

Municipal Wastewater Treatment Plant with Activated Sludge Tanks Aerated by CELPOX Devices as a Source of Microbiological Pollution of the Atmosphere

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Abstract

This paper characterizes the influence of a wastewater treatment plant with activated sludge aerated by CELPOX devices on the microbiological properties of the air at the plant grounds and in the vicinity. Field studies by the sedimentation method were carried out in seven measurement series in 2001. Sampling posts were each time set with regard to the current meteorological conditions like wind speed and wind direction. Microbiological analyses were comprised of: heterotrophic bacteria at 37°C and 26°C, hemolytic bacteria at 37°C and 10°C, staphylococci mannitol-fermenting and non-fermenting, *Escherichia coli*, coliforms *Pseudomonas*, enterococci, actinomycetes, yeasts and moulds.

The results indicate that generally - in accordance with the Polish Standards [1,2] the air at the plant grounds and in its vicinity was not polluted. However, few spots (mostly in some distance from the plant) were detected where a group of microorganisms was present in increased numbers which has qualified the air as polluted. Biological aerosols from the activated sludge tanks were not generated in considerable amounts, which was confirmed by the absence or small number of faecal bacteria (coliforms, enterococci), absence of mannitol-fermenting staphylococci and typical water-sewage bacteria of the *Pseudomonas fluorescens*.

The main sources of microbiological pollution were the grit removal chamber and the secondary settlers.

Keywords: wastewater treatment plant, microbiological atmosphere pollution, CELPOX aerators,

Introduction

The type and range of a wastewater treatment plant's environmental impact depends on the type and size of applied equipment, and mode of operation. Negative impact of a wastewater treatment plant on the surroundings can be determined based on the following criteria: size and capacity of the plant, degradation of chemical substances (including odour-active), degree of air dusting and noise

generation intensity, with parallel observation of meteorological conditions: temperature, humidity, solar radiation, air movement [3,4].

Depending on the type of equipment, plant size and mode of operation, the air can be polluted with toxic chemical gases, active substances, or microbiological pollutants [5]. Wastewater aeration system and airtightness of the plant's objects determine emission intensity and range. Wastewater aeration by aerators, diffusers, sprinklers, and dipper wheels increase the probability that microorganisms usually present in these devices are

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transported to the air. Propagation of microorganisms caused by underwater aeration is much smaller than in cases of surface aeration. One of the most promising solutions includes the CELPOX devices, inducing only minor turbulence in the tanks, and emitting aerosols to a much smaller degree than mechanical aerators with vertical or horizontal axis.

The aim of this study was to determine the actual range of the wastewater treatment plant's influence with CELPOX aerators on the microbiological properties of the atmosphere at the plant and in its vicinity.

Materials and Methods

Technical and Technological Characteristics of the Pasłek Wastewater Treatment Plant (WTP)

The wastewater treatment plant in Pasłek* consists of the following wastewater treatment objects:

- expansion chamber,
- horizontal-flow, rectangular grit removal chamber, with hydraulic cyclone for grit removal, and grit drying plot,
- phosphorus removal tank**,
- denitrification tank,
- nitrification tank,
- system for simultaneous dosing of PIX coagulant,
- secondary settlers,
- measurement devices.

The sludge treatment system is comprised of the following operations:

- mechanical dewatering: belt press-filter equipped with mechanical thickener,
- liming,
- deposition in sludge lagoons,
- WTP-area restoration + sludge use for agricultural and environmental purposes.

Primary treatment of wastes is performed outside the WTP, in the city of Pasłek. Wastewater collected by the sewage system or delivered by wastewater removing vehicles are strained on a 3-mm travelling screen of HYDROPRESS. The screen is equipped with a hydraulic feeder for screenings which are used simultaneously for their pressing.

After screening wastewater flows to the main pumping station and is pumped by submersible pumps to the extension chamber at the plant. A horizontal-flow, rectangular grit removal chamber serves for grit removal. Collected grit is continuously removed by pumps and hydraulic cyclones onto the nearby grit-drying plot. Grit

from the filled-up plot is periodically removed and hauled to a landfill. Operation of the grit removal chamber is regulated by a KPV-IV Venturi tube. The outlet channel has a KDG MOBREY flow-rate meter.

Mechanically treated wastewater flows to two parallel biological treatment systems by low-rate activated sludge method. Before the aeration tanks are situated:

- (a) P-removal tank - receiving sludge returned from the secondary settlers,
- (b) anoxic chamber - receiving sludge returned from the end-section of the aeration tank.

Mixing of the aeration tank contents is performed by means of submersible agitators. In such conditions (input of organic carbon contained in untreated sewage) phosphorus is released (P-removal tank) and nitrates reduced to the level required by the quality standards (denitrification tank). Nitrification is carried out in tanks aerated by CELPOX devices. The aerators provide oxygen and additionally enforce waste circulation in the tank. The applied aeration system is resistant to rapid changes of input loading, which is quickly dispersed in the circulating liquid.

Oxygen concentration in the nitrification tanks is regulated through alteration of the rotational speed of the air-sucking and waste-forcing pumps, controlled by oxygen probes.

As total phosphorus concentration in the effluent must not exceed the value of 1.5 g P/m³, simultaneous coagulation has been provided. For this reason the end-section of the aeration tank is dosed with PIX-coagulant. Coagulant dosages are dependent on waste flow rate (automatic regulation of dosing pump efficiency, depending on the flow rate).

From the nitrification tanks the mixture of wastes and activated sludge is directed to the secondary settlers where sedimentation takes place. Collected sludge is returned to the P-removal tank. Excess sludge is conveyed to an equalizing tank located in the belt press-filter house.

Treated wastewater is discharged to receiving water. The outlet channel is equipped with a flow rate ultrasonic meter.

Sludge collected in the secondary settlers is recirculated by the return-sludge pumping station to the anaerobic tank set before the denitrification tank. Part of the return-sludge, so-called excess-sludge, is pumped away to the mechanical dewatering station. Mixture of the excess-sludge and post-coagulation sludge is delivered to a mechanical thickener manufactured by NIJHUIS and later onto the belt press-filter (of the same origin). After dewatering on the press, sludge is mixed with lime and transported on a conveyor belt to a trailer. The full trailer is emptied to the sludge lagoon for storage. Lagoon capacity amounts to 1,000 days retention time, which promotes further sanitation and treatment of the sludge. Liquid from the flocculator, the compactor and the belt press-filter is conveyed to the WTP internal sewerage system and returned to the treatment process.

* hereafter referred to as Pasłek WTP

** hereafter referred to as P-removal tank

Microbiological Examinations

Sampling and microbiological examinations of air at the individual objects of the Paśłek WTP were carried out by the sedimentation method, in accordance with the Polish Standards (1989). Field studies were performed in 2001, in seven series: February 26th, March 16th, April 4th, August 10th, September 7th, October 17th, and November 12th. Sampling posts were each time set with regard to the currently observed wind speed and wind direction. Placement of the sampling posts is shown in a general layout of the WTP (Fig. 1). In all cases, measurements of the plant's environmental impact were performed upwind and the sampling posts were set up on the wind line. Simultaneous measurements were carried out downwind, outside the plant's premises where the examined objects had no impact (background). Additionally (two times) microbiological composition of sewage purified on activated sludge tank was determined.

Microbiological examinations included:

- heterotrophic aerobic bacteria on broth agar at 37°C /24 h and 26°C/72 h,
- hemolytic bacteria on broth agar with blood at 37°C /24 h and 10°C/24 h,

- mannitol-fermenting and non-fermenting staphylococci on Chapman's medium at 37°C/48 h,
- *Escherichia coli* Endo and Chromocult (MERCK) media at 37°C/24 h,
- Coliforms on Chromocult (MERCK) medium at 37°C/24 h,
- Total coliforms on Eijkman medium at 37°C/48 h,
- Faecal coliforms on Eijkman medium at 44.5°C/48 h,
- enterococci on m-Enterococcus broth agar at 37°C/48 h,
- *Pseudomonas fluorescens* on King B medium at 26°C/48 h,
- actinomycetes on Pochon medium at 26°C/7x24 h,
- yeasts and moulds on Sabouraud dextrose medium | at 30°C/5 x 24 h.

Results are given in CFU/m³ (i.e. colony forming units in 1 m³) of the examined air end MPN/100 cm³ or CFU/cm³ of sewage. Results of the microbiological examinations on the individual posts of air are presented in Tables 3 – 4. Results of microbiological analysis of treated wastewater from activated sludge are presented in Table 2.

Where justified, bacteria were identified with the help of API Staph. and API 20E tests of bio Merieux. Moulds were identified according to Microbiological Applications Laboratory Manual in General Microbiology [6].

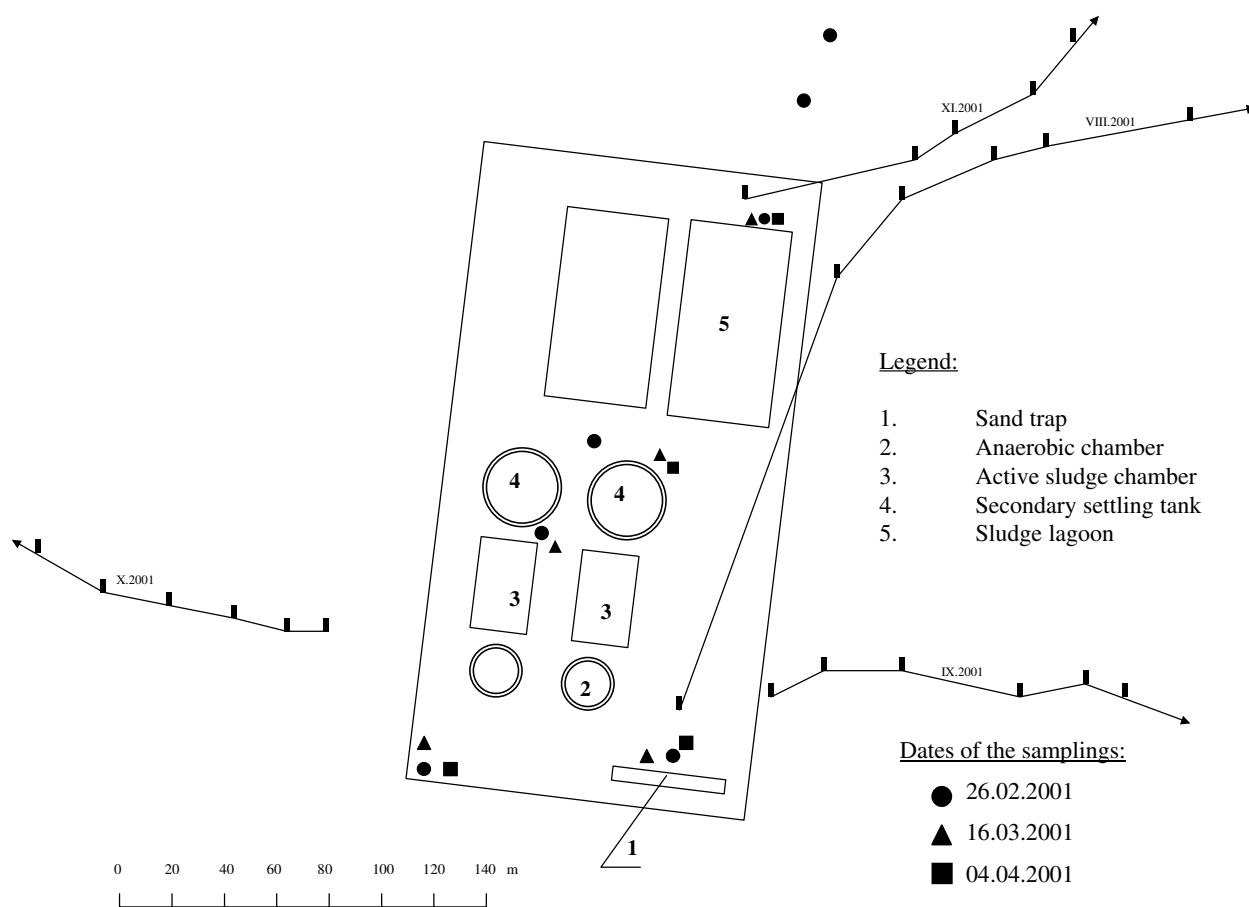


Fig. 1. General layout of the Wastewater Treatment Plant in Paśłek.

Climatic Conditions

Climatic conditions have major influence on the propagation of pollutants in the atmosphere and the range of their influence on the environment and people. In the annual section, the most favourable meteorological conditions (and thus conditions for pollution dispersion in the atmosphere) prevail from April through July. Increase of humidity stimulates transformations of the emitted substances in the atmosphere, as well as condensation of dust. Cloud cover, especially of the stratified type, indicates that the conditions for vertical air exchange have been hindered and as a result - conditions for dispersion of the emitted pollutants. From this point of view, the least favourable period of the year is November and December.

In winter-spring period during field studies (from 10 a.m. till 1 p.m.), wind prevailed in a north-eastern direction at a speed of 0 to 7 m/s. On February 26th the sky was very cloudy, snow with rain came at night, the temperature hovered around 0°C. On March 16th the cloudiness was medium, wind speed varied between 0 and 6 m/s. April 4th was a sunny day, drizzle came at night, wind speed did not exceed 2 m/s, temperature reached about 15°C.

The summer-autumn period was sunny. Only in November was the examination day cloudy; at night and in the morning it was drizzly. The wind direction was changing, the prevailing direction was eastwards. Only on 17th Oct. the wind was blowing in the western direction. The wind speed was low and varied between 0 and 6 m/s; on 12th Nov. it was a little higher: 3-7 m/s. Humidity ranged from 93 to 99 %, temperature from 19 to 25°C; in November it equalled 10°C. The results of the meteorological observations are presented in Table 1.

Study Results

Treated Wastewater from Activated Sludge

Quantitative composition of the wastes from the activated sludge tank was determined twice: in the beginning and at the end of the study (Table 2). 1 cm³ of the wastes

contained from $6.6 \cdot 10^6$ to $23.4 \cdot 10^6$ heterotrophic bacteria on broth agar at 26°C and from $1.2 \cdot 10^6$ to $4.2 \cdot 10^6$ at 37°C; β -hemolytic bacteria comprised $65.5 \cdot 10^3$ - $17 \cdot 10^4$, and α -hemolytic bacteria $72.5 \cdot 10^3$ - $41 \cdot 10^4$. Fluorescein creating *Pseudomonas fluorescens* on King B medium was marked in the amount of $35 \cdot 10^3$ - $18 \cdot 10^4$ cells in 1 cm³; enterococci: $27.5 \cdot 10^3$ - $345 \cdot 10^3$. MPN*/100cm³ of Total coliforms bacteria reached $15 \cdot 10^6$ and Faecal coliforms - $7.5 \cdot 10^5$. *Escherichia coli* was marked in the amount of $34.5 \cdot 10^3$ cells in 1 cm³. Mannitol-fermenting staphylococci were present in the amount of 1 000, non-fermenting forms from 965 to 9,000 in 1 cm³. Yeast content varied from $42.5 \cdot 10^3$ to $43 \cdot 10^4$ and moulds from 18,250- 20,000.

WTP Area

In the air on the individual sampling posts (Table 3) the total count of mesophilic bacteria varied between 0 and 313 in 1 m³ of the air which qualifies the air as unpolluted. Much higher numbers were detected in case of the total count on broth agar at 26°C. The sample taken on the reference post contained above 3,000 bacteria in 1m³ of air. These values were considerably exceeded near the grit removal chamber and the sludge lagoons. On the other hand, on the catwalks of the P-removal tank and the nitrification tank, the number of microorganisms in the air was relatively low. Exceptionally high was the count on broth agar at 26°C marked in the sample taken at the end of February aside the nitrification tank. The wind speed then reached 7 m/s and the bacteria were probably blown around from other objects, like for instance the grit removal chamber during the grit removal system operation. Spiral patterns of bacteria on the plates confirm such an assumption. In this group of bacteria, the pigment-creating forms, thus typical for air, often comprised more than 50% of the total heterotrophic count, especially in March and April.

β -hemolytic bacteria were detected also in the air near the grit removal chamber, on the catwalks of the P-removal tank and the nitrification tank (in March and April) and aside the aeration tank in February and April, as well as behind the secondary settler and the sludge lagoon

Table 1. Meteorological conditions during the experiment.

Sampling date	Dominating wind direction		Wind speed m/s	Temperature °C	Humidity %	Atmospheric observations
	from	to				
26 Feb., 2001	SW	NE	2.0 – 7.0	0	-	Snow cover. Rain and snow at night. Heavy cloud cover.
16 Mar., 2001	SW	NE	0.0 – 5.0	10	-	No snow cover. Medium cloud cover with cloud breaking.
4 April, 2001	SW	NE	0.0 – 2.0	15	-	Light cloud cover. Sunny. Drizzle at night.
10 Aug., 2001	SW	E	0.0 – 6.0	25	93	Sunny day.
7 Sept., 2001	W	E	0.0 – 2.0	19	96.9	Sunny day.
17 Oct., 2001	E	W	1.0 – 4.0	18	-	Sunny day.
12 Nov., 2001	S	NE	3.0 – 7.0	10	99	Drizzle at night and in the morning.

(in February). The number of hemolytic bacteria in the vicinity of the aeration tanks was relatively low in comparison to those reported for application of the mechanical aerators with vertical or horizontal axis. Among these bacteria there were no mannitol-fermenting staphylococci; therefore, in accordance with the Polish Standard [1] the air in the vicinity of the activated sludge tanks can be categorised as unpolluted.

The water-sewage bacteria of *Pseudomonas* genus were scarce: from 0 to 146. Among them the *Pseudomonas fluorescens* species was detected (April 4th) in the number of 9 cells only on the post aside the aeration tank and thus we may classify this air as unpolluted. It is very possible that the source of *Pseudomonas* was the operating hydraulic cyclone, as the grit removal chamber is situated on the examined air trace-line.

The number of actinomycetes – the organisms of soil origin – from 0 to 122 on the individual posts (including the reference post) indicates that the air can be classified as unpolluted or medium polluted (especially near the grit removal chamber, aside the nitrification tank and behind the secondary settler [1].

The number of fungi was very low with the dominance of moulds, especially with no snow cover. The max. quantities were detected behind the sludge lagoon but not more than 1,750. The following genus were marked: *Mucor*, *Oospora*, *Aspergillus*, *Penicillium*, *Cladosporium*, *Alternaria*, *Pullaria*, *Verticillium*, *Scopuloriopsis*,

Paecilomyces, *Fusarium*, *Diplosporium*, and the *Saccharomyces* yeasts. Yeasts were determined in small amounts both in the background air and aside the aeration tanks. It is of little probability that their source were aerosols of the sewage origin. Such an assumption can be confirmed by examinations of the typical sewage bacteria: enterococci, *Escherichia coli*, coliforms and other bacteria from *Enterobacteriaceae* emarked on Endo and Chromocult media. Enterococci were not detected in all examined aerosols. On the other hand, *Escherichia coli* was abundant - more than 100 cells - in April near the grit removal chamber when the hydraulic cyclone was operating, and in February beside the aeration tank - 17 cells in 1 m³ of air. However, it should be taken into consideration that the examinations in February were done while snow was covering the ground and the microbiological pollutants of soil origin had no influence on the bacterial properties of the air. On the other hand, it was very windy and the wind could blow around bacteria from other objects.

Analysis of the air sanitary indicators [5] especially of the M-indicator, has revealed that only near the grit removal chamber and behind the secondary settler the air might pose a sanitary risk because the values determining the ratio of total bacteria count on broth agar at 37°C detected in the examined air and in the background air is equal or higher than 2. Such a risk has not been determined for other posts (Table 3a).

WTP Surroundings

Table 2. Number of microorganisms (jtk / cm³) in treated wastewater from activated sludge tank.

Microorganisms	Number of microorganisms
Heterotrophic bacteria (TVC 37 °C)	1 240 000 (a)
	4 222 500 (b)
Heterotrophic bacteria (TVC 26 °C)	23 400 000
	6 615 000
Hemolytic bacteria (37 °C)	65 500 β
	170 000 β
	72 500 α
	410 000 α
Mannitol-fermenting staphylococci	1 000 (a)
Mannitol non-fermenting staphylococci	9 000 965
Total coliforms (MPN)/100	150 000 (a)
Faecal coliforms (MPN)/100	7 500 (a)
<i>Escherichia coli</i>	34 500 (b)
Enterococci	27 500
	345 000
<i>Pseudomonas fluorescens</i>	180 000
	35 000
Yeasts	430 000
	42 500
Moulds	20 000
	18 250

Date of sampling : (a) -26. 02. 01, (b) - 12. 11.01

*MPN – most probable number

While evaluating sanitary properties of air first of all the total number of bacteria on broth agar at 37°C should be taken into account. In the WTP's ambient air (Table 4) the number of mesophilic bacteria (with potentially pathogenic bacteria amongst) varied between a few tens (behind the sludge lagoons) and about 6.5 thousand in 1 m³ of air which categorises the air from unpolluted to heavily polluted. Unpolluted air was detected on 26th Feb. on the post behind the sludge lagoons in the distance from 50 to 100 m, on 17th Oct. in the distance up to 150 m from the fence; on 12th Nov. on all sampling posts located up to 155 m. Medium polluted air was detected on 10th Aug. on nearly all posts at a distance of 193 m from the WTP, and on 7th Sept. on most of the examined posts. The air was heavily polluted in the distances of 15, 50 and 100 m during the September examinations. These results have been confirmed by the analysis of the sanitary indicators (Table 4a). In September at the 100-m distance from the plant the air was so polluted that may have been sanitary hazardous: the ratio of the total number of bacteria on broth agar at 37°C between the examined air and the background air exceeded the value of 2. Such risk was not determined on other posts. However, it was a nearly windless day (wind speed < 2 m/s) and the air on the reference post contained above 2.6 thousand cells in 1 m³. Therefore, the bacteria may not have come from the WTP but it could be a local pollution. The thesis seems to be confirmed by the fact that in the distance

Table 3. Number of microorganisms in 1 m³ of air on sampled at the WTP area.

Sampling post	Heterotrophic bacteria		Hemolytic bacteria 37°C		Hemolytic bacteria 10°C		Staphylococci		E. coli	Other G ⁻ bacteria	E. coli	Colliforms	Enterococci	Pseudomonas fluorescens	Actinomycetes	Yeasts	Moulds
	37°C	26°C	α	β	α	β	m+	m-									
Reference post	1	26	3 187(0)	52	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	260	6039(290)	78	0	78	0	0	0	0	0	0	0	0	44	78	208
	3	130	130 (78)	78	0	0	0	0	0	0	0	0	0	19	9	26	261
Grit removal chamber	1	52	1339(104)	78	0	0	0	0	0	52	0	0	0	0	0	52	52
	2	52	260 (52)	0	0	0	0	0	0	0	0	0	0	0	44	0	130
	3	78	157 (548)	78	78	0	0	0	0	35	108	262	0	26	52	26	182
P-removal tank catwalk	2	52	260(290)	104	133	52	0	0	0	0	0	0	0	0	0	0	104
	2	26	182 (104)	0	0	26	0	0	0	0	0	0	0	0	0	0	313
Nitrification tank catwalk	3	26	157 (157)	0	26	26	0	0	0	0	0	0	0	9	17	0	157
	3	104	104 (78)	26	78	0	0	0	0	148	0	0	0	26	9	26	104
	1	26	3 312(34)	130	26	0	0	0	0	17	9	0	0	0	9	26	26
Aeration tank	2	26	208 (157)	0	0	0	0	0	0	0	0	0	0	0	0	157	861
	3	52	365 (365)	104	26	0	0	0	0	0	0	0	0	146 (9)	122	0	313
	1	26	1279(290)	52	0	0	0	0	0	0	0	0	0	0	0	104	130
Secondary settler	2	26	313 (182)	0	26	0	0	0	0	0	0	0	0	0	18	26	496
	3	313	1226 (2349)	235	52	0	0	0	0	0	0	112	0	26	52	208	
	1	0	13821(52)	26	0	0	0	0	0	0	0	0	0	0	0	0	157
Sludge lagoon	2	26	104 (78)	26	0	0	0	0	0	0	0	0	0	43	18	0	1749
	3	182	496 (940)	48	26	0	0	0	0	0	0	0	0	0	26	0	313

Date of sampling: (1)- 26 February, 2001; (2) - 16 March, 2001; (3) - 4 April, 2001.

() - pigmented or pigment-creating bacteria

m+ - mannitol fermenting staphylococci

m- - mannitol non-fermenting staphylococci

between 0 and 49 m the ratio was about 1.

Heterotrophic bacteria on broth agar at 26°C comprise micro-flora naturally present in the air. They were detected in the range from a few tens to a few thousand cells in 1 m³ of air, most of which was pigment-creating forms. These values were largely exceeded during the winter examinations on the post located 50 m from the sludge lagoons. Wind speed reached 7 m/s and the bacteria may have been blown by the wind (which confirms the spiral pattern on the plates) from the grit removal chamber during degritting operation, as well as from outside the plant's grounds.

Quite numerous in the WTP's ambient air (from few tens to few hundred cells) were β-hemolytic bacteria. However, since the group did not contain mannitol-fermenting staphylococci, in accordance with the Polish Standard the air can be classified as unpolluted. Exceptionally high (16) was the count of β-hemolytic staphylococci in October on the reference post downwind of the WTP. Identification of these bacteria by means of the API Staph test has revealed the following species: *Staphylococcus sciuri*, *Staphylococcus capitis*, *Staphylococcus warneri*. They can be of human and animal origin, but they are coagulase-negative. In certain conditions these bacteria can even be pathogenic. It cannot be rejected that they originated from the WTP as the survival rate is very long (100 days) for *Staphylococcus* in dry-out conditions e.g. on clothes [7].

Table 3a. Air pollution indicators determining sanitary risk to humans at the WTP area.

Sampling post	M	P	F
Grit removal chamber	2.0	4.2	-
	0.2	0.3	0.4
	0.6	3.2	0.7
	0.4	0.3	0.3
P- removal tank catwalk	-	-	-
	1	0.3	-
	-	-	-
Nitrification tank catwalk	1	0.3	-
	0.1	1.5	3.6
	0.8	1.3	1.1
Aeration tank	1.0	1.0	-
	0.1	0.9	3.6
	0.4	3.5	1.1
Secondary sedimentation tank	1	0.5	-
	0.1	1.2	1.9
	2.4	17.2	0.9
Sludge lagoon	0	4.3	-
	0.1	0.4	6.1
	1.4	6.9	1.1
	1.96	1	0.99
	0.03	0.4	1.4

The water-sewage *Pseudomonas fluorescens* bacteria were not present in the direct vicinity of the WTP. They were detected only in September at a distance of from 15 to 150 m from the plant which indicates medium and heavily polluted air [1]. They could be wind-blown from the plant's area at favourable atmospheric conditions, and survive in the environment.

The quantity of actinomycetes – typical soil microorganisms - varied from 0 to 175 on the individual posts which indicates unpolluted and medium polluted air; exceptionally in September and November it was heavily polluted at distances of 15 and 30 m from the fence [1].

The number of yeasts (pointing at the water-sewage origin) was very low. Dominant were moulds, especially in summer when up to 79 thousand were marked in 1 m³ of the air. In August the air on nearly all posts was heavily polluted with moulds, in September and October – medium polluted, and in November when the temperature decreased below 10°C – unpolluted. The F-indicator analysis has revealed that the sanitary condition of the air reflecting pollution with fungi (Table 4a) classifies the air in summer as hazardous to health (high temperatures stimulate growth of these microorganisms). In other periods such risk has not been determined.

Dominant among moulds were: *Alternaria*, *Cladosporium*, *Scopuloriopsis*, *Rhizopus*, *Diplosporium*, *Verticillium*, *Aspergillus*, *Fusarium*, *Pullaria*, *Trichothecium*,

Table 4a. Air pollution indicators determining sanitary risk to humans in the WTP surroundings.

Sampling post (distance from the WTP fence)	M	P	F
0 - 15 m	0.7	1	6.8
	1.2	0.6	0.6
	0.1	0.9	0.3
16 - 50 m	1	8.6	26
	1.8	0.6	1.1
	1.2	6.9	0.9
	0.3	0.8	0.7
51 - 100 m	0.3	2.8	0.4
	2	0.02	-
	1.1	1.3	0.9
	2.4	0.9	1.7
	0.3	1.2	0.8
101 - 150 m	0.1	1.4	1.2
	0.8	1.2	1.1
	0.4	0.2	0.7
	0.4	0.2	0.7
	0.4	0.2	0.3
151 - 200 m	0.2	1.2	0.4
	0.9	1.4	0.9
	3.6	0.5	0.9
	0.1	0.3	0.3

M - indicator: determines the ratio of total bacterial count marked on broth agar at 37 °C in the sampled air sampled and in the reference sample (background).

P - indicator: determines the ratio of total bacterial count marked on broth agar at 26 °C in the sampled air sampled and in the reference sample(background).

F - indicator: determines the ratio of total fungal count marked in the examined air sampled and in the reference sample.

Paecilomyces, *Penicillium*, *Mucor*, *Cunninghamella*, *Phoma*. These are typical organisms living on plants and in soil. Their sewage origin is of very little probability. Generally, the typical sewage bacteria were not detected, i.e. enterococci and Coliforms or *Escherichia coli* on Endo and Chromocult media. In the summer-autumn period (only in October) enterococci were present in the amount from a few to a few tens of cells, on nearly all posts. In the remaining study periods they were not detected. Likewise, the typical sewage bacteria *Escherichia coli* was not detected in the examined air. It was present (only in August) on the reference post but on that day the influence of the WTP should be excluded. Identification on the API 20E tests confirmed the presence of the following bacteria on the reference post: *Escherichia coli* and *Escherichia vulneis*, *Rahnella aquilis* and *Pantotea spp.* The sewage origin may not be fully eliminated although the bacteria most probably came from the neighbouring farms with animals grazing on the nearby pastures.

Discussion

There are plenty of atmospheric pollution types and thus sources of pollution are numerous and versatile. The latter can be divided into two main groups, i.e. natural and artificial. Among the artificial pollution sources industrial and domestic sources can be further distinguished. The domestic sources are various and comprise a large part of non-natural objects in the atmosphere. Beside gases and dust, the domestic pollutants are also: fungal spores, bacteria and viruses present in the air as aerosols [8]. Domestic wastewater contains a wide range of microorganisms (bacteria, fungi, viruses, protozoan cysts, worm eggs). Wastewater treatment plants are sources of biological aerosol emissions that in turn comprise an element of atmospheric pollution. The term biological aerosol is used to describe fine drops of liquid or fine particles of solid material containing fungal spores, bacteria, viruses, plant pollen and others. Waste aeration is the reason for emission of small or large droplets with attached microorganisms. In reference literature [9] it is reported that the most active in aerosol emissions to air is the thin surface layer (few mm thick) of wastes in which inorganic and organic substances, and microorganisms concentrate. Density of pollutants in this layer, like in the aerosols emitted to the air, exceed considerably, i.e. by 10-1,000 times the average concentration in the wastewater sampled from the middle of the aeration tank. Microorganisms can be lifted from the wastes to air when their quantity exceeds 10^3 cells in 1 cm^3 of air [10]. Such conditions were created in the activated sludge tank at the WTP in Pasłęk. Density of the microorganisms in 1 cm^3 of the wastes was much higher than reported for the aeration tanks in Bartoszyce WTP, where the total number of heterotrophic bacteria equalled 1,100 thousand [11].

The most exposed to aerosol influence are areas adjacent to aeration tanks. In Poland aeration tanks covering has

not been a frequently applied method. In such circumstances, the main way to reduce aerosol emission is by choosing proper aeration method. One of the possible solutions are the CELPOX aerators, not causing excessive turbulence, nor generating aerosols in quantities typical for mechanical aerators with vertical or horizontal axis. In the latter case, the number of microbiological pollutants can reach from a few tens of thousands in 1 m^3 [12] up to over 80 thousand/ m^3 [11].

The results of the microbiological examinations carried out at the Pasłęk WTP have shown that a wastewater treatment plant with CELPOX aerators does not deteriorate the microbiological quality of the air in the degree that would classify the air as polluted. Total number of bacteria used as air pollution indicator neither allows to estimate health risk, nor to indicate the sources of bacteria. Therefore, the examinations have been extended by analysis of faecal bacteria from *Enterobacteriaceae* family and enterococci. Bacteria from *Enterobacteriaceae* family in high quantities were detected in the air at the expansion chamber near the grit removal tank, especially during the hydraulic cyclone operation. They may have been carried over with the air current to the nitrification tank and thus in the April examinations the bacteria were marked on Endo medium whereas on Chromocult they were absent.

While assessing the degree of environmental hazard generated by a WTP the survival rate of microorganisms in given conditions should also be considered. In wastewater they find very favourable conditions for growth, thus the survival rate is very high and reaches tens of days. Microorganisms transferred from wastes to the air have to survive in less favourable conditions. Until now, reproduction of microorganisms in the atmosphere has not been reported [13,14]. Mortality of microorganisms during propagation in the air is a function of many factors such as: type and properties of cells, relative humidity, air temperature, oxygen concentration, visible and ultraviolet radiation, air pollution [7]. Some part of microorganisms present in the atmosphere set on the ground surface as a result of the settlement process. It has been reported that enteroviruses can survive on the ground surface in natural conditions up to 35 days, while only seconds in the air (depending on the conditions) [15].

The presence of pathogenic bacteria in aerosols does not always cause pathogenic alterations. Induction of the latter is directly related to the quantity of microorganisms and an organism's vulnerability to infection. Geldreich reports that infectious dosages of *Enterobacteriaceae* resultant in clinical symptoms are for *E.coli* 157:H7 10^2 - 10^9 cells, for *Salmonella* 10^6 - 10^7 cells, for *Yersinia enterocolitica* 10^9 cells, and for *Shigella* 10^2 cells [16]. It should be emphasised that there are no epidemic data regarding infections evoked by typical air-polluting microorganisms [17]. These studies have not revealed increased sick rate among WTPs employees [18,19]. In reference literature suggestions can be found that WTP employees gain resistance to sewage aerosols. On the other hand, the

Table 4. Number of microorganisms in 1 m³ of air sampled in the WTP surroundings.

Sampling post	Heterotrophic bacteria		Hemolytic bacteria 37°C		Hemolytic bacteria 10°C		Staphylococci		E.coli		Other G ⁻ bacteria	E.coli	Coliforms	Enterococci	Pseudomonas fluorescens	Actinomycetes	Yeasts	Moulds
	37°C		α	β	α	β	m+	m-	Endo	Chromocult								
Reference post	1	1799	1731 (301)	376	128	677	75	0	0	8	68	0	0	0	0	17	300 C	300 C
	2	2687	2709(2107)	504	173	2656	75	0	8	0	68	0	0	0	0	25	0	7 999
	3	351	376 (527)	-	-	-	-	16	0	0	0	0	0	8	0	25	0	1 705
0-15 m off the fence	4	853	38 (777)	100	25	0	25	0	17	0	0	0	8	0	16	25	25	1 178
	1	1355	1731(346)	549	75	452	978	0	0	0	0	0	12	0	42	75	75	79 416
	2	3085	1780(1174)	429	75	2483	150	0	40	0	100	0	25	0	125	75	75	5 064
16-50 m off the fence	3	226	324 (399)	-	-	-	-	0	16	0	17	0	0	42	0	25	0	452
	x	26	27 408 (0)	130	0	0	0	0	0	0	0	0	0	0	0	0	26	0
	2	4 492	1580(1227)	3648	25	2 130	150	0	0	0	100	0	33	0	25	25	25	8 428
51-100 m off the fence	3	426	5 591 (655)	-	-	-	-	0	8	0	0	0	0	0	0	0	0	1 630
	3	100	247(452)	-	-	-	-	0	17	0	0	0	0	0	0	0	0	1 254
	4	251	1279(1028)	25	0	0	25	0	17	0	8	0	8	0	33	175	326	
101-150 m off the fence	x	52	78(0)	183	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1881	2 084 (602)	354	173	828	827	0	0	0	108	0	25	0	25	25	98	10 836
	2	6 472	2 988 (1505)	579	474	5870	75	0	58	0	143	0	50	0	42	33	75	13 244
151-200 m off the fence	3	275	602 (476)	-	-	-	-	0	16	0	0	0	0	8	8	8	0	1 304
	4	75	301 (877)	25	0	0	0	0	16	0	33	0	25	0	16	75	1404	
	1	1482	2 205(248)	376	98	655	71	0	0	0	100	0	50	0	75	978	12 191	
Date of sampling: (x) - 28 February, 2001; (1) - 10 August, 2001; (2) - 7 September, 2001; (3) - 17 October, 2001; (4) - 12 November, 2001	2	1054	753 (324)	579	0	379	98	0	0	0	0	0	0	0	25	0	5 847	
	2	1031	476 (399)	25	278	376	25	0	0	0	25	0	0	0	25	25	173	2 604
	3	125	351 (275)	-	-	-	-	0	0	0	0	0	0	8	17	0	0	1 254
()	4	151	828 (151)	50	25	0	0	0	0	0	0	0	8	0	0	0	25	426
	1	1603	2 431 (474)	504	128	116	278	0	0	0	108	0	0	0	0	0	25	10 159
	3	1254	275 (150)	-	-	-	-	0	0	0	0	0	0	8	0	0	0	1 129
m+	4	100	226 (23)	25	25	0	0	0	17	0	0	0	0	0	0	0	50	350

Date of sampling: (x) - 28 February, 2001; (1) - 10 August, 2001; (2) - 7 September, 2001; (3) - 17 October, 2001; (4) - 12 November, 2001

() - pigmented or pigment-creating bacteria

m+ - mannitol fermenting staphylococci

m- - mannitol non-fermenting staphylococci

presence of pathogenic microorganisms can be especially risky to persons accidentally present in a WTP area [17].

Conclusions

1. Microbiological analysis of the air performed in the vicinity of the Pasłek WTP where CELPOX aerators have been used for activated sludge aeration allows to conclude that in regard to the current Polish Standards [1,2], the air at the plant's grounds and in the direct vicinity was mostly unpolluted.
2. Generation of considerable quantities of biological aerosols from the activated sludge tanks was not recorded. The conclusion confirms the absence or very small amounts of *E.coli* coliforms, enterococci, mannitol-fermenting staphylococci, and typical water-sewage *Pseudomonas fluorescens* bacteria in the examined air on the sampling posts near the aeration tanks.
3. The major source of microbiological pollution of the air at the Pasłek WTP were: the expansion chamber and the grit removal chamber (especially during the hydraulic cyclone operation) situated one close to another, and the secondary settler. These objects, together with the sludge lagoons (especially during sludge discharge) may comprise emitters of increased quantities of biological aerosols.
4. Analysis of the air sanitary indicators (especially of the M-indicator) confirms that only near the grit removal chamber and behind the secondary settler may the air pose a sanitary risk.
5. Reduction of the WTP's microbiological pollution of the ambient air can be obtained through the following measures:
 - covering the expansion chamber and the distribution chamber,
 - covering the grit drying plot,
 - replacement of hydraulic cyclone with grit separator and washer,
 - restoration of the "resting" lagoon by covering with black-earth and sowing with grass,
 - regular covering of sludge stored in the lagoon with loose isolation material,
 - introduction of a 3-level isolation green belt around the WTP (one of the levels planted with winter green).

References

1. Polska Norma, [PN-89/Z-04111/02], **1989**.
2. Polska Norma, [PN-89/Z-04111/03], **1989**.
3. CAMANN D. E. A. Model for Predicting Dispersion of Microorganisms in Wastewater Aerosols. EPA-600/9-80-028, 47-70, **1980**.
4. KULIG A., SKORUPSKI W. Dobór kryteriów oceny zasięgu oddziaływania oczyszczalni ścieków na otoczenie. Biuletyn Komisji ds. Ocen oddziaływania na Środowisko, **6**, 18 - 26, **1992**.
5. KALISZ L., KAŻMIERCZUK M., SAŁBUT J. Miejska oczyszczalnia ścieków jako źródło mikrobiologicznego zanieczyszczenia powietrza. Ochrona Środowiska i Zasobów Naturalnych nr 7, 33 - 54, **1994**.
6. BENSON H, J. Microbiological Applications. Laboratory Manual in General Microbiology. The McGraw-Hill Companies, Inc. **1998**.
7. JANOWIEC M. Mikrobiologia i serologia, Warszawa PZWL, **1988**.
8. RUTKOWSKI I. J. D. Źródła zanieczyszczeń powietrza atmosferycznego. Wydawnictwa Politechniki Wrocławskiej. Wrocław, **1993**.
9. BLANCHARD D.C., SYZDEK L.D. Water to air transfer and enrichment of bacteria in drops from bursting bubbles. Appl. Env. Microbiol. **43** (5), 1001 - 1005, **1982**.
10. KATZENELSON E., TELTSCH B. Dispersion of enteric bacteria by spray irrigation. Jour. Water Poll. Control Fed., **48**, 710 - 716, **1978**.
11. FILIPKOWSKA Z., JANCZUKOWICZ W., KRZEMIENIEWSKI M., PESTA J. Microbiological air pollution in the surroundings of the wastewater treatment plant with activated-sludge tanks aerated by horizontal rotors. Pol. J. Env. St. **4**, 273 - 280, **2000**.
12. FILIPKOWSKA Z., KORZEKWA K. Miejska oczyszczalnia ścieków źródłem mikroorganizmów zanieczyszczających powietrze. Inżynieria i Ochrona Środowiska, **2** (3-4), 333 - 345, **1999**.
13. SHLEGEL H. G.. Mikrobiologia ogólna. PWN. Warszawa, **1996**.
14. KRZYSZTOFIK B. Mikrobiologia powietrza. Wyd. PW., Warszawa, **1995**.
15. TELTSCH B., KATZENELSON E. Airborne enteric bacteria and viruses from spray irrigation with wastewater., Appl. Environ. Microbiol., **35**, 290 - 296, **1978**.
16. GELDREICH E.E. Pathogenic agents in freshwater resources. Hydrobiological processes, **10**, 315 - 333, **1996**.
17. NORTHROP R., CARNOW B., WADDEN R., ROSENBERG S., NEAL A., SHEAFF L., HOLDEN J., MEYER S., SCHEFF P. Health effects of aerosols emitted from an activated sludge plant. Water aerosols and diseases. Proceeding of a Symposium, A-600/9-80-028: 188-205, **1980**.
18. CAMANN D. E. Water aerosols and diseases, EPA-600/9-80-028, 168-178, **1980**
19. EPA (Environmental Protection Agency). Estimating microorganisms densities in aerosols from spray irrigation of wastewater. EPA-600/9-82-003, 1-27, **1982**.