Evaluation of microbiological quality of atmospheric air in a selected sewage treatment plant in Lesser Poland

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Abstract The adverse impact of sewage treatment plants on the environment, resulting from the emission of harmful biological agents to the atmosphere, depends mainly on the size of the facility, the quantity and composition of treated sewage as well as the technologies and equipment used. The aim of the conducted research was to determine the microbiological quality of atmospheric air at Municipal-Industrial Sewage Treatment Plant in Oświęcim, which is one of the largest treatment plants in Lesser Poland. Bioaerosol measurements were made at four points (raw sewage inlet, aeration chamber, purified sewage outlet and 150 m from the treatment plant, at the background point) in the period from January to December 2018. Bioaerosol samples were collected using Microbiological Air Sampler MAS-100 by Merck. The tested atmospheric air was characterized by a qualitatively and quantitatively diverse microflora. The largest source of emission of microorganisms to the atmosphere was the mechanical part of the sewage treatment plant (raw sewage inlet) and the biological reactor. The highest number of mesophilic bacteria was observed near the biological reactor (in the summer), the least at the control point. During the research, the least β -hemolytic bacteria was isolated at

the purified sewage outlet—on average 3 CFU m^{-3} , the highest at the biological reactor 16 CFU m^{-3} . Most of α -hemolytic bacteria was observed near the raw sewage inlet and was not found at the control point. Actinomycetes also occurred in a small amount ($0\text{--}40 \text{ CFU m}^{-3}$). A high concentration of mildew fungi occurred in summer when the air temperature was highest, the smallest quantities of these microorganisms were found in January and February.

Keywords Bioaerosol · Atmospheric air · Microbial contamination · Sewage treatment plant

1 Introduction

Microbiological contaminants occurring in the atmospheric air come from various sources, including, among others, municipal facilities, e.g., sewage treatment plants, landfills and composting. The side effect of these objects is the formation of biological aerosols containing numerous microorganisms. They pose a serious threat to human and animal health, and may also have a negative impact on the environment (Adamus-Białek et al. 2015; Michalkiewicz et al. 2011; Przybulewska and Czupryniak 2006; Vantarakis et al. 2016).

The bioaerosol formed in wastewater treatment plants includes viruses, bacteria and fungi, the form of

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which may be different, e.g., spores, conidia, parts of the mycelium, vegetative forms (Bawiec et al. 2016; Lee et al. 2016). Their survival in air compared to wastewater changes significantly, because the air does not contain nutrients and does not provide adequate physicochemical conditions (Bawiec et al. 2016; Lee et al. 2016).

Wastewater treatment plants, in addition to a positive role related to the protection of the natural environment, pose a certain risk to workers and people living nearby (Nowojewski and Mniszek 2006; Sánchez-Monedero et al. 2008). Bioaerosol, which releases into the air, carries active pathogens that can lead to serious inflammatory, infectious and allergic diseases. Exposure to biological agents in sewage treatment plant employees is most often associated with the occurrence of such diseases as alveolitis (Thorn and Kerekes 2001), rhinitis, pharyngitis, conjunctivitis and gastrointestinal infections (Ahire and Bhalerao 2017). In particular, the presence of fungi in elevated concentrations can cause a wide spectrum of diseases from simple allergies to serious infections (mycoses) (Krajewski et al. 2004). The most common complaints reported by employees of the treatment plants include malaise, coughing and breathing difficulties (Patil and Kamble 2017; Rylander 1999). The threat to health and the environment resulting from the emission of bioaerosol makes it necessary to control the microbiological contamination of air in the sewage treatment plant and in its immediate vicinity (Li et al. 2013; Bauer et al. 2002; Korzeniewska 2011).

Taking into account this state of affairs, the aim of the conducted research was to characterize the microbiological quality of atmospheric air in the area of the Municipal-Industrial Sewage Treatment Plant in Oświęcim.

2 Materials and methods

The research was carried out at the Municipal-Industrial Sewage Treatment Plant in Oświęcim. It is one of the largest wastewater treatment plants in Poland, located in the southern part of Lesser Poland. The sewage treatment plant receives municipal sewage from the city of Oświęcim and other towns belonging to the Oświęcim community as well as industrial sewage coming from Chemical Company

“Synthos.” The incoming sewage is treated in biological processes based on the activated sludge method in the anaerobic–aerobic system. The treated wastewater is discharged to the Vistula River.

The bioaerosol assessment was carried out from January to December 2018. Air samples were collected using Microbiological Air Sampler MAS-100 by Merck at four points: raw sewage inlet (point 1), aeration chamber (point 2), purified sewage outlet (point 3) and 150 m from treatment plant (point 4); this point was the background. Selected research points included the basic technological stages of wastewater treatment, therefore they were considered as potential sources of microbial contamination. Additionally, for the purposes of comparing the obtained results, a measuring stand was determined in which the background level was examined. The air sampler sucked in air into a 9-cm Petri dish containing a specific solid medium intended for the isolation of selected microorganisms. The volume of air intake was 100 and 200 dm³. In the case of fungi, 100 dm³ of air was collected for each sample, for the remaining microorganisms, 200 dm³ each. The device's inlet was always on the windward side. Air samples were taken from the height of 130 cm above ground level that is from the human breathing zone. Each air measurement for the tested groups of microorganisms was made in three replications. The following microbiological media were used for culturing microorganisms:

1. Tryptic soy agar (TSA LAB-AGARTM, Biocorp, Poland) with 5% addition of sheep blood, in order to determine the total number of bacteria, α - and β -hemolytic bacteria.
2. Gauze's medium for isolation of actinomycetes.
3. Malt agar (Malt Extract Agar, Biocorp, Poland) for the isolation of mildew fungi.

The TSA plates were incubated for 1 day at 37 °C, then 3 days at 22 °C and another 3 days at 4 °C. The Gauze's plates were incubated at 28 °C for 7 days, while MEA plates were incubated 4 days at 30 °C, then 4 days at 22 °C. After the incubation period, quantitative analysis of the grown colonies of microorganisms was performed. On the basis of the microorganism number obtained, the means were calculated from the colony forming units (CFU), separately for each of the groups of microorganisms studied. The number of positive holes for the Mas-100 air

monitoring system was worked out using a conversion table according to Feller and the obtained colony number was counted over 1 m^3 of the atmospheric air.

To determine the dependence between temperature and air humidity and the amount of isolated microorganisms, the Pearson correlation coefficient was calculated.

3 Results

The number of microorganisms isolated from atmospheric air at individual research points and the dependence between the number of microorganisms, temperature and air humidity are shown in Tables 1, 2, 3, 4, 5, 6 and 7 and illustrated graphically in Figs. 1, 2, 3, 4 and 5.

The total number of mesophilic bacteria in individual research points varied from 0 to 1360 CFU m^{-3} (Table 1). The largest amount of bacteria was isolated in August at the biological reactor. At the inlet of raw sewage and the outflow of purified wastewater, the largest amount of bacteria was isolated in September (1320 CFU m^{-3} and 670 CFU m^{-3} , respectively), and at the control point constituting the background in June (130 CFU m^{-3}). Mesophilic bacteria were not found in six analysis (at the outflow of purified wastewater: January, February and at the control point: January, February, November, December).

The average number of bacteria in individual research points ranged from 34 to 722 CFU m^{-3} . The highest number of mesophilic bacteria was observed near the biological reactor, the least at the control point (Fig. 1).

β -hemolytic bacteria were present in 24 out of 48 air samples (Table 2). Their numbers ranged from 0 to 50 CFU m^{-3} . The largest amount was found in June at the raw sewage inlet. At this point, they were isolated in five cases. In the place of biological purification, they were present in seven samples up to 45 CFU m^{-3} (March). At the outlet of purified wastewater, β -hemolytic bacteria were isolated in three cases in the amount of $10\text{--}15 \text{ CFU m}^{-3}$ (June, July, August). These microorganisms were most often present at the control point, in a maximum amount of 25 CFU m^{-3} (June).

During the research, the least β -hemolytic bacteria were isolated at the third point (purified sewage

outlet)—on average 3 CFU m^{-3} , the highest at the second point (biological reactor)— 16 CFU m^{-3} (Fig. 2).

The amount of α -hemolytic bacteria ranged from 0 to 30 CFU m^{-3} (Table 3). They were isolated in 12 samples of the air tested. Most often these microorganisms were present near the raw sewage inlet (point 1). At this point, the largest number (March) was also found. In the place of biological purification, the number of α -hemolytic bacteria ranged from 0 to 25 CFU m^{-3} , while in the vicinity of the outflow of purified sewage, it occurred in the amount from 0 to 15 CFU m^{-3} . These bacteria were not found at the control point.

The average number of α -hemolytic bacteria did not exceed 10 CFU m^{-3} . Most were observed near the raw sewage inlet. At the place of biological purification, an average of 5 CFU m^{-3} occurred, and at the outlet of purified sewage, 4 CFU m^{-3} (Fig. 3).

In the studied atmospheric air, actinomycetes occurred in a small amount; they were isolated only in six cases (Table 4). In the largest amount (40 CFU m^{-3}), they occurred twice in October at the raw sewage inlet and in June at the biological reactor. At the control point, no actinomycetes were observed.

The average concentration of actinomycetes in the examined atmospheric air was 5 CFU m^{-3} near the raw sewage inflow, 4 CFU m^{-3} at the biological reactor and 1 CFU m^{-3} in point 3 (Fig. 4).

The number of fungi at individual research points varied widely and ranged from 0 to 1910 CFU m^{-3} (Table 5). Most of mildew fungi were isolated in March near the raw sewage inlet, while in February, they were not observed in the place of biological treatment and near the outflow of purified sewage. At the control point, the most of fungi (810 CFU m^{-3}) were observed in July. A high concentration of mildew fungi occurred in summer when the air temperature was the highest. The smallest quantities of these microorganisms were found in January and February, when temperatures were negative and the surface of the earth was covered with snow.

The average number of fungi near the biological reactor, the outflow of purified sewage and at the control point was very similar (Fig. 5). The differences between these points did not exceed 65 CFU m^{-3} . The most fungi were found at the raw

Table 1 Number of mesophilic bacteria in the examined atmospheric air (CFU m⁻³)

The date of sampling	The number of colony forming units (CFU) in m ³ of the tested air			
	Raw sewage inlet	Aeration chamber	Purified sewage outlet	Control point
I 2018	260	390	0	0
II 2018	180	210	0	0
III 2018	380	420	120	10
IV 2018	410	450	160	20
V 2018	790	810	210	40
VI 2018	910	1100	420	130
VII 2018	1160	1230	630	80
VIII 2018	1030	1360	490	60
IX 2018	1320	1080	670	50
X 2018	680	710	220	20
XI 2018	510	560	90	0
XII 2018	310	340	30	0

Table 2 Number of β -hemolytic bacteria in the examined atmospheric air (CFU m⁻³)

The date of sampling	The number of colony forming units (CFU) in m ³ of the tested air			
	Raw sewage inlet	Aeration chamber	Purified sewage outlet	Control point
I 2018	0	0	0	0
II 2018	0	0	0	0
III 2018	20	30	0	10
IV 2018	0	35	0	10
V 2018	0	20	0	15
VI 2018	50	45	10	25
VII 2018	30	30	15	15
VIII 2018	15	20	10	20
IX 2018	10	15	0	20
X 2018	0	0	0	10
XI 2018	0	0	0	10
XII 2018	0	0	0	0

sewage inlet (573 CFU m⁻³), and the least at the control point (314 CFU m⁻³).

After calculating Pearson's linear correlation coefficient, a quite strong dependence was found only between the temperature and the amount of mesophilic bacteria. In relation to β -hemolytic bacteria and fungi, the dependence between temperature and their amount was moderate, and in the case of α -hemolytic bacteria and actinomycetes weak (Table 6).

Humidity of the air did not significantly affect the number of microorganisms studied. The weak

dependence was found in relation to the number of mesophilic and α -hemolytic bacteria, and in the case of β -hemolytic bacteria, actinomycetes and fungi, there was no linear dependence between humidity and their abundance (Table 7).

4 Discussion

The highest concentration of bioaerosol in the sewage treatment plant is observed near aeration chambers,

Table 3 Number of α -hemolytic bacteria in the examined atmospheric air (CFU m⁻³)

The date of sampling	The number of colony forming units (CFU) in m ³ of the tested air			
	Raw sewage inlet	Aeration chamber	Purified sewage outlet	Control point
I 2018	0	0	0	0
II 2018	25	0	10	0
III 2018	30	25	10	0
IV 2018	0	0	0	0
V 2018	0	20	15	0
VI 2018	25	0	15	0
VII 2018	0	0	0	0
VIII 2018	0	0	0	0
IX 2018	10	0	0	0
X 2018	0	0	0	0
XI 2018	0	10	0	0
XII 2018	25	0	0	0

Table 4 Number of actinomycetes in the examined atmospheric air (CFU m⁻³)

The date of sampling	The number of colony forming units (CFU) in m ³ of the tested air			
	Raw sewage inlet	Aeration chamber	Purified sewage outlet	Control point
I 2018	0	0	0	0
II 2018	0	0	0	0
III 2018	15	0	0	0
IV 2018	0	0	0	0
V 2018	0	0	0	0
VI 2018	0	40	15	0
VII 2018	0	0	0	0
VIII 2018	0	0	0	0
IX 2018	10	0	0	0
X 2018	40	5	0	0
XI 2018	0	0	0	0
XII 2018	0	0	0	0

sand catchers, settling tanks and biological deposits (Michałkiewicz et al. 2009; El-Sayed et al. 2015; Kvanli et al. 2008). The formation of a biological aerosol depends on the number of microorganisms in wastewater (Budzińska et al. 2011; Breza-Boruta and Paluszak 2007). Penetration of microorganisms into the air takes place mainly as a result of aeration and mixing of sewage (Hung et al. 2010; Krucalak and Olańczuk-Neyman 2004; Malakootian et al. 2013). In the studies of Filipkowska et al. (2008) and

Korzeniewska et al. (2008), there were no significant differences in the number of fungi and bacteria depending on the location of research points. However, slightly larger amounts of these microorganisms were found in the sewage treatment plant than outside its borders. In the own studies, the most mesophilic and β -hemolytic bacteria were observed in the place of biological purification (Tables 1, 2 and Figs. 1, 2), and in the case of α -hemolytic bacteria, actinomycetes and fungi, near the raw sewage inflow (Tables 3, 4, 5 and

Table 5 Number of mildew fungi in the examined atmospheric air (CFU m⁻³)

The date of sampling	The number of colony forming units (CFU) in m ³ of the tested air			
	Raw sewage inlet	Aeration chamber	Purified sewage outlet	Control point
I 2018	80	40	20	90
II 2018	70	0	0	30
III 2018	1910	1010	710	220
IV 2018	110	90	130	370
V 2018	620	550	480	410
VI 2018	510	580	520	480
VII 2018	780	510	840	810
VIII 2018	1160	490	690	490
IX 2018	730	610	420	370
X 2018	470	270	160	170
XI 2018	320	260	140	210
XII 2018	120	90	70	120

Table 6 Dependence between temperature and the number of microorganisms (CFU m⁻³) in the examined atmospheric air

The date of sampling	Temperature (°C)	The number of colony forming units (CFU) in m ³ of the tested air				
		Bacteria	β-hemolytic bacteria	α-hemolytic bacteria	Actinomycetes	Fungi
I 2018	− 13	650	0	0	0	230
II 2018	− 19	390	0	35	0	100
III 2018	4	930	60	65	15	3850
IV 2018	12	1040	45	0	0	700
V 2018	21	1850	35	35	0	260
VI 2018	23	2560	130	40	55	2090
VII 2018	28	3100	90	0	0	2940
VIII 2018	32	2940	65	0	0	2830
IX 2018	26	3120	45	10	10	2130
X 2018	18	1630	10	0	50	1070
XI 2018	11	1160	10	10	0	930
XII 2018	6	680	0	25	0	400
Average	12.41	1670.83	40.83	18.33	10.83	1610.83
<i>r</i> [*]	−	0.88	0.63	0.26	0.25	0.52

**r*: Pearson's linear correlation coefficient; < 0.2: no linear dependence; 0.2–0.4: weak dependence; 0.4–0.7: moderate dependence; 0.7–0.9: quite strong dependence; > 0.9: very strong dependence

Figs. 3, 4, 5). However, there has been analysis in which larger amounts of microorganisms were found outside the treatment plant. These observations mainly concerned fungi (Table 5).

Breza-Boruta (2012) claims that the concentration of microorganisms in the air depends mainly on

temperature. In the research conducted at the municipal waste landfill, the highest number of bacteria was recorded in the spring and summer season, and the fungi in the autumn season. Niazi et al. (2015) in research conducted in the sewage treatment plant in Tehran showed a significant dependence between

Table 7 Dependence between humidity and the number of microorganisms (CFU m⁻³) in the examined atmospheric air

The date of sampling	Humidity (%)	The number of colony forming units (CFU) in m ³ of the tested air				
		Bacteria	β-hemolytic bacteria	α-hemolytic bacteria	Actinomycetes	Fungi
I 2018	47	650	0	0	0	230
II 2018	32	390	0	35	0	100
III 2018	44	930	60	65	15	3850
IV 2018	53	1040	45	0	0	700
V 2018	57	1850	35	35	0	260
VI 2018	61	2560	130	40	55	2090
VII 2018	70	3100	90	0	0	2940
VIII 2018	46	2940	65	0	0	2830
IX 2018	67	3120	45	10	10	2130
X 2018	72	1630	10	0	50	1070
XI 2018	76	1160	10	10	0	930
XII 2018	81	680	0	25	0	400
Average	58.83	1670.83	40.83	18.33	10.83	1610.83
<i>r</i> [*]	–	0.26	0.01	0.31	0.19	0.05

**r*: Pearson's linear correlation coefficient: < 0.2: no linear dependence; 0.2–0.4: weak dependence; 0.4–0.7: moderate dependence; 0.7–0.9: quite strong dependence; > 0.9: very strong dependence

Fig. 1 Average amount of mesophilic bacteria at individual research points

environmental parameters and the concentration of bacteria and fungi in the air. The strongest effect on the occurrence of fungi was humidity, and on the occurrence of bacteria, the air temperature. In the case of bacteria, the effect of wind speed and UV index was also found. In studies by Michałkiewicz et al. (2016), the highest concentration of bacteria and fungi was recorded in the summer, when the temperature was

comparable to spring, but the humidity was higher. There were fewer microorganisms in other seasons. Perhaps the reason for the observed differences in the number of microorganisms tested was the different composition of sewage and sludge generated in the treatment process. Korzeniewska et al. (2008) in studies carried out in the area of the hydrophyte sewage treatment plant and in its vicinity also showed

Fig. 2 Average amount of β -hemolytic bacteria at individual research points

Fig. 3 Average amount of α -hemolytic bacteria at individual research points

a dependence between the number of microorganisms in the air and the season of the year. The highest amounts of bacteria were observed in summer, and the lowest in winter. The exception was the most numerous actinomycetes occurring in spring. In own research carried out in the Municipal-Industrial Sewage Treatment Plant in Oświęcim, a quite strong dependence was found only between the air temperature and the amount of mesophilic bacteria (Table 6), the number of which in winter months (December–February, temperature from 6 to -19°C) was

definitely less than in other seasons. Of all the microorganisms isolated from air, only 6% came from analysis carried out in winter, 25% in autumn, 27% in spring and as much as 42% in summer. In contrast, air humidity did not significantly affect the number of microorganisms studied (Table 7), which was confirmed in the literature (Guo et al. 2014; Seetha et al. 2013).

In research conducted by Budzińska et al. (2013), the highest amount of mesophilic bacteria was recorded in the spring and summer period at the sand

Fig. 4 Average amount of actinomycetes at individual research points

Fig. 5 Average amount of mildew fungi at individual research points

catchers (2020 CFU m⁻³), and in the autumn–winter period at the SBR reactor (1562 CFU m⁻³). In the own studies, the most mesophilic bacteria were found in early autumn near the raw sewage inflow (1320 CFU m⁻³), and in late summer at the biological reactor (1360 CFU m⁻³), however, their number was slightly lower (Table 1). Large quantities of bacteria, reaching 13,000 CFU m⁻³, were isolated by Breza-Boruta (2010) at the sand catchers in the summer. However, at points located near the aeration chamber, composting plant and outside the sewage treatment

plant, the amount of bacteria was much smaller and amounted to a maximum of several hundred CFU m⁻³. In other studies, the highest concentration of bacteria was observed near the compost storage site. At this point, from May to October, a strong pollution reaching up to 27,000 CFU m⁻³ was found. The number of bacteria exceeding 3000 CFU m⁻³ was also observed twice at the aeration chambers and twice at a distance of 100 m from the treatment plant (Breza-Boruta and Paluszak 2007). In the Municipal-Industrial Sewage Treatment Plant in Oświęcim, such high

amounts of mesophilic bacteria were not found in any of the analysis. The highest number of mesophilic bacteria was isolated at the aeration chamber (1360 CFU m^{-3}), while at the control point, their concentration was maximum 130 CFU m^{-3} (Table 1).

In research conducted by Wlazło et al. (2002) of the bacteria isolated from the air, about 35% were Gram-negative bacteria, mainly from the *Enterobacteriales* order. The most numerous were *Enterobacter agglomerans*, *Acinetobacter calcoaceticus*, *Pseudomonas putida*, *Yersinia enterocolitica* and *Citrobacter freundii*. Among the Gram-positive bacteria, the following species were present: *Micrococcus*, *Staphylococcus*, *Bacillus* and *Corynebacterium*. The α -hemolytic bacteria were most often present in air samples collected in the spring months, and β -hemolytic bacteria in the summer months. The highest concentrations were noted at the raw sewage inlet. In turn, Budzińska et al. (2013) observed an even amount of these organisms throughout the year, most often near sand catchers and settlers. In Breza-Boruta (2010) studies, the number of α -hemolytic bacteria ranged from a few to a dozen or so CFU m^{-3} , and β -hemolytic bacteria to 50 CFU m^{-3} . Most of these bacteria were isolated at the point of mechanical wastewater treatment. Similarly, in own research conducted in the Municipal-Industrial Sewage Treatment Plant in Oświęcim, the number of α -hemolytic bacteria was smaller than β -hemolytic bacteria. The amount of α -hemolytic bacteria was up to 30 CFU m^{-3} , and β -hemolytic bacteria up to 50 CFU m^{-3} . At the control point, α -hemolytic bacteria were not isolated in any of the analysis, while β -hemolytic bacteria were present in 75% of analysis. In total, at all research points, α -hemolytic bacteria were present in 25% of the examined air samples, while β -hemolytic bacteria in 50% (Tables 2, 3).

Research carried out in many wastewater treatment plants indicates that the most frequent and most frequently occurring actinomycetes occur in the composting and sewage sludge storage sites (Breza-Boruta 2010; Budzińska et al. 2011, 2013). In the Municipal-Industrial Sewage Treatment Plant in Oświęcim, actinomycetes appeared in the air in the smallest quantities (from 0 to 40 CFU m^{-3}). They were isolated mainly in summer and autumn. Near the inlet of raw sewage, they were present in three cases, at the biological reactor twice, and at the outlet of purified

sewage only once. At the control point, the actinomycetes were not isolated (Table 4). In the studies of Budzińska et al. (2013), the number of actinomycetes was higher. However, in the studies of Breza-Boruta and Paluszak (2007), the concentration of these microorganisms reached even 1040 CFU m^{-3} . Kolwzan et al. (2012) found that actinomycetes isolated from the air came from sources other than the sewage treatment plant, because there were few of them in the sewage. Korzeniewska et al. (2008) report that actinomycetes should not be considered as indicators of pollution when assessing the range of impact of these objects on atmospheric air, because they are constantly found near wastewater treatment plants. This is not confirmed by own studies, in which actinomycetes were isolated in only 13% of samples, and at the control point outside the wastewater treatment plant, they were not present in any analysis (Table 4).

According to Breza-Boruta (2012), about 70% of all microorganisms in the air are fungi. This is due to their small requirements in relation to the environment and food, and also involves the production of large amounts of spores. The concentration of fungi in the air in the treatment plant is very often comparable with the background air. Therefore, the assessment of air pollution based on fungi is not reliable because the highest fungus content (4600 CFU m^{-3}) was found at the control point located 150 meters from the treatment plant, while the aeration chambers and the compost storage area did not exceed 2000 CFU m^{-3} (Breza-Boruta 2010). Budzińska et al. (2011) also observed a higher content of fungi outside the treatment plant than near sand catchers or aeration chambers. This did not allow confirmation of the impact of the treatment plant on the content of fungi in the air. In the Municipal-Industrial Sewage Treatment Plant in Oświęcim, fungi constituted almost 50% of all isolated microorganisms, but their number was varied. Of the 48 research series, in three, the number of fungi at the control point was higher than at the inlet of raw sewage, and in five higher than at the biological reactors (Table 5). Cyprowski et al. (2008) analyzing air samples from four treatment plants showed the highest concentrations of fungi near sewage sludge processing sites (average 770 CFU m^{-3}), and the lowest in biological treatment sites (average 230 CFU m^{-3}). In these studies, there were no significant differences between the concentration of fungi in the treatment plant and in the background. In

own studies, the highest concentration of fungi was observed near the raw sewage inlet (average 573 CFU m⁻³), and the lowest at the control point (average 314 CFU m⁻³) (Table 5).

The results of the conducted research show that in the area of the Municipal-Industrial Sewage Treatment Plant in Oświęcim, air pollution occurs with microorganisms, including pathogenic ones. The bioaerosol that arises in this facility may adversely affect human health and the environment. The analysis showed differences in the number and quality of microorganisms depending on the location of the research point, season of the year and air temperature. The obtained results show that the microbial contamination of the air occurs periodically. For this reason, monitoring should be carried out for a longer period of time.

5 Conclusions

1. In the area of the Municipal-Industrial Sewage Treatment Plant in Oświęcim, there was a diverse bacterial and fungal microflora.
2. The highest air pollution with microorganisms was observed at the inlet of raw sewage and at the biological reactor.
3. The studies have shown the impact of the season and temperature on the number of microorganisms in the air.
4. In the majority of analysis, the air in the sewage treatment plant was characterized by a higher content of microorganisms than at the control point.
5. The results of the conducted research indicate that air pollution of microorganisms, including pathogens, occurs in the treatment plant.
6. Bioaerosol generated in the Municipal-Industrial Sewage Treatment Plant in Oświęcim may contribute to the deterioration of the quality of atmospheric air and adversely affect human health and the environment.

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