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MICROBIOLOGICAL CHARACTERISTICS OF BIOAEROSOLS AT THE COMPOSTING PLANT

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Abstract

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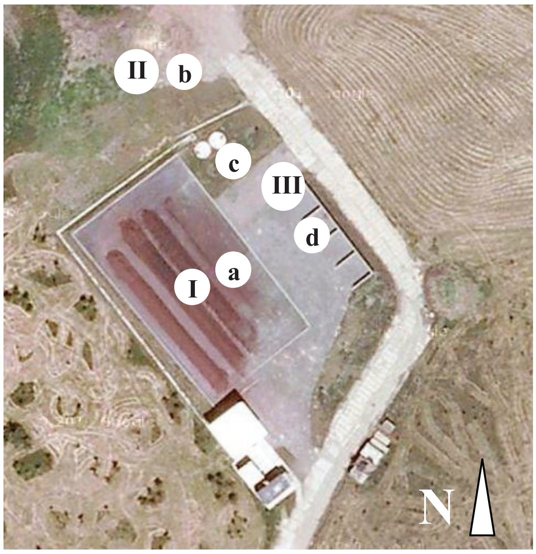
The diversion of biodegradable waste from landfill is of key importance in developing a sustainable waste strategy for the next decade and beyond. The proliferation of waste treatment technologies such as mechanical biological treatment, anaerobic digestion and composting will be paramount in achieving this strategic goal. Composting plant is one of the end technology, which is widely used in waste processing of the biodegradable waste. These wastes originate from the maintenance of green areas in the cities and the municipalities and from the separatelly collected biodegradable waste from the citizens. There is also possible to process other biodegradable materials whose origin may be in other technologies of waste management at the composting plant. The most commonly used technology of composting is windrow system. Technological operations, which are necessary for the proper conduct of the composting process, may have negative influence on the environment in the immediate vicinity of composting plant. As pollutants we can mark particular odor and microorganisms. The largest group of microorganisms in the monitored air were psychrophilic and mesophilic bacteria and microscopic thermotolerant fungi. The amount of thermophillic actinomycetes ranged from 10 to 84.000 CFU·m^{-3} (colony forming units per m^3). Furthermore, it was confirmed that the maximum air contamination has been found during aeration of windrow by compost turner and during the sieving of the mature compost. For each indicator, the increase in concentrations due to the turning of compost windrow as compared to the background concentration obtained in natural environments and upwind of composting plants was determined. At a distance of 150 m from the composting plant, only low numbers of indicator organisms at a regular occurrence in the air has been found.

composting facility, microbial air contamination, bioaerosol, bacteria, indicator

Our paper deals with the issue of microbial contamination of air, called bioaerosols in composting plants (Griffith and DeCosemo, 1994). Stages of the composting process is accompanied by an increase in temperature of composted material at the range of 55 °C to 70 °C. The increase of temperature in the compost is accompanied with increase of the number of thermophilic and thermotolerant microorganisms. These include for example, mucoraceous fungi, penicillia, aspergilli and *Aspergillus fumigatus* expecially (Fischer, 2005). Composted material is often turned, and at the end of the composting process sieved. Because a part of the mentioned microorganisms are able to produce airborne spores, these propagules can be released into the surrounding during various steps of biodegradable waste treatment. Composting facility may affect the environment in many different ways, according to its basic parameters. These are mainly the size of composting area, technology used, machinery used and treating method used. One of the most improtant contaminants in the composting process are bioaerosols, which contain different types of microorganisms (Brenner et al., 1988). These bioaerosls may contain bacterial, viral and fungal species (Douwes *et al.*, 2003; Drew *et al.*, 2010), and may affect respiratory health for workers of compost facility (Sykes *et al.*, 2007).

A significant risk is also posed by microbial allergens and endotoxin (Lange *et al.*, 2003). Dose–

response relationships have not been established for most biological agents and knowledge about threshold values is sparse. In the Czech republic there is only CSN P CEN/TS 16115-1 Ambient air quality – Measurement of bioaerosols – Part 1: Determination of moulds using filter sampling systems and culture-based analyses. The aim of this study was to identify microbial indicators that are most useful for monitoring bioaerosol emittance and dispersal by industrial composting plants. The objective was to estimate the microbial risk potential of bioaerosols over the progressing stages of outdoor pile composting. This paper evaluates the scientific information needed to undertake an effective assessment of the potential public health risks from exposure to bioaerosols in the vicinity of commercial composting activities. Knowledge gaps currently exist in the scientific and regulatory community that limit our ability to effectively characterise source-term emissions, develop reliable dose-response data and accurately model the dispersion of bioaerosols.



1: *Scheme of the composting plant*
a – hard surface with compost piles, b – sieving of the compost, c – leachate reservoir, d – repository of finished compost
I – sampling point 1, II – sampling point 2, III – sampling point 3

MATERIAL AND METHODS

To make the determination of microbial contamination of bioaerosols composting plant using windrow technology with the windrow turner has been selected. This composting facility may utilize the amount of 950.000 kg of biodegradable waste per year. Composting plant utilizing biodegradable waste originating from the citizens and from the maintenance of gree areas of the city. This material is brought into the composting plant by mixing wagon, which ensure homogenization of the biodegradable waste. So the biodegradable waste is crushed and mixed enough during its collection. At the composting plant the biodegradable waste is unloaded by integrated conveyor, which is equipped by magnetic separation system that captures any metal admixtures. The biodegradable waste is then stored to the piles, which are 50 m long, 2 m wide, and 1.5 m heigh. During the composting process the material is several times turned by pull-type compost windrow turner and moistened by leachate that flows from hard surface area into leachate reservoir. After 70 days of composting the finished compost is sieved onto the drum sieve, where the larger impurities are separated. Compost is then used as a material for fertilization. Description of the composting plant is shown in Fig. 1.

Three sampling points marked in Fig. 1 by numbers I–III has been selected at the composting plant. Sampling point I has been located directly on the hard surface area (a) designated for composting, sampling point II has been located at the place (b) where the sieving of finished compost was carried out, sampling point III has been located between the leachate reservoir (c) and the repository of the finished compost (d). Sampling point IV for determination of the contamination of the ambient air (background) has been located 150 m from the composting plant and its location depended on the prevailing wind flow during sampling (downwind). Results indicated in the figures as "active" represents at the sampling point I samples taken during compost pile turning and at the sampling point II samples taken during sieving of the finished compost. Conversely results indicated in the figures as "passive" represents samples taken at the time when there was no compost windrow turning, sieving of the finished compost or movement of the technique. Samples marked as III and IV have been taken at the sampling points, where was no utilization of compost, so it is no divided into the above mentioned two variants.

For the air sampling the air sampler MAS-100 (Merck, Germany) has been located at a height of 1.5 m above the Earth's surface. Strictly determined air volume was sucked onto Petri dish with agar medium. Sampling rate was 1.6 $dm^3 \cdot s^{-1}$, the volume of the air flowing through has been selected based on the expected contamination of the air and ranged from 100 dm^3 to 1 000 dm^3. Samples were taken from compost windrows (passive emissions) and during agitation activities (active emissions) on site, such as turning, shredding and screening. Sampling was undertaken between April and October 2012 in triplicates (Table I). Environmental factors such as wind speed, turbulence, humidity and water availability will influence when spores are released.

Five groups of microorganisms were cultured in parallel: psychrophilic bacteria, mesophilic bacteria, actinomycetes, fungi and bacteria *Escherichia coli* (Matějů, 2009). Standard methods for quantification of airborne bacteria are based on cultivation and counting of grown colonies (Albrecht *et al.*, 2007). Total mesophilic and psychrophilic bacteria

I: *Conditions during the measurement*

Date	Temperature	Atmospheric pressure	Wind speed	Wind direction
[-]	[°C]	[hPa]	[m/s]	[-]
11. 4. 2012	9.9	982	4.2	NW
25. 4. 2012	26.9	991	4.3	NW
11. 5. 2012	15.4	1002	3.8	NW
25. 5. 2012	25.8	990	3.5	W
8. 6. 2012	21.4	994	2.4	NW
29. 6. 2012	29.0	993	2.2	NW
6. 7. 2012	28.6	992	2.6	WE
27. 7. 2012	25.8	994	2.8	W
3. 8. 2012	20.4	998	3.5	NW
31. 8. 2012	29.9	999	3.9	NW
1. 9. 2012	25.1	1001	4.5	WE
29. 9. 2012	8.7	987	4.1	E

number was estimated on Nutrient agar (Sigma-Aldrich, CZ), incubation at 37 °C for 48 hours and at 20 °C for 72 hours. Total number of thermotolerant fungi was estimated on malt extract agar (Merck, Germany) mixed with 0.01% w/w antibacterial chloramphenicol (Sigma-Aldrich, CZ), incubation at 37 °C for 3–14 days. Thermophilic actinomycetes were cultivated on the Actinomyces agar (Merck, Germany, incubation at 44 °C for 7 days) and *Escherichia coli* on Endo-agar (Merck, Germany), incubation conducted at 37 °C for 24 hours. Based on the detected amount of microorganisms mean value of the parameter CFU (colony forming unit) has been calculated and converted into a cubic meter of air. All data has been measured in three replications. Figures below show arithmetic means of collected data.

RESULTS AND DISCUSSION

The total number of bacteria in the air at the composting facility ranged from 10^1 to 10^5 CFU·m^{-3}. The number of mesophilic bacteria varied in the range from 13 CFU·m^{-3} to 25,000 CFU·m^{-3} (Fig. 2).

Lower numbers of mesophilic bacteria have been found in April and May compared to the summer months. Almost one order of magnitude more increased incidence of mesophilic bacteria in June, during the active manipulation with the compost piles (sampling point I active). Fig. 1 confirmed our hypothesis that during manipulation with the composted material much more mesophilic bacteria gots into the air. This situation was similar for all groups of monitored microorganisms. At the sampling point II only a limited number of mesophilic bacteria occurred, its numbers did not reach the value of $1{\cdot}10^3$ CFU·m^{-3}.

The number of psychrophilic bacteria ranged from 56 CFU·m^{-3} to 345,000 CFU·m^{-3} (Fig. 3).

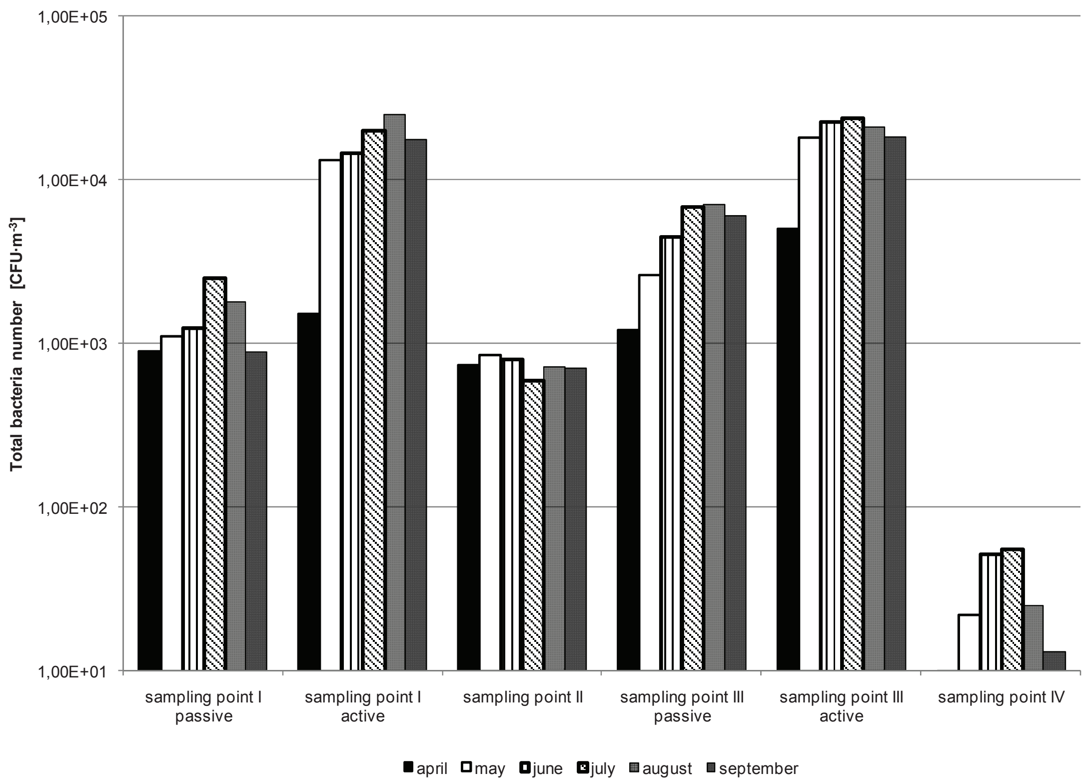
The highest average number of bacteria has been recorded in June at the sampling point I, during compost pile turning at the amount of $3.45{\cdot}10^5$ CFU·m^{-3}.

Thermotolerant fungi in the air at the composting plant ranged from 10 CFU·m^{-3} to 56,700 CFU·m^{-3}, Fig. 4. The highest average number of fungi has been recorded in July at the sampling point I active at the number of $5.7{\cdot}10^4$ CFU·m^{-3}.

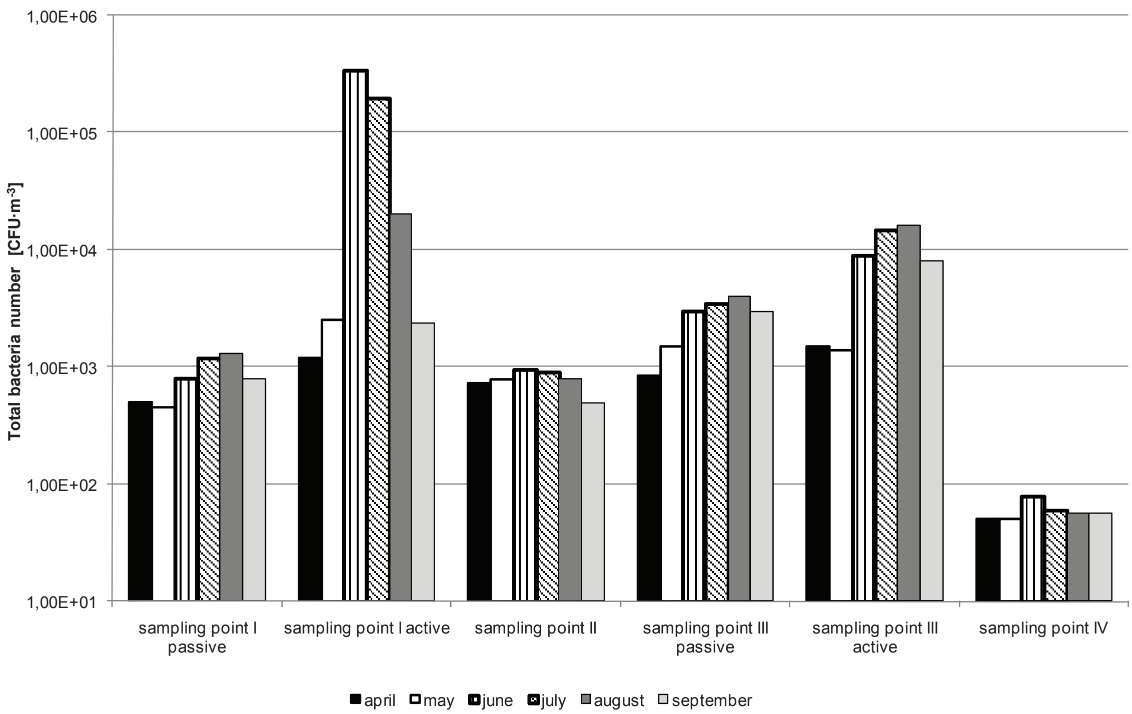
Actinomycetes in the air at the composting facility ranged from 10^1 CFU·m^{-3} to 10^4 CFU·m^{-3}, Fig. 5. Also in this case, large differences in the numbers of actinomycetes between sampling points have been observed. Significantly highest number of actinomycetes contained samples at the time of compost pile turning at the sampling point I active ($8.4{\cdot}10^4$ CFU·m^{-3}), followed by samples taken above the place for sieving of the finished compost (sampling point III active). Conversely, at the sampling points II and IV actinomycetes have been recorded only in tens in 1 m^3 of the air.

This is in accordance with the literature, for example concentrations ranged from 10^2 CFU·m^{-3} to 10^3 CFU·m^{-3} have been reported in the air samples collected upwind from the composting plant. The average concentration of viable bacteria detected in natural air samples has been around 10^3 CFU·m^{-3} (Persoons *et al.*, 2010). *Escherichia coli* in the air at the composting plant ranged from 10^1 CFU·m^{-3} to 10^3 CFU·m^{-3}, Fig. 6.

The highest average number of bacteria *E. coli* has been recorded in August at the sampling point I. active in the number of $2.5{\cdot}10^3$ CFU·m^{-3}. At a distance of 150 m from the composting plant has no been occurrence of *Escherichia coli* in the air during whole composting season recorded (Fig. 5). Le Goff *et al.* (2012) states that for all the composting plants studied, an impact has been measureable up to distances of 100 m. In terms of government regulations, the minimum distance between a composting plant and the neighboring residents has been fixed at 200 m in France, 250 m in England and 300 m in Austria (Swan *et al.*, 2003). In the Czech Republic any distance is no set in the legislation for



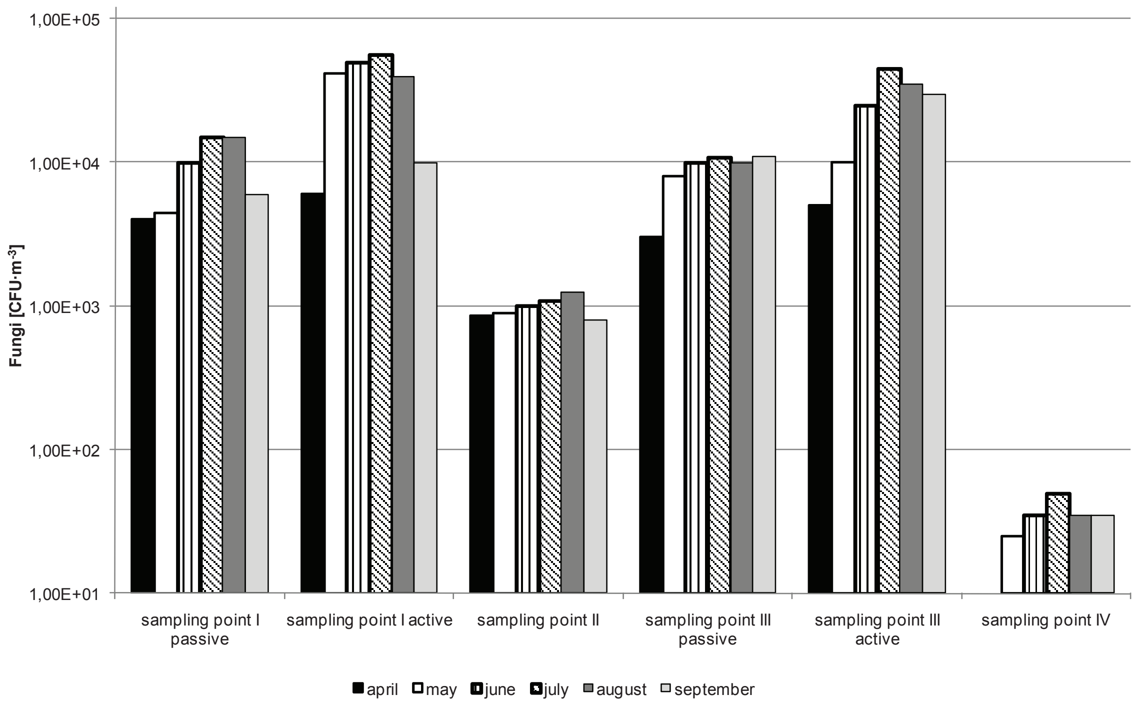
2: *Number of mesophilic bacteria in the air at the composting plant*



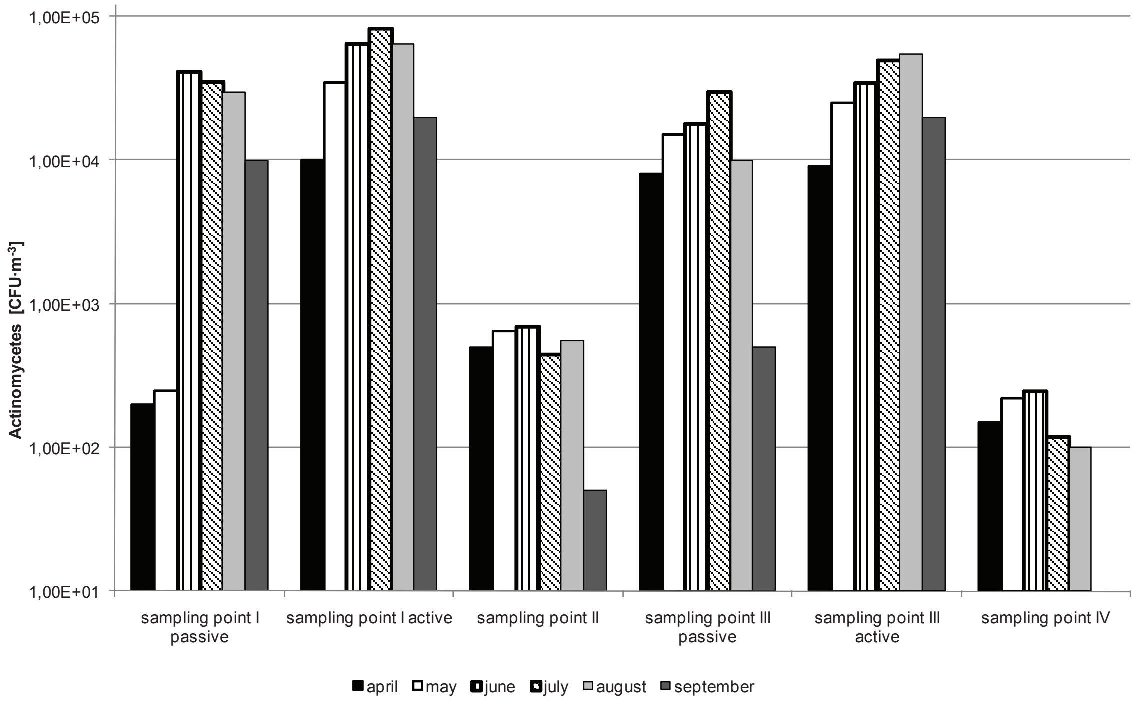
3: *Number of psychrophilic bacteria in the air at the composting plant*

the distance between the composting plant and the neighboring residents.

In general, the microbial concentrations were relative stabil over time of pile composting. Nielsen *et al.* (1997) describes in contradiction with our results an increase in all number of monitored groups of microorganisms during the composting process. These authors noted also very high



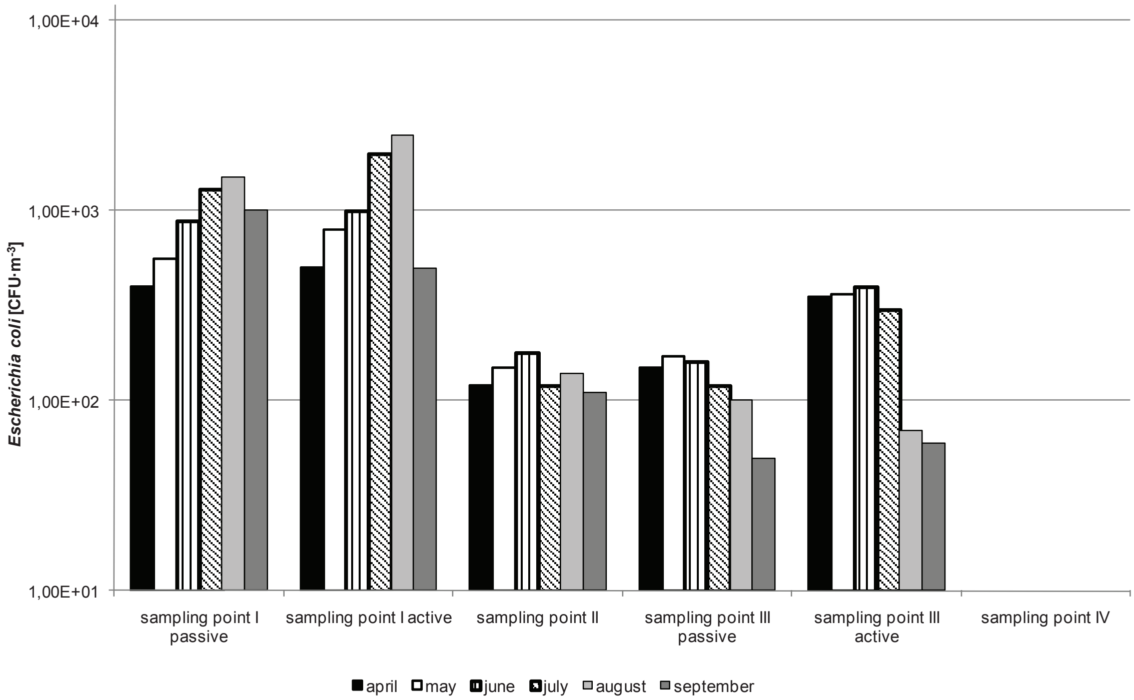
4: *Number of thermotolerant fungi in the air at the composting plant*



5: *Number of thermotolerant actinomycetes in the air at the composting plant*

concentration of microorganisms in the air samples at the composting plant, the maximum viable concentrations in bioaerosols was $1.7 \cdot 10^7$ CFU·m^{-3} for bacteria and $1.5 \cdot 10^7$ CFU·m^{-3} for thermophilic actinomycetes. Conversely, our findings confirmed the authors Taha *et al.* (2007), who reported that the age of compost has little effect on the bioaerosol concentrations emitted for passive windrow sources.

Obviously, cultivation based methods underestimate the real amount of airborne microbes. In addition, from literature it is known that inactive or even dead cells can also have the



6: *Number of Escherichia coli in the air at the composting plant*

potential to cause health effects (Albrecht *et al.*, 2007).

A slight increase in the concentration of microorganisms in the air at the composting plant can be observed in the warmer months of the year (May-August), and especially during manipulation with the composted material by turning, separating at the drum sieve and moistering.

Authors Taha *et al.* (2007) states, that emissions from compost widrow turning during the early stages may be higher than during the later stages of the composting process. The bioaerosol emissions from passive sources were in the range of 10^3–10^4 CFU·m^{-3}, with releases from active sources typically 1log higher. Air inversions in particular can lead to high concentrations of microorganisms (> 10^4–10^5 CFU·m^{-3} of thermophilic actinomycetes and thermotolerant fungi) in the surroundings of composting plants. Those authors emphasize, that both thermotolerant fungi and thermophilic actinomycetes can serve in this case as indicator organisms (Albrecht *et al.*, 2008). Bioaerosol concentration decrease to below typical background concentrations for 250 m (Taha *et al.*, 2007). On the other hand, low concentrations recorded in the immediate vicinity of the plant suggested a limited environmental impact from the composting activity (Persoons *et al.*, 2010).

SUMMARY

This paper deals with the study of microbial air contamination at the composting plant and its immediate surroundings. Composting process technology brings with it the emergence of bioaerosols in the air, which can be a dangerous source of health problems for composting facility staff. Our objective was to evaluate the risk not only in composting plant, but also at a distance of 150 m far from this composting plant. Samples taken from April 2012 to September 2012 were subjected to microbiological analysis. We determined the number of culturable mesophilic and psychrophilic bacteria, thermotolerant fungi, thermophilic actinomycetes and bacteria *Escherichia coli*. Our results suggested that the most contaminated air in the process is during compost widrow turning and sieving of finished compost. The numbers of microorganisms increases with temperature air with a peak during June to August. We confirmed that the selected group of microorganisms are usable as appropriate indicators for the monitoring of air quality at the compostin plant and its surrounding. At the distance of 150 m from the composting plant there is no increased risk of contamination due to bioaerosols in the air.

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