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MICROBIAL AND ENDOTOXIN IMMISSIONS IN THE NEIGHBORHOOD OF A COMPOSTING PLANT*

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Abstract: Objective of the study was the evaluation of microbial and endotoxin immissions in an area surrounding a composting plant. Immissions of microorganisms and endotoxin originating from a composting plant working with the Herhof box-system were measured. Samples were collected in the vicinity of the plant with filter samplers using gelatin filters (MD 8 of Sartorius). Total aerobic bacteria, staphylococci, coliforms and total Gram-negative bacteria were recorded. Mesophilic fungi were investigated using two different media: DG 18 agar and malt extract agar with two different incubation temperatures (22°C and 30°C). *Aspergillus fumigatus* was scored using malt extract agar with an incubation temperature of 45°C. Measured airborne microbial concentrations expressed as cfu per m^3 air were used to calculate the emission rate expressed as cfu per h by employing a dispersal model according to the German TA Luft, Annex C or a modified formula for emission from chimneys. Immissions in the area surrounding the plant were recalculated using these models. As a result of these calculations no significant increase of microbial concentration compared to the concentrations described in literature for ambient air could be predicted at a distance of more than 500 m under the conditions employed. This indicates that composting facilities of the investigated type do not initiate heavy immissions in their vicinities. Only very small endotoxin concentrations could be detected outside the composting plant.

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INTRODUCTION

The hazards imposed on employees by biological agents have been discussed for a couple of years. The intention of workers protection has led to the formulation of the EC-guideline 90/679 [1] in this field.

Concerning waste management, the separate collection of biological waste has increased in Germany during the last decade. Now separate collection and biological treatment of biological wastes is official policy in Germany [5]. This fact rises the question how to maintain the personal safety of workers employed in biological waste treatment plants (e.g. composting facilities). The problem of providing adequate protection to the workers is discussed at different institutions ([2, 14], CEN/TC 137). Many basic problems related to biological agents (e.g. standards for sampling and analyzing biological agents in the working place atmosphere) are not solved up

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to now [10]. In addition public discussion has spread to the safety of people living in the vicinity of biological waste treatment plants.

In Germany people living in the neighborhood of projected composting plants are concerned by the question whether the biological emissions of the operating plant might have negative impact on their health.

Therefore the current study was conducted to elucidate the levels of biological agents in the vicinity of a composting plant. Immission concentrations of biological agents were calculated using models which are the approved standard in the calculation of immissions of chemical agents.

MATERIAL AND METHODS

Air samples were collected in the vicinity of the composting plant located at Stapelfeld near Cloppenburg in the northern part of Germany. Reference samples were taken at a control location where a similar composting plant is projected. When samples were taken there was no additional microbial load originating from a composting plant in the air of the control site.

The Stapelfeld plant is working with the Herhof box system illustrated in Figure 1. The Herhof procedure is characterized by an intensive decomposition conducted in closed composting boxes. The exhaust air of the intensive decomposition is purified by a biofilter. Following the intensive decomposition the compost material is subjected to a post-curing on windrows for a period between six and 12 weeks. In the Stapelfeld plant the post-curing is conducted in an open hall. This hall is roofed while walls are missing allowing a free flow of the wind throughout the hall. The material is shifted several times during the post curing. The bulk of microbial emissions into the environment is supposed to originate during the shifting and sieving of compost material in this open hall.

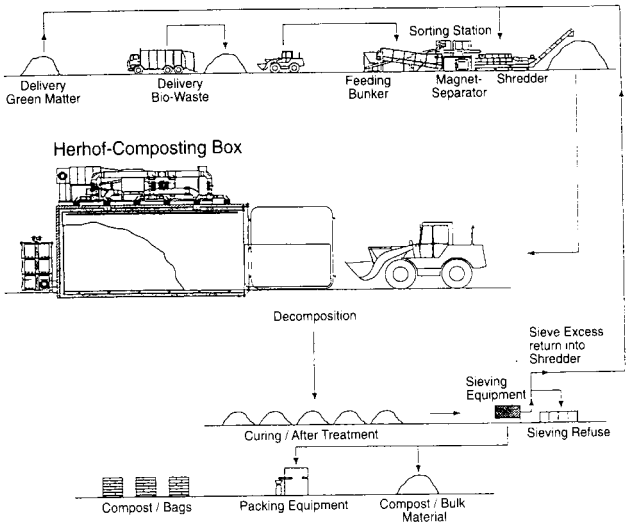

Figure 1. Display of biowaste decomposition with the Herhof box system.

Air samples for the determination of microorganisms and endotoxin content were taken in the neighborhood down-wind from the composting facility. The sampling points were positioned on along four lines down-wind the composting plant. The lines originated in the composting plant and were each separated by an angle of 45°. Controls were performed inside the open hall when the compost material was moved by a rotating sieve and

Table 1. Media and conditions used for the cultivation of airborne microorganisms.

Medium	Selectivity	Incubation temp.	Incubation length	Special remarks
CaSo Nutrient Agar (Merck No. 5458)	no specific selectivity	37°C	2 d	predominantly for bacteria
MacConkey Agar, (Merck No. 5465)	*Enterobacteriaceae*, Gram-negative bacteria	37 °C	2 d	coliforms bacteria produce red colonies, other Gram-negative bacteria like *Salmonella* or *Pseudomonas* can grow as well, growth of most Gram-positive bacteria is inhibited
Malt Extract Agar (Merck No. 5398)	yeasts and molds	22 °C	7 d	only molds were scored
Malt Extract Agar (Merck No. 5398)	yeasts and molds	30 °C	7 d	only molds were scored
Malt Extract Agar (Merck No. 5398)	thermophilic yeasts and molds (e.g. *Aspergillus fumigatus*)	45 °C	2 d	*Aspergillus fumigatus* was identified according to its morphology
DG 18 Agar plus Chloramphenicol (Oxoid CM 729)	xerophilic molds	22 °C	7 d	only molds were scored
DG 18 Agar plus Chloramphenicol (Oxoid CM 729)	xerophilic molds	30 °C	7 d	only molds were scored
Baird Parker Agar (Oxoid CM 275)	staphylococci	37 °C	2 d	suspected isolates were examined microscopically and by coagulation assay

outside the composting plant 75 m directly against the direction of the wind.

Sampling of air was conducted with a Sartorius MD 8 device (Sartorius AG, Göttingen, Germany) using the corresponding gelatin membrane filters. Samples of 1 m^3 volume were taken using a flow rate of 6 m^3/h. Three consecutive samples were taken at a definite sampling point. Filters were transferred into sterile plastic bags directly after sampling. The bags were closed and transferred to the laboratory within 24 hours as described earlier [3]. The gelatin filters were dissolved in 20 ml of 0.9% NaCl solution and shaken on a rotary shaker until a clear homogenous solution was produced. Fractions (volume 0.1 ml) of this solution were plated directly onto the different solid media described in Table 1 (two replicates of each solution). Culture and enumeration of microorganisms were conducted using the conditions listed in Table 1.

Microorganism concentrations were calculated as a mean of the three different filters sampled at each collecting point.

Samples for the investigation of airborne endotoxin were taken using a Stroehlein VC 25 dust sampler and quartz filters (Munktell MK 360, 150 mm, Cryo-Technik, Hamburg, Germany). The samples were collected at the same places as for microorganisms.

The analysis of endotoxin content was conducted using the *Limulus* assay as described earlier [3].

For the calculation of microbial emission per unit of time the mean of the concentrations measured at a distance of 150 m was used. Using these concentrations the emission rate was recalculated with the computer program AUSTAL-PC 3.2 (employing a dispersal model according to the official German TA Luft [4], supplied by Geomet, Berlin, Germany). Based on the calculated microbial emission the immissions in the vicinity of the composting plant were determined. The program AUSTAL-PC 3.2 is routinely used for the calculation of the immission of dust or chemical compounds in the neighborhood of industrial plants.

Alternatively to the AUSTAL-PC program, the means of the concentrations at a distance of 150 m away from the plant were used to calculate the emission of microbes with Giebel´s formula. This formula has been originally developed by Giebel [11] empirically based on the measurement of NO_x-emissions in the close neighborhood of industrial plants. The modified formula used in this study is

$$s = \frac{Q}{2 \times E^{1.6} \times u} \times 2 = \frac{Q}{E^{1.6} \times u}$$

with s = immission concentration of microbes in cfu/m^3 air,
Q = emission of microbes from the source in cfu/s,
u = wind velocity in m/s,
E = distance between source and place for which the immission is calculated in m.

In this formula the equation originally published by Giebel is multiplied by a factor of two. This was done since the original Giebel formula was developed for emission from high chimneys. However, the maximum emission from composting plants is comparatively close to the surface. Therefore the factor of 2 was brought into the original Giebel formula to correct for this fact.

RESULTS

Airborne microbial concentrations as determined in the vicinity of the Stapelfeld plant are shown in Table 2.

The emission from the rotating sieve for total bacteria was calculated iteratively to be 1×10^{12} cfu/h corresponding to 2.78×10^8 cfu/s using the TA-Luft dispersal model.

When Giebel´s formula was used to calculate the emission of total bacteria based on the concentrations measured at a distance of 150 m from the Stapelfeld composting plant, the emission was calculated to be 4.5×10^{10} cfu/h corresponding to 1.25×10^7 cfu/s.

These values are roughly in the same order of magnitude as published in the literature for the dispersal of *Aspergillus fumigatus* from sewage sludge compost piles [17]. These authors calculated for *Aspergillus fumigatus* an emission of 4.6×10^6 cfu/s corresponding to 1.66×10^{10} cfu/h.

When immission concentrations at defined distances from the source are calculated using the TA-Luft model

Table 2. Microbial concentrations determined in the air near a composting plant at Stapelfeld/Germany (figures are given in cfu/m^3 air for microbes, and in ng/m^3 air for endotoxin).

	Total bacteria on nutrient agar	Gram-negative bacteria on MacConkey Agar	*Aspergillus fumigatus*	Molds at 22°C on malt extract agar	Molds at 30°C on malt extract agar	Molds at 22°C on DG 18 agar	Molds at 30°C on DG 18 agar	Endotoxin[a] (ng/m^3 air)
Stapelfeld: near the rotating sieve	7.67×10^4	9.66×10^2	2.03×10^3	2.73×10^3	2.83×10^3	7.33×10^2	3.63×10^3	20.704
Stapelfeld: 75 m up-wind	4.33×10^2	0.00×10^0	0.00×10^0	2.67×10^2	1.00×10^2	3.30×10^1	1.00×10^2	0.161
Stapelfeld: 150 m down-wind[b]	2.83×10^3	0.00×10^0	2.00×10^2	3.67×10^2	8.16×10^2	8.35×10^1	2.92×10^2	0.236
Exhaust air emitted from the biofilter	3.30×10^1	3.30×10^1	6.00×10^2	1.43×10^3	8.33×10^2	5.67×10^2	9.33×10^2	0.008
Control location[c]	3.11×10^2	0.00×10^0	7.77×10^1	5.22×10^2	7.34×10^2	2.33×10^2	1.14×10^2	0.017

[a]Endotoxin values have been determined from a single sample per sampling point; [b]Mean of four sampling points composed of three single measurements each; [c]Mean of three sampling points composed of three single measurements each.

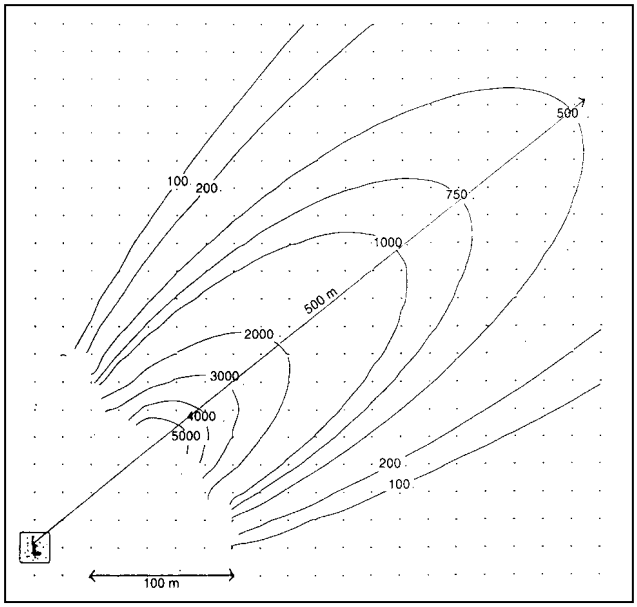

Figure 2. Prediction of microbial immissions in the vicinity of a compost plant (airborne bacteria) according to TA-Luft. L = source of emission. Curves with numbers = calculated concentrations of airborne bacteria (cfu/m^3).

with a maximum assumption (wind blowing constantly into one direction, dispersion class AK 4 (AK 4 means unstable temperature stratification) and wind velocity WG 3 (1.9–2.3 m/s), the calculation yields immission concentrations for total bacteria of less than 500 cfu/m^3 air at a distance of more than 500 m from the source with an orientation with the direction of the wind (Fig. 2).

According to the Giebel equation and assuming a wind velocity of 1.5 m/s, an immission concentration of 400 cfu/m^3 was calculated for a distance of 500 m from the source with the direction of the wind. These recalculations were conducted with approximately identical meteorological conditions as recorded during the sampling period.

DISCUSSION

The endotoxin data of this study clearly demonstrate that much lower endotoxin concentrations are found in the vicinity of the composting plant than in the working place atmosphere when compost material is moved around. Low values were also found at the control location without influence from a nearby composting facility.

Airborne endotoxins are discussed to pose a health risk to humans. However, generally accepted threshold values do not exist. For the working environment in livestock industries and an eight hour shift-length a threshold limit between 50 and 100 ng/m^3 air is discussed [8, 9, 12, 13]. The results of this study show that the endotoxin concentration found at a distance of 150 m downwind of the composting plant is by a factor of 100 lower than close to the rotating sieve in the plant. The endotoxin concentration found outside the plant is also 200 times lower compared to the threshold value of 50 ng/m^3 mentioned above. It seems that people living more than 150 m away from composting facilities of the investigated type do not bear a significant risk due to exposure to endotoxin emitted from the composting plant.

The highest concentrations of airborne microorganisms were determined directly near the rotating sieve where compost material is processed. Since the rotating sieve was located in an open hall microorganisms can be carried by air into the vicinity of the plant. Outside the plant, higher microbial levels were found down-wind compared to the measurements conducted up-wind. This indicates that at least a part of the microbial burden of the air found 150 m down-wind may be due to emissions from the composting plant. However, in some cases the value of ambient air at the control location without any composting plant was higher than the corresponding value determined near the Stapelfeld plant (e.g. 522 cfu/m^3 compared to 367 cfu/m^3 for molds at 22°C on malt extract agar). This fact demonstrates that the natural microbial burden of ambient air may contribute significantly to the microbial concentrations measured down-wind the Stapelfeld plant. Future research should be dedicated to a deeper investigation of the travel distances and the deposition characteristics of particulates from biocompost plants.

In this study the calculation of the emission which is in turn the basis for the dispersal calculation was conducted with the measured data at a distance of 150 m from the plant assuming that the total microbial burden detected originates from the emission of the facility. This leads to an overestimation of immission concentrations. In addition, both the TA-Luft model and the empirical Giebel formula are models for the dispersion of gases. The models do not consider sedimentation or inactivation processes which have a significant impact on bacteria or fungi in an airborne state. These facts also lead to an overestimation of immission concentrations when the above mentioned models are used.

The evaluation of the calculated immission with respect to the sanitary risks is a difficult problem. No generally accepted limiting concentrations for biological agents exist up to now. However, there are some recommendations in the literature, especially for the evaluation of microbial indoor concentrations. Reynolds *et al.* [19] state that airborne fungal concentrations of more than 500 cfu/m^3 indicate an abnormal condition in the indoor environment. Morey *et al.* [18] suggest that a level of viable microorganisms in excess of 1,000 cfu/m^3 indicates that the indoor environment may be in need of investigation and improvement. According to Rüden and Moriske [20] total viable microorganisms of 1,000 cfu/m^3 may occur indoors and do not mean any health risk for the inhabitants. For *Aspergillus fumigatus* Holmberg [15] stated that concentrations of thermotolerant *Aspergillus* of more than 50 cfu/m^3 turned out to be a significant risk factor with regard to eye irritation and respiratory symptoms.

The Niedersächsisches Landesamt für Ökologie, Hannover, Germany, recommends that the number of viable microorganisms in the working place atmosphere should not exceed 10,000 cfu/m^3. This value is under discussion in Germany but has been adopted nationwide

for evaluation of the working place atmosphere in recycling plants [2]. For the protection of people living in the vicinity of possible emission sources this value might be too high since it was stated for workers which are usually healthy whereas people living in the vicinity of plants might be weak, old or immunocompromised.

The published concentrations of airborne microorganisms found in ambient air outdoors vary to a great extent. Bovallius *et al.* [7] published bacterial counts in outdoor air between 100 and 10,000 cfu/m^3. For *Aspergillus* spp. and *Penicillium* spp. 1,000 cfu/m^3 have been published [16]. The same author found 3,000 cfu/m^3 for the mold genus *Cladosporium* and Bagni *et al.* [6] recorded up to 10,000 cfu/m^3 for molds.

The immission concentrations calculated in this study at a distance of about 500 m from the plant indicate that the calculated concentrations probably are within the natural variation range even if a composting plant as an additional source exists with the emissions determined in this study.

The health related properties of the biological emissions of a composting plant should not differ specifically from the properties of the natural ambient airborne microflora. So no specific risks related to biological emissions from composting can be expected.

However, little is known currently about the question whether the dispersion models applied in this study fit for the modeling of microbial emissions. A lot of systematic sampling of airborne microorganisms in the vicinity of significant emitents is necessary to answer this question. Standardization of methods in the field of sampling and laboratory analyses is necessary [8]. In the light of data obtained through systematic measurements, the existing models formulated for the dispersion of chemical compounds might have to be modified.

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