed significant differences in the concentrations of fungal aerosol between the medium fraction sorting room, control room and the outdoor air ($p<0.05$). In the indoor air of the waste sorting plant, the lowest concentrations of fungal aerosol were observed in control rooms. In the air of sorting rooms, the lowest concentration of fungal aerosol was observed in the paper sorting room (27.55×10^3 $cfu \cdot m^{-3}$) and the highest concentration was observed in the medium fraction sorting room (116.21×10^3 $cfu \cdot m^{-3}$); however, the analysis didn't show significant differences in the concentrations of fungal aerosol between the sorting rooms ($p>0.05$). In two of the examined rooms of the waste sorting plant (bottles sorting room and medium fraction sorting room), the obtained concentrations of fungal aerosol were higher than the reference values for fungi in the worksplaces contaminated by organic dust (50×10^3 $cfu \cdot m^{-3}$) recommended by the Panel of Experts of Biological Factors [Górny 2010]. It should be emphasised that the highest concentration of fungi in the air can lead to various diseases, allergies and serious respiratory tract infections [Cyprowski et al. 2009]. The prevalence of fungi in the air can be limited by the production of spores, and insufficient amount of nutrients and environmental requirements [Adhikari 2004]. In the case of municipal waste sorting plants, biological agents may be present in waste, but they can also be released into air. At waste sorting plants, aerosol in the workplace usually consists of dust with bacteria and fungi [Szadkowska-Stańczyk 2007].

Using a six-stage Andersen cascade impactor allowed to obtain information about the size distribution of air microflora at the investigated measuring points of the municipal waste sorting plant (Figure 1 a,b). The analysis of bioaerosol particle size distribution indicated that the bacterial concentration had a maximum value in a range of particle diameters 3.3–7.0 μm. It shows that these microorganisms were present in the air as single cells and large aggregates and can be deposited in the human respiratory tract in mouth, nose, throat, trachea and primary bronchi. The fungal concentration also had a maximum value in a range of particle diameters 3.3–7.0 μm. It shows that fungi were present in the air as fungal aggregates and fungal-dust aggregates. These microorganisms can be deposited in the human respiratory tract in throat, trachea and primary bronchi [Owen and Ensor 1992, Wlazło et al. 2008].

Microclimate conditions may affect the number of microorganisms and their spread in the air [Katial et al. 1997, Barabasz et al. 2005]. Microclimate parameters and concentration of dust are presented in Table 2. An analysis of the impact of temperature

Table 1. The concentration of bacterial and fungal aerosol (cfu·m^{-3}) at the Barycz municipal waste sorting plant.

Environment		Bacteria	Fungi
Indoor air	Paper sorting room	5.81 × 10^3 ab*	27.55 × 10^3 ab
	Bottles sorting room	44.80 × 10^3 b	60.99 × 10^3 ab
	Medium fraction sorting room	129.02 × 10^3 c	116.21 × 10^3 b
	Control room I	4.87 × 10^3 ab	25.62 × 10^3 ab
	Control room II	12.09 × 10^3 ab	5.31 × 10^3 a
Buffer zone		15.46 × 10^3 ab	33.91 × 10^3 ab
Outdoor air		1.78 × 10^3 a	4.35 × 10^3 a

*Means marked with the same letters are not significantly different by Tukey`s test (α = 0.05).

Table 2. The values of climatic parameters and concentration of dust in the indoor and outdoor air at the Barycz municipal waste sorting plant.

Environment		Temperature [°C]	Relative humidity [%]	Concentration of dust – particulate matter fraction 10.0 µm [mg·m^{-3}]	Concentration of dust – particulate matter fraction 4.0 µm [mg·m^{-3}]
Indoor air	Paper sorting room	22.9	75.3	0.129	0.101
	Bottles sorting room	21.9	69.6	0.114	0.100
	Medium fraction sorting room	23.5	70.5	0.449	0.219
	Control room I	22.2	42.8	0.055	0.052
	Control room II	23.5	59.0	0.075	0.070
Buffer zone		25.5	60.3	0.173	0.098
Outdoor air		29.0	45.4	0.071	0.081

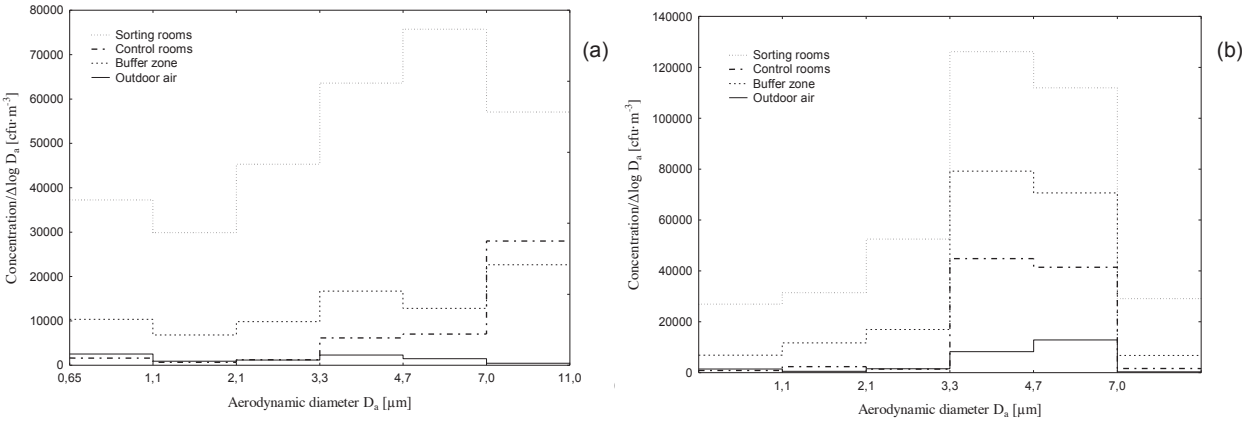

Figure 1. Bioaerosol size distribution in outdoor and indoor air at the Barycz municipal waste sorting plant: (a) bacteria; (b) fungi.

and relative humidity on the observed bacterial and fungal aerosol showed that these factors had no significant effect on the concentration of the total number of airborne bacteria and fungi (p>0.05). However, the analysis showed a significant correlation between the concentration of bioaerosol and particulate matter – fractions 10.0 and 4.0 µm (for bacteria accordingly: R=0.92 and R=0.93; p<0.05; for fungi accordingly: R=0.79 and R=0.80; p<0.05). It proves that the increase in the concentration of dust affects the increase in the concentration of bacteria and fungi in the air at the municipal waste sorting plant, which is consistent with the observations of other authors [Li and Kendrick 1995, Krzywicka et al. 1997].

4. SUMMARY

A high concentration of bioaerosol at the municipal waste sorting plant may indicate the potential health risks for workers and people staying there temporarily. In the air of the three examined rooms of the waste sorting plant, concentrations of bioaerosol obtained in this study were higher than the reference values for bacteria and fungi recommended by the Panel of Experts of Biological Factors. The results of this study clearly suggest that the ventilation in sorting rooms does not provide adequate microbiological air quality. Therefore, a high-performance mechanical ventilation or air conditioning system, providing the appropriate microbiological quality of air, should be introduced in these sorting rooms. It is also recommended that the workers should use protective clothing and dust masks to minimize exposure to biological agents.

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