Polish Journal of Environmental Studies Vol. 9, No. 4 (2000), 273-280

Microbiological Air Pollution in the Surroundings of the Wastewater Treatment Plant with Activated-Sludge Tanks Aerated by Horizontal Rotors

Z. Filipkowska[1], W. Janczukowicz[2], M. Krzemieniewski[2], J. Pesta[2]

[1] Department of Environmental Microbiology
[2] Department of Environmental Engineering
Division of Ecological Engineering; Warmia and Mazury University in Olsztyn,
10-950 Olsztyn, Prawochenskiego 1

Received: January 7, 2000
Accepted: March 10, 2000

Abstract

Wastewater treatment plants affect the environment in many different ways. It can be assumed that the intensity and range of microbiological emission is the crucial factor in determining the range of restricted-usage zone. This paper presents emission levels of microbiological pollutants from the wastewater treatment plant in Bartoszyce, Poland. It is a new plant with multifunctional activated-sludge tanks where wastewater is aerated by horizontal-axis aerators. The study has shown that aeration tanks constitute a significant source of biological aerosol emissions. Considerably smaller amounts of microorganisms are emitted into the atmosphere from wastewater-collection posts and secondary settling tanks.

Keywords: wastewater treatment plant, aerosols, emission, microorganisms, meteorological observations

Introduction

In July 1998, the Ministry of Environmental Protection, Natural Resources and Forestry issued a decree regarding investments which are particularly harmful to the environment and to human health. Wastewater treatment plants of 150,000 PE or more were categorized as particularly harmful, and those from 400 to 150,000 PE as potentially deteriorating the environmental condition [1]. At the same time, wastewater treatment plants (besides other investments, e.g. landfills) were classified as structures which may necessitate establishing a restricted-usage zone in their surroundings. This decision can be explained by the fact that it is impossible to eliminate environmentally- negative effects of the treatment plant outside the area to which its owner has legal rights.

Wastewater treatment plants affect the environment in many different ways. According to the type of the equipment used, a plant's capacity, and its method of operation, it may pollute the air with toxic chemical gases, smell-active substances and microorganisms.

In the case of municipal wastewater treatment plants the key factor in determining the range of restricted - usage zone will undoubtedly be the intensity and range of microbiological emissions. This is due to the fact that wastewater treatment plants emit aerosols which transport bacteria, viruses and fungal spores witch can be detrimental to human health.

The level and range of emission is determined by the sewage aeration system and the plant's degree of hermetization. Microorganismal expansion is smaller when depth aeration rather than surface aeration is employed.

This paper presents the issue of microbiological pollution in the surroundings of the municipal wastewater treatment plant in Bartoszyce, Poland (equipped with BI-WATER rotors).

Treatment Facilities in the Wastewater Treatment Plant in Bartoszyce, Poland

The technological system of the plant utilizes the following facilities and devices:

- travelling screen,
- raw-wastewater pumping station,
- vertical grit chambers,
- combined activated-sludge tanks,
- secondary settling tanks,
- flocculator,
- post-flocculation clarifier,
- mechanical thickener,
- press filter bed.

Wastewater entering the plant through the main collection channel brought in by the waste removing vehicles is initially treated on the travelling screen of 6 mm spacing, which retains large solid material. The screen, coupled with a hydraulic feeding device, serves as the press for the screenings. The stand-by unit used for filtering wastewater in case of break-down is the manual bar rack.

The next element of the system is the intermediate pumping station. Three submersible pumps working simultaneously convey wastewater free of solid waste to the two simultaneously working vertical-flow grit chambers. The separated grit is removed by means of a mammoth pump to a specially adjusted trailer, and hauled to a landfill. From the grit chambers wastewater flows by way of gravity to the two simultaneously working systems of biological treatment as low-rate activated sludge. The system starts with the anoxic tank, which receives wastewater pre-treated mechanically and the return activated sludge.

From the anoxic tanks wastewater flows to the aeration tanks where nitrification takes place. Wastewater is aerated by the horizontally mounted surface aerators Maxi Rotor of BIWATER. The aerators play a double role: aerate the activated sludge and agitate the liquid. The aerators utilize oxygen probes and are controlled by computer.

From the aeration tanks the mixture of wastewater and activated sludge flows to the secondary settlers for sedimentation. Part of the sludge settled in the funnels is returned to the denitrification tanks, the other part - the so-called waste sludge - is pumped off for further treatment.

Wastewater from secondary settlers flows to the flocculator where phosphorus is chemically precipitated by the PIX coagulant. The coagulant dosing rate is automatically controlled by the system, which regulates the volumetric pump's efficiency according to the flow-rate. Flocculation takes place in two tanks of rapid and slow mixing, providing the maximum efficiency of the process. Wastewater flows from the flocculator to the post-flocculation clarifier and is finally discharged into the recipient.

Waste sludge collected in the secondary settlers and in the post-flocculation clarifier is conveyed to the waste-sludge pumping station. The sludge mixture is pumped to the thickener, then to the preliminary flocculator, and finally to the mechanical thickener (compactor). Those facilities allow to preliminarily thicken the sludge to about 10% of dry-base. From the compactor the sludge is passed on to the horizontal belt filters for dewatering.

Dewatered sludge is mixed with hydrated lime and the resulting mixture is pumped onto trails and hauled to a landfill for composting with municipal waste.

Methods

Sampling and microbiological examinations were conducted in accordance with the Polish Standards [2, 3, 4, 5]. The field study utilized the sedimentation method and was carried out in three measurement series. July 1st, July 7th, and Sept. 10th, 1998. Each time the sampling posts were selected on the basis of meteorological observations of wind speed and direction. Sampling post distribution is shown in block diagram (Fig. 1). All measurements of the effect of the plant were taken upwind. The sampling posts were situated on the wind-line and assigned the following numbers:

1 - at the wastewater collection post,
2 - at the pumping station,
3 - at the thickener,
4 - on the bridge connecting the aeration tanks,
5 - between the secondary settlers,
6 - 12 m from the post-flocculation clarifier,
7 - at the discharge point,
8, 9, 10 - outside the fence at 25, 50 and 100 m, respectively.

Analogous measurements were carried out downwind and defined as the background.

The microbiological markings comprised the following:

- heterotrophic plate count (HPC) on broth agar at 37°C/24h and 26°C/72h,
- hemolytic bacterial count on broth agar with blood at 37°C/24h,
- mannitol-fermenting and non-fermenting staphylo cocci on Chapman's medium at 37"C/48h,
- *Enterobacteriaceae* on Endo medium at 37°C/24h,
- *Aeromonas hydrophila* on mA medium at 37°C/24h,
- *Pseudomonas* on King A medium at 37°C/48h and King B medium at 26°C/48h,
- Actinomycetales on Pochon medium at 26°C/7x24h,
- yeast and moulds on Sabouraud dextrose medium at 30°C/5x24h.

All measurement results were expressed in CFU/m^3, i.e. colony forming units in 1 m^3 of the examined air.

Meteorological measurements included: temperature, humidity, insolation, wind speed and direction (see Table 1).

Results

The results refer to the respective technological units the waste water treatment plant in Bartoszyce, from the moment of wastewater inflow through the successive treatment stages to the outlet.

Examinations of air, constituting the background, were also carried out in the place free of any direct effect

Table 1. Meteorological observations for research period.

Date of sampling	Direction of wind		Speed of wind	Temperature	Weather conditions
	from	on	m/s	°C	
01.07.1998	north-west	south-east	0 – 0.85	14	sunny day, little cloudy
07.07.1998	north-west	south-east	0 – 1	10	sunny day
10.09.1998	south-east	north	4-5	15	cloudy day after rains

of the treatment plant. All results are expressed in CFU/m^3, which means the values in the tables represent the number of colonies in 1 m^3 of air. Microbiological pollution generated by the plant's individual sub-systems are presented in Table. 2.

Microbiological Count in Background Aerosols

The sampling posts were designated in various places of the plant with regard to wind direction. The dominating wind was from the north-west to the south-east (on July 1st and July 7th, 1998); only on September 10th there was the south-eastern wind blowing north. The wind speed was rather low and ranged from 0 to 1 m/s in July, reaching 5 m/s in September. The sampling days in July were sunny, and in September it was slightly cloudy after all-night rainfalls.

The sampling posts in July were situated at the bottom right-hand corner of the fence, 50 and 75 metres from the office building; and in September, 50 metres from the post-flocculation clarifier. Locating the sampling posts at a further distance was impossible because of the wind direction and the vicinity of the furniture plant. The number of aerobic heterotrophic bacteria collected at these posts ranged from 490/m^3 (Sept. 10th) to 1,240/m^3 (July 7th). Fluorescein-creating forms dominating in July were undetectable or very few in September. Hemolytic bacteria were present in large quantities: from 47/m^3 in September to over 100/m^3 in July. The examined air also contained mannitol-fermenting staphylococci, from 8 to 26, and 9 cells/m^3 of *Escherichia coli*. Other bacteria of the *Enterobacteriaceae* family were not detected. Only in September were single cells of *Aeromonas hydrophila* found. Bacteria of the *Pseudomonas* genus, producing pyocyanin on King A and fluorescein on King B media were not detected, yet forms with no pigments were abundant, i.e. a few hundred cells in 1 m^3 of the examined air. Fungi were detected in small quantities with the dominance of moulds. Actinomycetales were present in quantities up to a dozen cells.

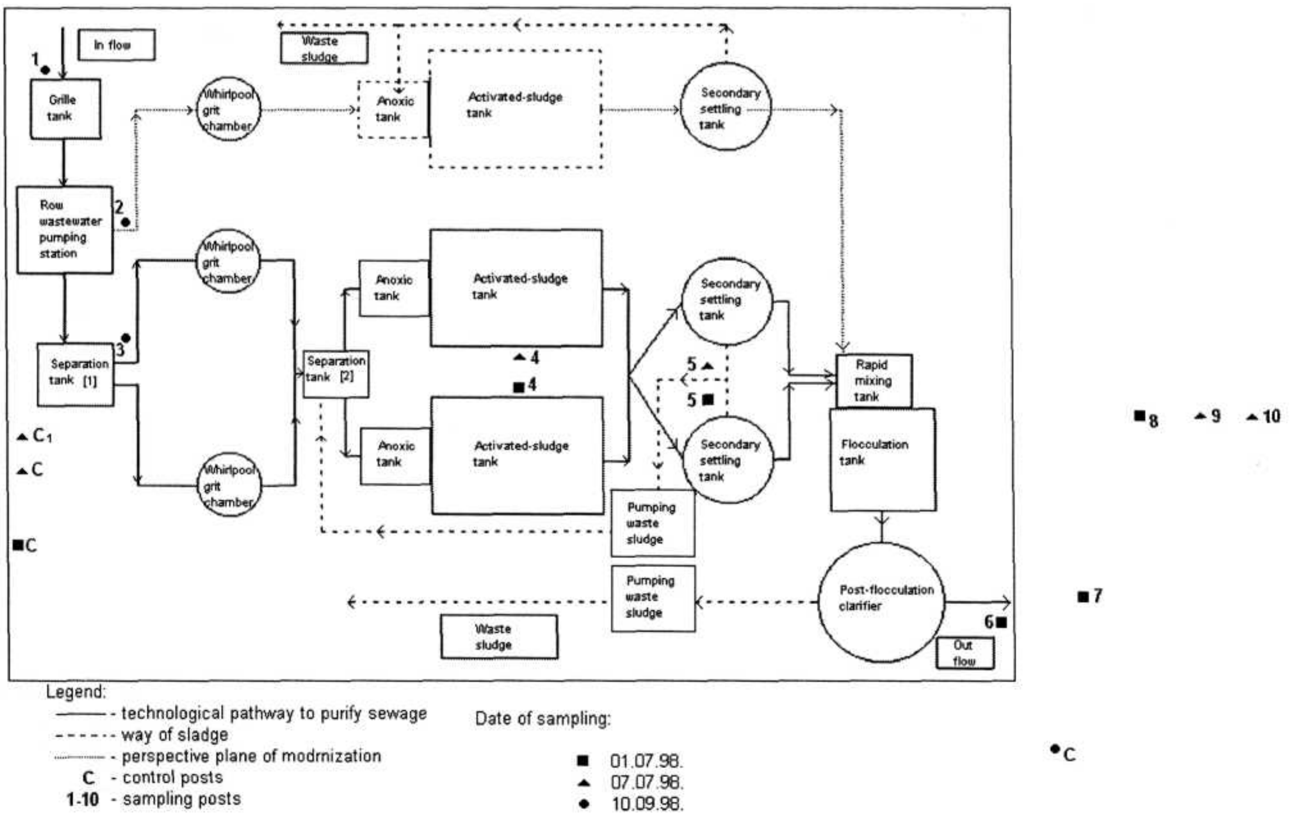

Fig. 1. Technological scheme wastewater treatmant plant in Bartoszyce.

Table la. Microbiological analysis of sewage from aeration tanks (number of bacteria on 1 cm^3 sewage).

Kind of detection	Medium	Incubation [°C]		Number
Heterotrophic bacteria	Broth agar	37		490,000
		20		520,000
Mannitol fermenting staphylococci	Chapman	37		5,600
Non fermenting mannitol staphylococci	Chapman	37		10,100
Total coli	Eijkman	37		110,000
Faecal coli	Eijkman	44.5		90,000
Enterococci	Slanetz-Bartley	37		20,000
Aeromonas hydrophila	mA	37		28,000
Pseudomonas strains	King A	37	pigments non pigments	0 62,000
	King B	25	pigments non pigments	0 423,000
Yeasts	Sabouraud	30		130,000
Filamentus fungi	Sabouraud	30		1,100

Table 2. The number of microbiological pollutants in 1 m^3 of air on sampling posts

Sampling posts		Heterotrophic bacteria				Hemolitic bacteria		Staphylococci		Enterobacteriaceae		Aeromonas hydrophila	Pseudomonas				Yeasts	Mould	Actinomycetales
		37°C		26°C		37°C	10°C	37°C		37°C		37°C	37°C		25°C		30°C	30°C	26°C
								m+	m-	E.coli	other								
C*	1	(126)	440	(118)	204	102	78	16	0	0	0	0	(0)	217	(0)	539	204	1934	8
	2	(440)	157	(52)	157	78	0	0	0	9	0	0	(0)	618	(0)	445	597	2248	15
	2^1	(361)	180	(440)	259	129	0	26	0	9	0	0	(0)	393	(0)	322	47	3302	15
	3	(47)	235	(0)	204	47	0	8	8	0	0	8	(0)	445	(0)	42	180	180	8
I	3	(23)	1422	(23)	39317	581	0	60	16	0	0	8	(0)	1745	(0)	348	1448	676	94
II	3	(76)	471	(23)	157	180	0	34	26	0	0	0	(0)	794	(0)	94	361	574	26
III	3	(47)	314	(23)	125	102	0	52	0	0	0	0	(0)	500	(0)	146	416	550	26
IV	1	(416)	15671	(204)	12526	> 40000	>1000	243	262	60	2104	1100	(0)	9976	(26)	7050	4348	1124	0
	2	(36038)	38790	(2126)	7493	35904	0	173	60	17	112	5677	(17)	6306	(78)	6351	4741	1045	34
V	1	(888)	37556	(596)	33732	(338) 0	0	854	296	68	1652	0	(8)	13120	(112)	13908	8020	496	16
	2	(124)	180	(104)	104	52	0	26	0	0	9	9	(0)	715	(9)	235	23	1989	16
VI	1	(157)	0	(0)	157	416	157	0	8	0	0	16	(0)	34	(0)	26	78	1022	8
VII	1	(204)	833	(157)	1179	707	236	8	8	0	8	872	(0)	734	(16)	611	393	112	8
VIII	1	(157)	78	(78)	236	495	283	8	0	0	180	0	(0)	131	(0)	138	0	1336	0
IX	2	(181)	47	(102)	287	15	0	52	0	147	147	0	(0)	432	(17)	461	181	2092	16
X	2	(260)	156	(417)	181	52	0	0	0	26	0	0	(0)	191	(9)	165	126	2438	0

m+, m – mannitol fermenting and non fermenting; ( ) – pigments bacteria or forming pigments; 1, 2, 3 – date of sampling (1.07; 7. 07; 10. 09; 1998), C* – control station

The number of Actinomycetales, *Pseudomonas fluorescens* and the general heterotrophic bacteria count revealed that according to the Polish Standard [3] the air in the immediate vicinity of this sampling post could be categorised as medium polluted at most.

Microbiological Count in Aerosols in Respective Treatment Units

Wastewater flows to the treatment plant through the main collection channel and is brought in by waste-removing vehicles. The vehicles discharge the sewage at the collection post (sampling post No. 1). Afterwards the wastewater enters the screens building, where the preliminary treatment takes place, and it flows off to the pumping station (sampling post No.2).

Microbiological examinations of aerosols at these posts were conducted once, in September 1998. At the wastewater collection post heterotrophic bacteria were found in large numbers, i.e. about 41,000/m^3. The forms without pigments were dominant, yet this group of bacteria was less numerous at the pumping station - about 700/m^3. Both posts recorded high concentrations of hemolytic bacteria: at post No. 1 - 1,580/m^3, at post No. 2 - 180/m^3. At both posts, a few tens of mannitol-fermenting staphylococci in 1 m^3 were also found. *Pseudomonas* bacteria producing pyocyanin on King A and fluorescein on King B media were absent. The forms producing no pigments on these media were recorded at the wastewater collection post in greater numbers than at the pumping station. Among fungi, yeast dominated at the wastewater collection post whereas moulds prevailed at the pumping station. Actinomycetales were also quite abundant, especially at post No. 1 - 94/m^3.

Considering the total count of heterotrophic and hemolytic bacteria, air at sampling post No. 1 was categorized as heavily polluted. At the pumping station this criterion refers to hemolytic bacteria only.

Post No. 3, situated at the thickener, was characterized by the relatively small number of heterotrophic microorganisms. Hemolytic bacteria, however, were present in large numbers. The *Pseudomonas* genus without pigments was also numerous. It is not very likely that they originated from the thickener; probably they came from the aeration tanks, as post No. 3 was situated downwind of the tanks. Yeast and moulds were detected in more or less even quantities, i.e. about 500/m^3.

Sampling post No. 4 was situated on the bridge connecting the aeration tanks. Wastewater is aerated there by the horizontally mounted rotors which also agitate the liquid in the tanks. Microbiological analysis of the biological aerosols revealed large numbers of all the examined groups of microorganisms. Heterotrophic bacteria (from 30,000 to 84,000 in 1 m^3) were dominated by mesophilic forms. The number of hemolytic bacteria reached nearly 30,000/m^3. *Enterobacteriaceae* were also found in very large numbers, especially on July 1st (over 2,000/m^3). The *Pseudomonas* genus bacteria were also abundant, between 6,000 and 9,000/m^3. The number of fluorescein-producing forms ranged from 17 to 78/m^3. Fungi were dominated by yeast - over 4,000/m^3 and mould quantities were 4 times fewer.

According to the Polish Standard [3], air in the vicinity of this sampling post was categorized as heavily polluted. Only Actinomycetales, present in small numbers, did not fit this category. Also in terms of the total number of the fungi, air was categorized as polluted and having a potentially negative impact on humans [4]. Large numbers of bacteria in biological aerosols above the aeration tanks were generated by the treated wastewater containing large amounts of psychrophilic and mesophilic microbes as well as typically faecal and potentially pathogenic ones, including *Salmonella* (see Table la).

Sampling post No. 5 was situated between the secondary settlers, about 25 metres downwind of the aeration tanks. This can explain the high concentration of microorganisms in aerosols, especially of July 1st when they contained large numbers of heterotrophic bacteria (about 73,000/m^3). Their concentration was much smaller on July 7th - just over 500/m^3. Among the bacteria detected, hemolytic forms were plentiful: about 340 (July 1st) and 50 (July 7th) as well as mannitol-fermenting staphylococci: 854 (July I^{s,}) and 26 (July 7th). Also the bacteria of *Enterobacteriaceae* family were numerous; approximately 1,650, out of which *E.coli* constituted 70 cells. *Pseudomonas* were also in abundance: about 14,000 on King A medium and 13,000 on King B medium. Among fungi, yeast prevailed (over 8,000/m^3); moulds were present in small numbers (about 500/m^3). The reverse situation was recorded on July 7^{,h}, where moulds were predominant (about 2,000/m^3) and yeast were only about 20/m^3.

The study confirmed that on July 1^{SI} air could be categorized as heavily polluted whereas on July 7th this criterion was satisfied only by hemolytic bacteria and mannitol-fermenting staphylococci, both detected in high quantities. The generally smaller numbers of microorganisms can be linked to windless periods and thus the lack of direct impact of the aeration tanks.

Wastewater from the secondary settlers flows next to the flocculator, where chemical precipitation of phosphorus by the PIX coagulant takes place. From the flocculator wastes flow to the post-flocculation clarifier. Sampling in the 12-m distance from the settler (post No. 6) was conducted only on July 1st. The collected samples revealed high counts of hemolytic bacteria: 573 at 37°C and 157 at 10°C. Mannitol-fermenting staphylococci were not detected, nor were the fluorescein-producing bacteria of the *Pseudomonas* genus, which were generally very few in aerosols at this post. Moulds dominated (over 1,000/m^3); yeast amounted to only a few dozen.

Wastewater is discharged from the post-flocculation clarifier to the recipient, i.e. the Lyna River. Examinations of the aerosol samples from this post (No. 7) were carried out on July I$^{s'}$. Heterotrophic bacterial count was 2,400/m^3, 707 of which were the forms hemolyzing at 37°C, and about 236 at 10°C. Mannitol-fermenting staphylococci were poorly represented - 8/m^3, and so was the *Enterobacteriaceae* family. *E.coli* was not detected. *Aeromonas hydrophila* was rather plentiful- about 870/m^3. Among the *Pseudomonas* genus, 610 cells had grown on King B medium, 16 of which were fluorescein-producing forms. King A medium produced 730 microorganisms; pyocyanin-producing forms were not recorded. Fungi were dominated by yeast : about 390/m^3, more than 100 of which were moulds. Actinomycetales were few.

Sampling posts No. 8, 9 and 10 were situated outside the plant's fencing, at distances of 25, 50 and 100 meters, respectively. The aerosol analysis was carried out on July 7th. HPC in the examined air ranged from about 500 (post No. 8) to over 1,000/m^3 (post No. 10). Hemolytic bacteria were abundant: about 500 ones hemolyzing at 37°C, and about 280 at 10°C (post No. 8). The bigger the distance from the plant, the smaller the number of these bacteria, decreasing to 15 at post No. 9 and then increasing again to 52/m^3 at post No. 10. Mannitol-fermenting staphylococci were recorded in relatively small numbers: 8/m^3 at post No. 8. The number increased to 52 at post No. 9, and again decreased to zero at post No. 10. The bacteria of *Enterobacteriaceae* family were detected in all sampling posts, the smallest amounts being recorded at post No. 8 and relatively big/ high ones at post No. 9, i.e. 147 cells of *E.coli* in 1 m^3 air, and finally 26 at post No. 10. The *Pseudomonas* genus bacteria were only few; their highest concentration was recorded at the 25-m distance from the fence. At the 100-m distance their numbers did not exceed 400/m^3. The fluorescein-producing forms were also found among them. Moulds prevailed at all sampling posts. Actinomycetales were quite few - a dozen or so in 1 m^3 of air.

Given the number of hemolytic bacteria, i.e. 50 or more, air at the sampling posts outside the treatment plant can be classified as heavily polluted [3]. The number of other microorganisms is characteristic of unpolluted or medium-polluted air.

The analysis of the M and G indicators (see Table 3), and of M in particular, allows to presume that if the indicator value is equal to or higher than 2, the number of microorganisms at a given post is two times higher than their number in the background, which accounts for a sanitary risk to humans. The sampling posts where such value was recorded (No. 1, 4 and 5) delineate the zone of the increased sanitary risk around the treatment plant. There is a noticeable difference in the propagation distance of mesophilic bacteria (M indicator) and conidia of moulds and yeast (G indicator). Mould conidia, much lighter and physiologically adapted to wind-fertilization, could be propagated over longer distances as compared to heavier bacterial cells. They usually originate from the immediate vicinity of a sampling post and not from a point-source of pollution. In the aeration tanks yeasts have a fivefold predominance over moulds. Therefore, only at the sampling posts No. 6, 7, 8 and 10 the G indicator was much lower than 2. At the remaining posts, the G indicator exceeded this value considerably, reaching 5.9 at post No. 1.

Discussion

Wastewater treatment plants rank quite high among various sources of atmospheric pollution. They are a substantial emitter of microorganism-conveying aerosols or pathogenic bacteria, viruses and fungal spores. Wastewater aeration in particular causes the emission of smaller or larger droplets containing protein material, the cause of various allergies, and some microorganisms as well.

Table 3. Indicators of air pollutants determining sanitary risk to humans.

Sampling posts	M	P	G
1 – collection post	5.12	192.89	5.9
2 – pumping station	1.9	0.88	2.59
3 – thickener	1.28	0.72	2.68
4 – aeration tanks	145.9	40.9	3.14
5 – secondary settlers	30.01	150.3	3.29
6 – flocculator	0.27	0.48	0.5
7 – dropping to the Łyna	1.83	4.14	0.23
8 – 25 m from fencing	0.41	0.97	0.62
9 – 59 m from fencing	0.8	1.71	2.12
10 – 100m from fencing	1.46	2.63	1.65

M - indicator determining the ratio of the general bacteria count marked on broth agar at 37°C in the air sampled to the analogus number of bacteria in the control air (beckground).

P - the same ratio as above, refers to bacteria on broth agar at 26°C.

G - ratio of general fungi count(total number of moulds and yest) determined in the sampled and control air.

Other subsystems of the treatment plant also constitute a source of biological aerosol emission. Summing up all the effects of the treatment plant's indirect sources can help us answer the question of the amount and type of pollutants a treatment plant can generate into the atmosphere with aerosols. Data concerning weather conditions (wind speed especially) have a great impact on the propagation of microorganisms outside the plant's site. At low wind speed the generated aerosols settle close to the aerosol-forming source. During the study carried out at the municipal wastewater treatment plant in Bartoszyce, the wind speed oscillated between 0 and 1 m/s in July, and reached 5 m/s in September. Therefore, in September only weather conditions could have had a crucial impact on the aerosol propagation outside the plant.

The study revealed that the biggest source of biological aerosols were the aeration tanks. Microorganisms can be elevated from the wastewater surface into the atmosphere if their concentration exceeds 10^3 cells in 1 cm^3 [6]. A large number of microorganisms was emitted into the air during wastewater aeration (and their subsequent agitation) by the surface aerators. Air-bubbles with droplets around them, formed during wastewater aeration, move with various velocities, depending on the aeration technique. Each bubble stays in the solution for a short time, then it bursts and ejects plenty of tiny droplets into the air. Those droplets also carry away some microorganisms from the wastewater. The microorganism concentration in the droplets substantially exceeds their medium concentration in the wastes, i.e. by 10 to 1,000 times [7]. Furthermore, large droplets and splashes falling down onto the wastewater surface create smaller droplets of 50-100 µm diameter, causing the secondary emission. Small droplets in the air evaporate quickly, decreasing their diameter to 10-20 µm, which in turn decreases their settling velocity (to approximately 0.003 m/s). When driven by horizontal air currents these little particles can be carried away from the plant. In this manner biological aerosols from different sources can overlap [8].

The total count of bacterial pollutants detected in July at the post situated on the bridge connecting the aeration tanks oscillated around $140,000/m^3$ and fungi pollutants values reached about $6,000/m^3$. These amounts were much higher than those recorded over the aeration tanks of the municipal wastewater treatment plant in Olsztyn (60,000 m^3/d flow-rate). The total bacterial count amounted to 70,000 in 1 m^3 [9]. Much smaller amounts of bacterial pollutants (from a few hundreds to $4,000/m^3$) and fungi (140 - $900/m^3$) were recorded at the dairy wastewater treatment plant in Suwatki of 800 m^3/d flow-rate [10]. Also Kalisz *et al.* [11] has detected much smaller amounts of bacterial pollutants (about $1,400/m^3$) and fungi (about $550/m^3$) in biological aerosols from the treatment plant. The microbiological examinations, however, regarded only heterotrophic bacteria, *E. coli, Enterobacter* and *Pseudomonas.* The aforementioned authors have not found bacteria of the *Enterobacteriaceae* family, quite abundant near the aeration tanks in Bartoszyce [from 120 to $3,000/m^3$] and in Olsztyn, where the bacterial count on Endo medium ranged from 3,000 to $14,000/m^3$.

Microorganisms emitted from the Bartoszyce plant originate mainly from the aerated domestic waste and wastewater from the woodworking and textile industries. Other emission sources play a minor role.

The number of heterotrophic bacteria in the treated wastewater reached the value of 10^5, the faecal forms amounted to $90,000/cm^3$. The *Salmonella* genus bacteria were also detected. The relatively small amounts of microflora, of 10^5, can be explained by wastewater from the furniture plant. Generally, microflora in the aerated wastewater of municipal treatment plants is very rich (10^6 - 10^8 of cells), with the dominance of *Enterobacteriaceae* and *Pseudomonadaceae* [7].

Such high microorganism contents can be pathogenic to humans who reside in the vicinity of aeration tanks. The condition of the immune system, which is a very individual feature, can also largely influence the course of sickness. The recorded contents of biological aerosols generated at the aeration tanks as well as at the wastewater collection post and secondary settlers, can be regarded as very dangerous to human health.

According to the condition of the immune system of an individual, many potentially pathogenic microorganisms found in municipal wastewater can cause various diseases. Northrop *et al.* [12] enlists some diseases which can be transmitted in particular months and their sickness rates. His studies revealed that respiratory system diseases are most common and the most favourable period to contract them is the beginning of October. The situation is similar with the alimentary tract. Biological aerosols can cause ear and eye diseases, and they are most likely to be contracted at the beginning of May and in mid September. In the very end, the author mentions skin diseases. The reason for the increased sickness rate of the alimentary tract and respiratory diseases might be that biological aerosols and microorganisms enter these systems while breathing or swallowing. For a disease to develop, however, the concentration of pathogenic microorganism cells in the respiratory system and, subsequently, in blood has to be high enough, and the body has to be vulnerable to a given microbe. The ability to cause infections depends on the amount of microbes, their virulence, spreading ability, ability to adapt to live in human tissues, and invasive propensity. It should be considered that the workers of the treatment plant may immunize themselves by breathing in the pathogenic microorganisms, yet people who show up at the plant occasionally may get infected [12, 13].

The initially high numbers of microorganisms at the aeration tanks decrease considerably with increasing distance. Presumably, biological aerosols from the aeration tanks overlap with the pollutants originating from the secondary settlers; thus, the posts between the secondary settlers revealed very high amounts of microorganisms of sewage origin. A considerable decrease of the microorganism concentration in biological aerosols was observed at the flocculator, even up to 90%. This is probably connected to the 50-m distance from the emission source (aeration tanks) as well as the wind direction, as this sampling post was situated upwind of the aeration tank. Another factor that might have naturally purified the air was the all-night rainfall. At the longer distances - from 100 to 215 meters from the aeration tanks, the number of microorganisms typical of sewage origin *(E. coli,* the *Pseudomonas* bacteria, yeast) decreases noticeably. On the other hand, the effect of the plant's surroundings on air pollution becomes very distinct. The number of moulds and Actinomycetales, typical of soil pollution, increases; so do the potentially pathogenic hemolytic bacteria present in large numbers.

Due to high concentration of individual technological objects at the treatment plant in Bartoszyce on the area of 4.5 ha, and close vicinity of the furniture-making works, the sampling posts situated upwind had to be located within the plant's limits. The distance of about 90-130 meters between the sampling posts and the aeration tanks (if we consider that they were not always located downwind) could have influenced the bacterial count, especially of hemolytic bacteria.

Air is not the favourable environment for microorganism growth. Generally, it is assumed that microorganisms do not reproduce in the air but only travel from place to place, moved by air currents. The carriers can also be insects, e.g. flies. Seasons also strongly influence microbiological air-pollution; the highest microbial concentrations are being recorded in the summer months, from June to August. In Bartoszyce, microorganism levels in biological aerosols were highest in July. The microorganisms; ability to survive in the air also depends on their vulnerability to drying out. *Pseudomonas aeruginosa,* and many other staphylococci are resistant to drying out, and die out very slowly in the air. *Staphylococcus aureus* can survive on clothing even 130 days, and 7 days on paper; *Shigella dysenteriae* survives 10 days in dust, and 17 days on clothes; *Salmonella typhi* survives 10 days in dust, 97 days on clothes and 90 - 119 on a tree [14].

Change in wind direction could push the cloud of biological aerosols, which was held on by the belt of bushes and trees, outside the treatment plant. When the wind direction reverses, they could become the source of secondary pollution at the post situated 100 meters outside the fence. This hypothesis was confirmed by the study results obtained at posts No. 8, 9 and 10; the results suggest that from the microbiological point of view there is no clean air in the immediate vicinity of the plant.

Consequently, the range of the treatment plant's effects depends on many technical and technological factors, meteorological conditions and survival chances of microorganisms.

Conclusions

Wastewater treated in aeration tanks contains large amounts of microorganisms, many of which are potentially pathogenic. The number and type of the microorganisms emitted by the treatment plant into the air can be the basis in designating a sanitary zone.

The study results allow the authors to state the following:

1. Aeration tanks are a significant source of biological aerosol emission.
2. In the air above the aeration tanks yeasts are predominant. Their number decreases with the increasing distance, but then the number of moulds increases, which indicates the presence of soil pollutants in the air.
3. High microorganism content is reduced by 90-99% in the 200-m distance from the emission source.
4. Much smaller amounts of microorganisms are emitted into the air at the wastewater collection post and the secondary settlers.
5. Hemolytic bacteria count of over 50 in 1 m^3 in all sampling posts situated within the plant's limits and at the reference post, indicates heavy air pollution with potentially pathogenic bacteria.
6. The wastewater treatment plant in Bartoszyce can be the reason for increased numbers of microorganisms present in the air, causing local deterioration of the sanitary conditions of the plant's surroundings.

References

1. Rozporzadzenie Ministra Ochrony Srodowiska, Zasobow Naturalnych i Lesnictwa z dnia 14 lipca 1998 r. w sprawie okreslenia rodzajow inwestycji szczegolnie szkodliwych dla srodowiska i zdrowia ludzi albo mogacych pogorszyc stan srodowiska oraz wymagan jakim powinny odpowiadac oceny oddzialywania na srodowisko tych inwestycji, Dz. U. Nr 93 poz. 589, **1998.**
2. Polska Norma. Ochrona czystosci powietrza. Badania mikrobiologiczne. Postanowienia ogolne i zakres normy (PN-89/Z-04111/01), **1989.**
3. Polska Norma. Ochrona czystosci powietrza. Badania mikrobiologiczne. Oznaczanie liczby bakterii w powietrzu atmosferycznym (imisja) przy pobieraniu probek metoda as piracyjna i sedymentacyjna (PN-89/Z-04111/02), **1989.**
4. Polska Norma. Ochrona czystosci powietrza. Badania mikrobiologiczne. Oznaczanie liczby grzybow mikroskopowych w powietrzu atmosferycznym (imisja) przy pobieraniu probek metoda aspiracyjna i sedymentacyjna (PN-89/Z-04111/03), **1989.**
5. Polska Norma. Ochrona czystosci powietrza. Pobieranie probek. Pobieranie probek powietrza atmosferycznego (imisja) do badan mikrobiologicznych metoda^ aspiracyjna i sedymentacyjna (PN-89/Z-04008/08), **1989.**
6. KATZENELSON E, TEICH B., SHUVAL H.I, JENKINS S.H. Spray irrigation with wastewater: the problem of aerosolization and dispertion of enteric mocroorganisms. Water Pollution Research. 8 th International conference of the International Association on Water Pollution Research Sydney, Australia, October 1976. progress in Water Technology. **9,1-4,1-11,21,1978.**
7. OSSOWSKA-CYPRYK K. Rola wybranych grup mikroorganizmow w ocenie oddzialywania obiektow komunalnych na otoczenie. Materialy PZITS Warszawa, 34-75, **1987.**
8. CAMANN D.,E. A Model for Predicting Dispersion of Microorganisms in Wastewater Aerosols. EPA-600/ 9-80-028, **47-80,1980.**
9. FILIPKOWSKA Z, KORZEKWA K. ,,Miejska Oczyszczalnia Sciekow w Olsztynie jako zrodlo bioaerozoli". Matcriaty Konferencji Naukowej ,,Mikrozanieczyszczenia w srodowisku cztowieka". Politechnika Czestochowska, **1999.**
10. FILIPKOWSKA Z., JANCZUKOWICZ W., KRZEMIENIEWSKI M, PESTA J. Zanieczyszczenia mikrobiologiczne powietrza w otoczeniu oczyszczalni sciekow mleczarskich. Materialy **VII** Ogolnopolskiego Seminarium Eksploatacji Oczyszczalni Sciekow, Sielpia IX, 219-230, **1997.**
11. KALISZ L., KAZMIERCZUK M., SALABUT J. Miejska oczyszczalnia sciekow jako zrodlo mikrobiologicznego zanieczyszczenia powietrza, Ochrona Srodowiska i Zasobow Naturalnych **7,** 33, **1994.**
12. NOTHROP 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 Symposium. Sep. 19-21, 1979 A - 600/9-80-028, 203-205, **1980.**
13. CAMANN D., E.Water aerosols and diseases, EPA-600/9-80-028, 169-178, **1980.**
14. JANOWIEC H. Mikrobiologia i serologia. PZWL, Warszawa, **1988.**