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Sanitary State of the Air in the Selected Waste Incineration Plant

Stan sanitarny powietrza w wybranych spalarniach odpadów

No standards for evaluation of the sanitary state of air exist in Poland. Waste is an important source of emission of bioaerosol to the air. Several municipal waste incineration plants have been constructed in Poland in recent years. Their effect on the sanitary state of air has not been investigated so far. Therefore, the objective of this paper was evaluation of the sanitary state of air in the new municipal waste incineration plant. For this purpose the concentration of indicator microorganisms in the indoor air and atmospheric air was determined. The species composition of fungal aerosol was also determined. The research was conducted in an incineration plant adapted for thermal processing of approximately 94,000 Mg of waste annually, with production of electricity. It is located in the outskirts of the city in a flat area. Aerosol samples were collected by means of the impact method (200 dm^3 of air). Samples were collected in the manoeuvring yard in front of the unloading hall, in the unloading hall, in the boiler operation-revision hall, and on the operation terrace of the bunker to which waste is unloaded, during the technological break caused by maintenance of the installation and during normal operation of the plant. During the operation of the plant, concentrations of mesophilic bacteria, *Enterobacteriaceae*, actinomycetes, and microscopic fungi were higher than in control, and concentrations in particular rooms were variable. During the technological break, concentrations of mesophilic bacteria, mannitol positive staphylococci, actinomycetes, microscopic fungi, and yeasts were higher than in control, and concentrations in particular rooms were variable. The concentrations were lower than values considered acceptable. The air of the studied rooms also contained *Pseudomonas fluorescens* and *Pseudomonas aeruginosa* bacteria. A total of 12 fungal species were found in the premises of the incineration plant). The species diversity of fungi was higher during the break in operation (10 species) than during the operation of the plant (7 species). They were dominated by species from genus *Penicillium*. Species from genera *Aspergillus*, *Cladosporium*, and *Fusarium* were also present. Results of this study and literature data allow for recommended research on mesophilic bacteria, actinomycetes, *Pseudomonas fluorescens* and *Pseudomonas aeruginosa*, as well as moulds and yeasts for use in the monitoring of the sanitary state of air in the premises and vicinity of waste management installations.

Keywords: **bioaerosol, bacteria, microscopic fungi**

Introduction

Quality of air in Poland is unsatisfactory as a result of long-term negligence in the scope of limiting pollution emission. Acceptable concentration of suspended dusts are exceeded. In addition to chemical pollutants, microorganisms and their fragments called bioaerosol are adsorbed on the dust. Their acceptable concentrations have not been specified so far.

The primary objective of the study on the microbiological composition of the air is the determination whether the composition is acceptable in terms of epidemiological safety of people breathing it. This requires comparison of the determined concentrations of microorganisms with reference values. In Poland in the years 1989-2015, reference values for atmospheric air were specified in PN [1, 2]. The norms, however, were not implemented as obligatory by any legal document. The currently binding norms of PN [3-6] specify selected aspects of the methodology of collecting air samples, but do not specify acceptable concentrations of microorganisms in the air or classes of microbiological air pollution.

The only legal document specifying the acceptability of occurrence of particular species of microorganisms in the air is the regulation of the Minister of Health [7]. The reason is lack of sufficient epidemiological data necessary to prepare legal regulations or norms in the scope [8]. It is therefore justified to undertake further research on the sanitary state of atmospheric air in rooms serving different functions.

Waste is an important anthropogenic source of emission of aerosol to air. Therefore, works presenting study results on the sanitary state of air in the premises and vicinity of objects related to waste management are numerous [9-11]. In Poland, more papers are encountered concerning the sanitary state of atmospheric air in the premises and vicinity of waste dumps [12-14] and composting plants [14-15], and at points of collection of waste from residents [16].

Due to changes in the system of waste management in Poland, introduced by the act on waste [17], six municipal waste incineration plants have been commissioned in Poland in recent years, and further ones are under construction or planned.

Municipal waste incineration plants in Poland are new installations. Therefore, research on the sanitary state of air inside the rooms of the incineration plants and atmospheric air in their premises has not been conducted so far. It is important due to the safety and work hygiene of employees of the incineration plant, and protection of the life environment of people residing in the vicinity of the plant. Microscopic fungi present in the waste can also cause biological corrosion of the buildings of the incineration plant.

The objective of the presented paper was the determination of concentrations of selected groups of microorganisms in indoor air of the rooms of the incineration plant, and in atmospheric air in its premises. The research was conducted during

regular operation of the installation and in the technological break caused by maintenance works. Criteria of selection of groups of bacteria considered in the study included the possibility of their occurrence in municipal waste and potential epidemiological threat they may create. The selection was also based on guidelines of the Team of Experts for Biologial Factors of the International Commission for the Highest Acceptable Concentrations of Factors Harmful for Health in the Environment [18] and PN [1, 2] revoked without effect in 2015. The species composition of microscopic fungi in the air was also determined.

1. Study object

The study was performed in the premises of a municipal waste incineration plant in Poland adjusted to thermal processing of approximately 94,000 Mg of waste annually with production of electricity (up to 47,000 KWh) and heat (up to 120 GJ). The installation is located in the outskirts of the city in a flat area. The adjacent areas include industrial plants, waste dumps, as well as agricultural areas, forests, and lakes.

2. Methodology

2.1. Sample collection

Aerosol samples were collected by means of the impact method onto agarised microbiological substrates on Petri dishes with a diameter of 90 mm. Duo SAS Super 360 devices were applied with two heads with 401 openings, as well as SAS Super IAQ with one head with 401 openings. The volume of collected air from which aerosol was sampled equalled 200 dm^3. The samples were collected twice, during the technological break caused by the installation maintenance and during regular operation of the plant. Aerosol samples were each time collected at the following research sites:

- in the manoeuvre yard in front of access gates to the unloading hall at a distance of 50 m from the gates (control),
- in the unloading hall on the edge of waste collectors to the bunker from which they are dosed to the boiler - the place of unloading of vehicles supplying waste,
- in the boiler operation-revision hall,
- on the boiler operation terrace.

During the technological break, samples of bioaerosol were also collected from the bottom of the bunker where waste is stored directly before its supply to the incinerator.

2.2. Quantitative microbiological research

Sampled microorganisms were incubated in conditions appropriate for each group (Table 1). In different rooms of the incineration plant concentrations of microscopic fungi with their species composition and selected groups of bacteria were compared: mesophilic bacteria, *Enterobacteriaceae*, staphylococci, *Pseudomonas fluorescens*, *Pseudomonas aeruginosa*, actinobacteria. After the completion of incubation, colonies of microorganisms growing on substrates were calculated with consideration of the correction recommended by the sampler producer. Most samples were collected in three repetitions. On sampling places where large variation of results were expected samples were collected in six repetitions. Results were provided in the form of number of colony-forming units (cfu) in a unit of air volume (1 m^3) - arithmetic mean for three or six repetitions and standard deviation.

Table 1. **Methodology of incubation of microorganisms according to PN-89/Z-04111/02 and PN-89/Z-04111/03 [1, 2]**

Group of microorganisms	Microbiological medium	Incubation temperature °C	Incubation time day
Mesophilic bacteria	Nutrient agar	37	1
Enterobacteriaceae fermenting lactose	MacConkey agar	37	1
Mannitol fermenting staphylococci	Chapman agar	37	1-2
Pseudomonas fluorescens	King B agar	26	5
		4	7
Pseudomonas aeruginosa	CN agar for *Pseudomonas*	26	5
Actinobacteria	Pochon agar	26	3
Fungi	Czapek-Dox agar	26	3-5
Yeasts	Sabouraud agar with TTC	26	3-5

The assessment of microbiological air pollution employed criteria proposed by the Team of Experts for Biological Factors of the International Commission for the Highest Acceptable Concentrations of Factors Harmful for Health in the Environment for dusty rooms (Table 2).

Table 2. **Variability of concentrations of bacterial and fungal aerosol in the rooms of the incineration plant during the technological break and normal operation of the plant. Acceptable concentrations: to 100 000 cfu/m^3 for mesophilic bacteria and to 50 000 cfu/m^3 for microscopic fungi [18]**

Room	Group of microorganisms	Technological break			Operation of the plant			t	P
		mean	SD	N	mean	SD	N		
Control	Mesophilic bacteria	143	59	3	50	27	3	2.51	0.07
	Mannitol positive staphylococci	0	0	3	0	0	3	not calculated	
	Enterobacteriaceae	3	6	3	0	0	3	1.00	0.37
	Actinobacteria	33	33	3	3	6	3	1.57	0.19
	Microscopic fungi	1173	142	3	333	31	3	10.02	0.0006
	Yeasts	12	13	3	13	23	3	0.11	0.92
Unloading hall	Mesophilic bacteria	1700	1247	6	17963	12668	6	3.13	0.01
	Mannitol positive staphylococci	402	324	6	0	0	6	3.04	0.01
	Enterobacteriaceae	2	4	6	123	138	6	6.18	0.0001
	Actinobacteria	113	72	6	538	130	6	7.01	0.00004
	Microscopic fungi	4689	2910	6	17447	7280	6	3.99	0.003
	Yeasts	2	3	6	183	61	6	7.26	0.00003
Operation-revision hall	Mesophilic bacteria	5667	2459	6	803	438	6	4.18	0.03
	Mannitol positive staphylococci	9717	5808	3	10	11	6	4.42	0.003
	Enterobacteriaceae	67	72	6	73	85	6	0.15	0.89
	Actinobacteria	1003	107	3	1080	72	3	1.03	0.36
	Microscopic fungi	6533	3	3	1780	299	3	27.56	0.00001
	Yeasts	1	2	6	3	8	3	0.72	0.37
Bunker operation terrace	Mesophilic bacteria	4477	605	3	320	40	3	11.87	0.0003
	Mannitol positive staphylococci	250	50	3	7	12	3	8.21	0.001
	Enterobacteriaceae	0	0	3	0	0	3	not calculated	
	Actinobacteria	420	20	3	40	40	3	14.71	0.0001
	Microscopic fungi	13047	40	3	927	150	3	130.78	0.000000
	Yeasts	0	0	3	7	12	3	1	0.37
Anova test results (df = 3)	Mesophilic bacteria	F = 8.09		P = 0.002	F = 7.00		P = 0.004		
	Mannitol positive staphylococci	F = 11.74		P = 0.0009	F = 1.55		0.24		
	Enterobacteriaceae	F = 0.53		P = 0.67	F = 4.26		P = 0.02		
	Actinobacteria	F = 41.23		P = 0.00003	F = 87.73		P = 0.000000		
	Microscopic fungi	F = 12.40		P = 0.0008	F = 13.59		P = 0.0005		
	Yeasts	F = 3.83		P = 0.03	F = 19.77		P = 0.0001		

2.3. Statistical analysis of results

Samples were collected in 3-6 repetitions. The statistical significance of differences between mean concentrations of microorganisms in particular rooms during the same research series was analysed by means of a single factor ANOVA test ($P \leq 0.05$). The statistical significance of differences between mean concentrations of microorganisms in the same room in two subsequent research series (technological break and regular operation of the plant) was analysed by means of a t-Student test for samples independent towards variables ($P \leq 0.05$). All calculations were performed by means of Statistica 12 software.

2.4. Analysis of the species composition of fungi

Identification of fungi was performed based on their morphological features by means of a key [19] and atlas [20]. An in vivo microscope slide was prepared for each morphologically distinguished colony, subject to microscope observation.

3. Results and discussion

3.1. Concentrations of microorganisms in air

Concentrations of the majority of the analysed groups of microorganisms were higher in the rooms of the waste incineration plant than at the control site in the manoeuvring yard, in front of the entrance to the unloading hall, and their variability in particular rooms was statistically significant, both during the operation of the plant and in the technological break (Table 2). The effect of technological processes of the incineration plant on the sanitary state of the air was therefore limited to the rooms of the incineration plant, both during the operation of the plant and in the technological break. Concentrations of mesophilic bacteria and fungi in the air of the analysed rooms was lower than values considered acceptable by the Team of Experts for Biological Factors [18]. The effect was therefore inconsiderable.

Concentrations of the majority of the analysed groups of microorganisms in the unloading hall were higher during the operation of the plant than during the technological break - the differences were statistically significant. This pointed to unloaded waste as the source of aerosol in the air. The situation was the opposite in the operation-revision hall. The concentration of the majority of groups of microorganisms was higher during the technological break than during the operation of the plant. This could be caused by maintenance works that caused not measured but organoleptically felt dusting of the air (Table 2).

During the technological break, concentrations of mesophilic bacteria, mannitol positive staphylococci, and *Enterobacteriaceae* were higher on the bottom of the bunker than on the operation terrace - the differences were statistically significant. In one case (operation-revision hall during the technological break), the number of mannitol positive staphylococci on Chapman medium was higher than the number

of mesophilic bacteria on the agar medium. This could be caused by inhibition of staphylococci growth by bacteria grown on agar. Concentrations of actinobacteria and fungi were mutually approximate (Table 3).

Table 3. **Variability of aerosol concentrations on the bottom of the bunker (directly above waste) and on the bunker operation terrace**

Group of microorganisms	Bottom of the bunker			Operation terrace			t	P
	Mean	SD	N	Mean	SD	N		
Mesophilic bacteria	6817	1169	3	4477	605	3	3.08	0.04
Mannitol positive staphylococci	707	150	3	250	50	3	4.95	0.008
Enterobacteriaceae	23	12	3	0	0	3	3.50	0.025
Actinobacteria	487	59	3	420	20	3	1.87	0.21
Microscopic fungi	13070	0	3	13047	40	3	1.00	0.37
Yeasts	0	0	3	7	12	3	1.00	0.37

The air of the analysed rooms also contained bacteria *Pseudomonas fluorescens* and *Pseudomonas aeruginosa*. Concentrations of *Pseudomonas fluorescens* bacteria incubated at a temperature of 26°C during the technological break were as follows: 1.7±2.4 cfu/m^3 (N = 3) at the control site, 13.33±24.22 cfu/m^3 (N = 6) in the operation-revision hall, during the operation of the plant: 6.67±10.33 cfu/m^3 (N = 6) in the unloading hall, and 0.83±2.04 cfu/m^3 (N = 6) in the operation-revision hall. The difference in concentrations in the operation-revision hall during the technological break and operation of the plant was not statistically significant (t = 1.26, P = 0.24). The presence of *Pseudomonas fluorescens* incubated at a temperature of 4°C was only determined during the operation of the plant in the following halls: unloading hall - concentration of 20.00±17.89 cfu/m^3 (N = 6), and operation-revision hall - concentration of 3.33±8.64 cfu/m^3 (N = 6). During the operation of the plant in the unloading and operation-revision hall, the presence of *Pseudomonas aeruginosa* was determined. The concentration in both halls was the same, and equalled: 6.67±16.33 cfu/m^3 (N = 6).

A considerable variability of concentrations of microorganisms determined in the air of the rooms of the waste incineration plant analysed in the study was also observed in the premises and vicinity of other waste management objects such as: municipal waste dumps [9, 12, 21-23] and waste composting plants [10, 15]. The variability points to the need of monitoring of the sanitary state of the air in the premises and vicinity of objects related to waste management. No uniform composition of indicator microorganisms has been adopted so far that should be considered, or concentrations considered acceptable. The concentration of mesophilic bacteria suggests substantial variability. This is important in the analysis of spreading of microorganisms in the air. Due to the diversity of the bacteria group, however,

the unambiguous determination of their source of origin can be difficult. The actual health hazard caused by this group of microorganisms depends not only on their abundance, but also their species composition. Good indicators of the sanitary state of the air in the premises and vicinity of waste management objects include actinobacteria and *Pseudomonas fluorescens.* They are related to the soil environment, and occur in waste subject to decomposition. Actinobacteria participate in the decomposition of difficult to decompose chemical compounds (long-chain fats, hydrocarbons, steroids, heterocyclic nitrogen compounds, celuloses, and lignins) occurring in municipal waste in considerable amounts. Many actinobacteria are pathogenic or potentially pathogenic for man. *Pseudomonas fluorescens* bacteria are also potentially pathogenic. They are often detected in the air in the premises and vicinity of waste management objects [12, 15, 22-24]. Worse indicators of the sanitary state of the air in the vicinity of waste management objects such as a waste incineration plant proved to be mannitol positive staphylococci and *Enterobacteriaceae*. Waste containing the bacteria in high amounts, particularly sewage sediments and contagious medical and veterinary waste, should be managed outside the municipal waste incineration plant. Therefore, *Enterobacteriaceae* [15] and staphylococci [12] are more seldom considered in microbiological air monitoring in the premises and vicinity of waste management objects. Studies on the sanitary state of the air in the premises and vicinity of waste management objects performed by authors of other available papers did not consider *Pseudomonas aeruginosa* bacteria. But they should be considered in the monitoring of the sanitary state of air due to the health hazard for people this opportunistic bacteria cause, especially for people with weakened immune system (wound infection, ear infection, bacteremia).

Fungal concentrations in the air of rooms of the waste incineration plant analysed in this paper were approximate to those determined in the premises and vicinity of other waste management objects: municipal waste dumps: 320÷1200 cfu/m^3 [21] and waste composting plants: 780÷2080 cfu/m^3 [15]. Waste management objects also included those in the premises or vicinity of which concentrations of fungi were higher than in the rooms of the analysed waste incineration plant, e.g. on municipal waste dumps in Poland: 700÷11 000 cfu/m^3 [21], 28÷45 000 cfu/m^3 [25], 52÷20 210 cfu/m^3 and in Taiwan: 3065÷15 976 cfu/m^3 [9]. The concentration of fungi is an important indicator of the sanitary state of air. They find favourable conditions for development in biodegradable waste, participating in its decomposition. Some of them can infect people causing mycosis. They produce substances with cytotoxic, mutagenic, teratogenic, neuro- and nephrotoxic, and tremorgenic properties. Many of them are allergens. They also cause biological erosion of building materials and rotting of food. Therefore, next to the determination of the concentration of fungi in the air, it is important to determine their species composition. Yeasts are an important group of fungi in terms of health protection. Some of them occur on the surface of human skin and may cause yeast infections. Other authors investigating the sanitary state of the air in the premises and vicinity of waste management objects, however, did not consider this group of fungi.

3.2. Species composition of moulds

A total of 12 fungal species were found in the premises of the municipal waste incineration plant - in the rooms and at the control site in front of the building (Table 4). The species diversity of the fungi was higher during the break in operation (10 species) than during the operation of the plant (7 species). In the unloading hall, the species diversity of fungi was higher during the break in operation than during the operation of the plant. In the operation-revision hall, it was the same. On the bunker operation terrace it was higher during the operation of the plant than during the break in operation. But on the bottom of the bunker in the break in operation, the species diversity was higher than on its operation terrace. In all of the analysed rooms, species from genus *Penicillium*, and particularly *P. chrysogenum* and *P. expansum*, were quantitatively predominant (Fig. 1). In all of the rooms, the less abundant genus *Aspergillus* (particularly *Aspergillus niger*) was also represented. In part of the rooms, fungi from genera *Cladosporium* and *Fusarium* also occurred. Their abundance, however, was low.

Table 4. **Fungal species identified in the air of particular rooms**

Genus and species	Technological break					Operation of the plant			
	Control	Unloading hall	Operation--revision hall	Terrace	Bottom of the bunker	Control	Unloading hall	Operation--revision hall	Terrace
Aspergillus niger	+	+	+	+	+		+	+	+
Aspergillus versicolor	+	+				+			
Cladosporium herbarum	+		+			+			+
Fusarium graminearum	+					+		+	
Penicillium chrysogenum	+	+	+	+	+	+	+	+	+
Penicillium expansum	+	+	+	+	+	+	+	+	+
Penicillium lanosum		+				+			
Penicillium notatum			+			+	+	+	+
Penicillium verrucosum	+					+	+	+	
Rhizopus nigricans		+							
Rhizopus stolonifer (=*R. nigricans*)		+	+		+				
Trichoderma viridae		+							
Species in total	7	8	6	3	5	8	5	6	5

All fungi determined in the paper are common species of saprophytic moulds, usually occurring on organic substrates in the soil environment. The majority of them, however, in the case of abundant occurrence and longer contact, can cause a threat to people (e.g. *Penicillium expansum* produces toxic patulin and may cause inflammation of cornea, *Penicillium chrysogenum* inflammation of the ear, eye, and endocardium, and *Aspergillus niger* often causes mycosis and allergic bronchial

inflammation). *Fusarium graminearum* recorded at several sites is a well-known cereal parasite.

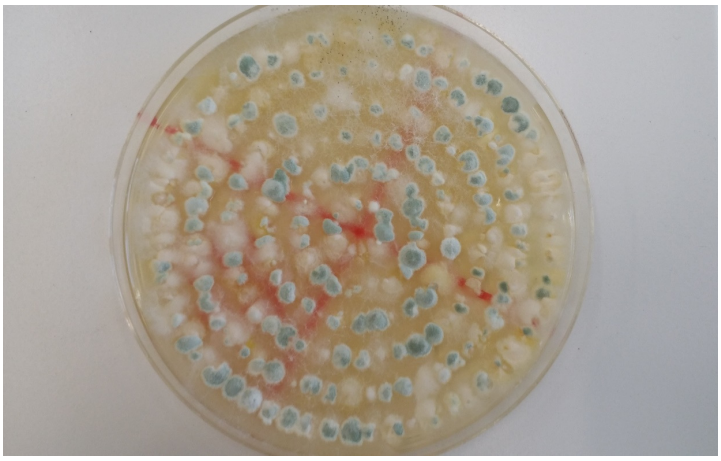

Fig. 1. Mould colonies, particularly *Penicillium* sp. (unloading hall)

The most frequently detected fungi in the air of one of British waste incineration plants also included: *Penicillium sp*. (62.9%), *Aspergillus fumigatus* (18%), and *A. flavus* (6%). Samples of waste processed there usually contained fungi from genera *Penicillium sp*. (57.5%), *A. fumigatus* (22.3%), and *A. niger* (12.8%). *Stachybotrys chartarum* and other toxigenic fungi from group *A. flavus* were not detected in the waste [11]. Fungi from genus *Cladosporium* were the most abundant in the premises and vicinity of other waste management objects: composting plants and waste dumps [9, 15, 25]. Fungi from genera: *Aspergillus, Penicilillium*, and *Fusarium* also showed common occurrence, and fungi belonging to other genera were scarcer [9, 15, 25].

Conclusions

The obtained study results show that the air in the rooms of the waste incineration plant is polluted with microorganisms not only during works related to waste disposal, but also during the technological break. Concentrations of microorganisms in the air in the premises of the analysed incineration plant and waste management objects studied by other authors showed high variability. This confirms the need of development of uniform criteria of assessment of the sanitary state of air, already postulated earlier [16]. Proposing one set of indicator organisms for different environments can be difficult. Results obtained in this paper and literature data allow for recommended research on mesophilic bacteria, actinobacteria, *Pseudomonas fluorescens*, and *Pseudomonas aeruginosa* bacteria, as well as moulds and yeasts for the purpose of their use in monitoring of the sanitary state of air in the premises and vicinity of installations related to waste management. Mannitol-fermenting

staphylococci and *Enterobacteriaceae* occurred less useful indicators of sanitary state of air in waste incineration plant then other used microorganisms. The effect of technological processes of the incineration plant on the sanitary state of the air was limited to the rooms of the incineration plant, both during the operation of the plant and in the technological break.

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Streszczenie

W Polsce brakuje standardów oceny stanu sanitarnego powietrza. Istotnym źródłem emisji bioaerozolu do powietrza są odpady. W ostatnich latach w Polsce powstało kilka spalarni odpadów komunalnych, ich wpływ na stan sanitarny powietrza nie był dotychczas badany. Dlatego celem tej pracy była ocena stanu sanitarnego powietrza na terenie nowej spalarni odpadów komunalnych. W tym celu określono liczebność wskaźnikowych mikroorganizmów w powietrzu pomieszczeń oraz w powietrzu atmosferycznym. Określono też skład gatunkowy bioaerozolu grzybowego. Badania prowadzono w spalarni przystosowanej do termicznego przekształcania ok. 94 000 Mg odpadów rocznie z wytworzeniem energii elektrycznej. Jest ona zlokalizowana na obrzeżach miasta na terenie równinnym. Próbki bioaerozolu pobierano metodą zderzeniową (200 dm^3 powietrza). Próbki pobierano na placu manewrowym przed halą rozładunkową, w hali wyładunkowej, w hali eksploatacyjno-rewizyjnej kotła i na tarasie eksploatacyjnym bunkra, do którego wyładowywane są odpady podczas przerwy technologicznej spowodowanej konserwacją instalacji oraz podczas normalnej pracy zakładu. Podczas pracy zakładu stężenia bakterii mezofilnych, *Enterobacteriaceae*,

promieniowców i grzybów mikroskopowych były większe niż w kontroli, a stężenia w poszczególnych pomieszczeniach były zróżnicowane. W czasie przerwy technologicznej stężenia bakterii mezofilnych, gronkowców mannitolododatnich, promieniowców, grzybów mikroskopowych i drożdżaków były większe niż w kontroli, a stężenia w poszczególnych pomieszczeniach były zróżnicowane. Stwierdzone liczebności były niższe od wartości uznanych za akceptowalne. W powietrzu badanych pomieszczeń obecne też były bakterie *Pseudomonas fluorescens* i *Pseudomonas aeruginosa*. Na terenie spalarni stwierdzonych zostało 12 gatunków grzybów. Różnorodność gatunkowa grzybów była większa podczas przerwy eksploatacyjnej (10 gatunków) niż podczas pracy zakładu (7 gatunków). Dominowały wśród nich gatunki z rodzaju *Penicillium*, obecne też były gatunki z rodzajów *Aspergillus*, *Cladosporium* i *Fusarium*. Wyniki uzyskane w tej pracy oraz dane literaturowe pozwalają na rekomendowanie badania bakterii mezofilnych, promieniowców, *Pseudomonas fluorescens* i *Pseudomonas aeruginosa* oraz grzybów pleśniowych i drożdżaków do wykorzystania w monitoringu stanu sanitarnego powietrza na terenie i w sąsiedztwie instalacji związanych z gospodarką odpadami.

Słowa kluczowe: **bioaerozol, bakterie, grzyby mikroskopowe**