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The assessment of airborne microorganisms in large-scale composting facilities and their immediate surroundings

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Abstract

The number of airborne microorganisms in the area of large-scale composting facilities with different composting techniques (A: open facility using the intensive decomposition process [4000 t/year], B: closed facility with compost containers [7000 t/year], C: closed facility with table-pile composting and automatic turning equipment [22 000 t/year]) was investigated using impactor sampling systems (Andersen samplers). All counts carried out inside the closed facilities, especially during the turning process, showed values of $> 5.0 \times 10^5$ CFU/m^3 for viable bacteria and moulds with a proportion of *Aspergillus fumigatus* of up to 64%. Depending on the type of facility, different median values were determined inside the plant area. Counts were highest in the immediate area around the biofilter outside of Facility C (1.7×10^4 CFU/m^3 for bacteria and 9.5×10^3 CFU/m^3 for moulds). In view of the high load of ambient airborne microorganisms inside the composting facilities, adequate occupational health measures are urgently required. Counts determining the hazard to neighbourhood residents at distances of between 150 and 2000 m showed, depending on the facility, annual median values of 170–330 CFU/m^3 for bacteria, 75–340 CFU/m^3 for moulds, and 15–52 CFU/m^3 for *A. fumigatus*. Higher individual counts – up to 3×10^3 CFU/m^3 for moulds and up to 350 CFU/m^3 for *A. fumigatus* – were found as a result of specific climatic influences, (e.g. winds) and activities as well poor operation. Given the high proportion of *A. fumigatus* in the exhaust air, this mould can serve as an indicator for the evaluation of the health risk. However, the maximum values found in the present study, may also be caused by other events in rural areas, (e.g. agricultural activities). With regard to neighbourhood residents, odour complaints are more important than pollution by microorganisms.

Keywords: Bioaerosols; Airborne microorganisms; Composting facilities; *Aspergillus fumigatus*

1. Introduction

Composting facilities process waste and residual materials which may have a high load of potentially pathogenic microorganisms. In the course of the composting process, a growth of various mesophilic and/or thermophilic species occurs. In the course of processing compost, organic dust is stirred up. As microorganisms are frequently adsorbed to dust particles and may be inhaled, dust is also a significant parameter for the bacterial load. Bioaerosols resulting from whirled-up compost consist of inert particles and, significantly, of adsorbed live microorganisms as well as components of dead microorganisms such as bacterial peptidoglycans, cell wall glucans of moulds as well as airborne endotoxin (Seidl, 1995).

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Table 1
Description of composting facilities

Facility	Method	Capacity	Active composting
A	Open/aerated piles with intensive decomposition	4000 t/year	5–6 weeks
B	Closed system/containers with intensive decomposition process/biofilter	7000 t/year	7–10 days
C	Enclosed/table-pile composting windrows with automatic turning equipment/biofilter	22 000 t/year	Approx. 8 weeks

Table 2
Sampling days and intervals in the three facilities

	No. of sampling days	Intervals between sampling period (weeks)	Samples	Sampling period
Facility A	12	4	$n = 972$	Oct. 93–Oct. 94
Facility B	10	2	$n = 720$	Apr. 95–Oct. 95
Facility C	3	4	$n = 135$	Dec. 95–Mar. 96

The goal of this study was the quantitative and qualitative investigation of viable aerobic airborne microorganisms (bacteria and fungi) in three different large scale composting facilities and the assessment of occupational health hazards to plant employees as well as the potential hazard to neighbourhood residents.

2. Materials and methods

2.1. Description of composting facilities

Three different composting systems, including two enclosed facilities (B: containers with intensive decomposition process; C: table-pile composting) were selected for this study (Table 1). All three facilities treat predominantly organic fractions of municipal solid waste as well as yard waste and organic waste from agriculture and forestry. Whereas Facilities A and B are located in a rural area, Facility C is situated in an industrial area surrounded by numerous major construction sites.

2.2. Counting methods for airborne microorganisms

Airborne microorganisms were measured by means of impactors every 2–4 weeks, depending on the facility (Table 2). Sampling was always carried out between approximately 11:00 AM and 2:30 PM at 1.60 m above the ground level. At each sampling location, parallel measurements were conducted for culturable bacteria, mycelial-forming fungi (subsequently referred to as moulds) and yeasts as well as Gram-negative bacilli (only for facility C) using two Andersen 6-stage viable cascade impactors (Graseby©, USA; air intake volume 28.3 l/min).

Table 3
Concentration/m^3 inside the three different facilities at a time of no major activity

Plants	Bacteria			Moulds and yeasts		
	Median	Minimum	Maximum	Median	Minimum	Maximum
Facility A ($n = 36$)						
Open windrows	2.8×10^4	7.5×10^3	4.0×10^4	1.5×10^4	8.0×10^3	3.5×10^4
Facility B ($n = 18$)						
Postrot area/indoor	3.5×10^5	3.5×10^5	3.5×10^5	6.5×10^4	4.2×10^4	9.5×10^4
Facility C ($n = 45$)[a]						
C1 dropoff area	7.9×10^4	7.1×10^4	1.2×10^5	7.1×10^4	6.4×10^4	7.9×10^4
C2 composting area I[b]	$> 5 \times 10^5$	$> 5 \times 10^5$	$> 5 \times 10^5$	1.1×10^5	$> 8 \times 10^4$	1.5×10^5
C3 composting area II[c]	$> 5 \times 10^5$	$> 5 \times 10^5$	$> 5 \times 10^5$	1.1×10^5	$> 8 \times 10^4$	1.4×10^5
C4 sieving area	$> 5 \times 10^5$	$> 5 \times 10^5$	$> 5 \times 10^5$	5.8×10^4	5.3×10^4	6.3×10^4
C5 sorting area	5.7×10^4	5.3×10^4	7.5×10^4	4.2×10^4	3.7×10^4	8.0×10^4

[a] Indoor sites in the enclosed facility.
[b] Fresh material.
[c] 6–8 Week-old material.

As a rule, 6-stage viable Andersen samplers allow a more precise microbiological evaluation as well as separation of the organisms according to particle size. The Andersen sampler separates microorganism-carrying particles in 6 stages according to particle size: stage 1: >7 μm, 2: 4.7–7.0 μm, 3: 3.3–4.7 μm, 4:2.1–3.3 μm, 5: 1.1–2.1 μm, 6: 0.65–1.1 μm aerodynamic diameter. Larger microorganism-carrying particles, in the size range 4 μm and 8 μm, are separated in the first three stages whereas smaller particles (<4 μm) are separated in the three lower stages. This allows the differentiation of respirable (stages 4–6) and non-respirable (stages 1–3) particle-adsorbed microorganisms in the ambient air. The particles of the stages 5 and 6 reach the alveoli (Andersen, 1958).

Table 4
Counts, species and percentage of the most frequent Gram-negative bacilli at the various sampling locations in Facility C ($n = 12$)[a]

Location	CFU/m^3	Species	Proportion (%)
C1	700	*Serratia marcescens*	24
		Acinetobacter anitratum	19
		Enterobacter agglomerans	16
		Pseudomonas fluorescens	14
		Serratia rubidea	9
		Pseudomonas aeruginosa	6
		Enterobacter cloaceae	4
		Flavimonas oryzihabitans	4
		Enterobacter omnigenes	4
C2	1700	*Xanthomonas maltophilia*	50
		Klebsiella oxytoca	14
		Pseudomonas aeruginosa	22
		Acinetobacter anitratum	8
		Pseudomonas fluoreszenz	5
		Acinetobacter lwoffii	1
C3	450	*Pseudomonas aeruginosa*	22
		Enterobacter agglomerans	22
		Enterobacter omnigenes	20
		Acinetobacter anitratum	15
		Alcaligenes faecalis	13
		Enterobacter cloaceae	8
C4	850	*Enterobacter omnigenes*	22
		Klebsiella oxytoca	20
		Enterobacter cloaceae	20
		Acinetobacter lwoffii	15
		Klebsiella oxytoca	13
		Alcaligenes faecalis	10
C5	180	*Pseudomonas cepacia*	35
		Acinetobacter anitratum	30
		Xanthomonas maltophilia	20
		Serratia rubidea	15

[a] n, Petri dishes per sampling site.

2.3. Microbiological evaluation

The microbiological counts of airborne microorganisms conducted in the course of this study include three groups: culturable bacteria, Gram-negative bacilli, mycelial-forming fungi (moulds) and yeasts. For the determination of the various groups, the following culture media (18 ml each in plastic Petri dishes) were used:

2.3.1. Bacteria

(Blood agar) Casein-soybean meal pepton (Oxoid CM313) with an addition of 50 ml/l defibrinated sheep's blood (BAG 3005) and 0.3 g/l Actidion (Serva 10 700).

2.3.2. Moulds and yeasts

Malt extract (Oxoid Nr.1) (5:3), bactericide/bacteriostatic additive: 0.1 g/l penicillin and 0.2 g/l streptomycin sulphate.

2.3.3. Gram-negative bacilli

McConkey–Agar (Oxoid Nr.3), fungicide additive: 0.3 g/l Actidion (Serva 10 700).

The culture media for bacteria and Gram-negative bacilli were incubated at 37°C for 48 h (depending on the growth for a minimum of 24 h to a maximum of 72 h) and the culture media for moulds and yeasts for 7 days at 25°C. Following the colony count, subcultures were identified according to the following microbiological methods: different staining procedures (e.g. Gram, methylene blue) and light-microscopy, API (Appareils et procédés d'identification, bioMerieux) and Vitek system (automated identification system, bioMerieux Vitek, Inc.). A detailed qualitative evaluation of Gram-negative bacilli of the samples was based on the measurements contained from indoor sites in Facility C.

With an intake volume of 28.3 l/min, a 4-min sampling time equals an upper detection limit of 21.202 CFU/m^3, a 1-min count 84.808 CFU/m^3 etc. Sampling times were between 10 s (composting area, Facility C) and 4 min.

The statistical evaluation was conducted by means of the ANOVA test (SPSS, Inc.). The mean significance level for the comparison of culturable counts between two types of samples was established with $\alpha = 0.05$.

3. Results

3.1. Counts inside compost facilities

In the three compost facilities, all data which were collected during the different activities (grinding, turning of windrows etc.) exceeded the upper detection limit of 5×10^5 CFU/m^3. In the absence of these activities,

Table 5
Percentage proportion of the most frequent moulds at the various sampling locations in Facility C ($n = 48$)[a]

Sampling location	*Aspergillus fumigatus*	*Aspergillus flavus* group	*Aspergillus niger*	*Aspergillus* ssp.	*Mucor* ssp.	*Rhizopus* ssp.	Other species[b]
C1	62	5	8	1	2	10	12
C2	64	2	1	11	10	5	7
C3	28	28	15	13	6	6	4
C4	53	28	0	1	15	1	2
C5	60	18	4	0	1	11	6

[a] n, Petri dishes per sampling site.
[b] Other species are mostly: *Penicillium* spp., *Fusarium* spp., *Candida* spp.

median values were highest inside Facility C in the composting area with $> 5 \times 10^5$ CFU/m^3 for bacteria and 1.1×10^5 CFU/m^3 for moulds and yeasts and lowest inside the open Facility A in the area of the windrows with 2.8×10^4 CFU/m^3 for bacteria and 1.5×10^4 CFU/m^3 for moulds and yeasts (Table 3).

The largest number of Gram-negative bacilli was found in the active composting area (C2) with 1.7×10^3 CFU/m^3 and in the sieving area (C4) at 8.5×10^2 CFU/m^3 as well as in the dropoff area (C1) with 7.0×10^2 CFU/m^3. A total of 20 different types of Gram-negative bacilli, mostly from the Enterobacteriaceae were isolated (Table 4).

Of the moulds, *A. fumigatus* was most frequently isolated. In the composting area I (C2), the proportion of *A. fumigatus* spores was highest at 64%, but lowest in the same room (at a distance of approx. 150 m) in the area of the older windrows (C3) at 28% ($P < 0.05$). The proportion was similarly high in the dropoff area (C1) at 62% and in the sorting area (C5) at 60% (Table 5).

A comparison of the different sampling locations in Facility C show that there are no differences in the distribution of bacteria and moulds in the different dust fractions. Graphic representation of mould distribution in the different dust fractions shows that the proportion of the fractions reaching lungs and alveoli is between 55 and 73% [C1: 57%, C2: 55%, C3: 62%; C4: 73%; C5: 71%] and thus higher than the non-respirable proportion ($P < 0.05$; see Fig. 1) (ISO, 1995).

3.2. Counts in the neighbourhood of the composting facilities

In the area directly surrounding the facilities at a distance of approximately 5 m, the highest median values were in the vicinity of the biofilter (rind material) of Facility C with 1.7×10^4 for bacteria and 9.5×10^3 CFU/m^3 for moulds and yeasts (Table 6). Here, isolations of different species of *Cladosporium* spp. were most frequent at 65% whereas the percentage of *A. fumigatus* was only 5%. The lowest counts were determined at Facility B with 2.5×10^2 for bacteria and 2.1×10^2 CFU/m^3 for moulds and yeasts ($P < 0.05$) (Table 7). At 5 m distances around the open Facility A,

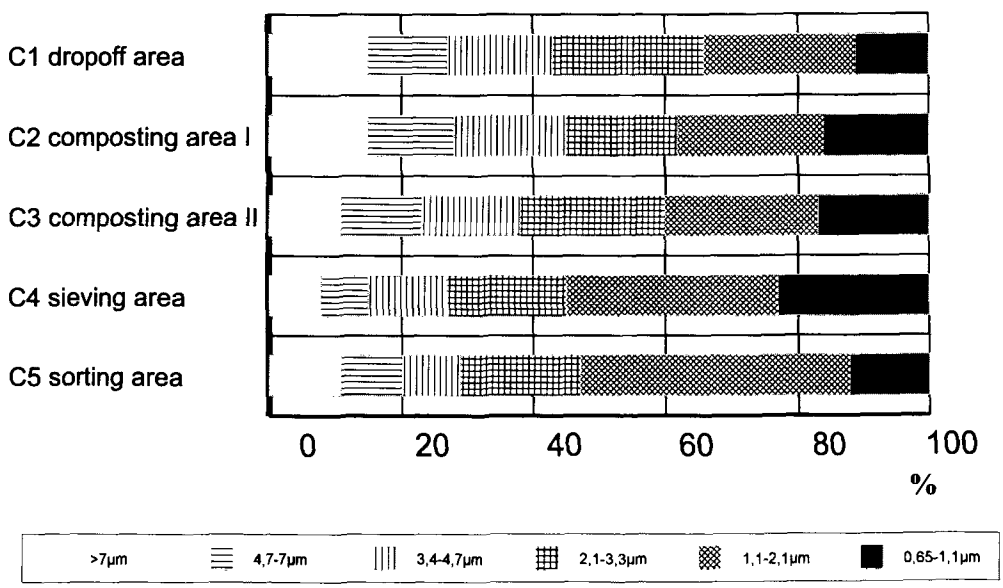

Fig. 1. Proportion of the moulds on the six stages from the Anderson-impactors (Facility C).

Table 6
Concentrations of outdoor airborne microorganisms near Facility C[a]

Sampling site	Bacteria			Moulds and yeasts		
	Median	Maximum	Minimum	Median	Maximum	Minimum
5 m E[b]	17 000	28 000	14 000	9500	12 000	8000
50 m W	841	1168	513	532	780	284
150 m W[c]	1350	1380	421	1400	2213	1250
300 m W	647	1154	220	265	280	205
300 m E[d]	8550	9100	2300	690	900	513

[a] Three observation days; $n = 45$ individual counts per sampling location (all values in CFU/m^3).
[b] Biofilter.
[c] Very busy road.
[d] Construction site during construction work with intensive dust formation.

depending on wind direction, counts were between 7.4×10^2 (upwind) and 1.6×10^3 CFU/m^3 (downwind) for bacteria and between 2.9×10^2 (upwind) and 6.8×10^2 CFU/m^3 (downwind) for moulds and yeasts (Table 8).

Median values in the vicinity of Facility A at a distance of up to 700 m were between 1.8 and 4.8×10^2 CFU/m^3 for bacteria and between 0.8 and 1.4×10^2 CFU/m^3 for moulds. By comparison, the value in an urban 'clean air area' at a distance of 30 km was lower at 1.7×10^2 CFU/m^3 for bacteria and 0.5×10^1 CFU/m^3 for moulds ($P < 0.05$). Values in the immediate vicinity of the Facility A were higher in the summer months compared to the colder winter months during which composting activity was reduced and the presence of snow cover did not promote microbial proliferation (Fig. 2 and Fig. 3).

Median values in the vicinity of Facility B up to a distance of 2 km are equally constant at between 1.4 and 3.3×10^2 CFU/m^3 for bacteria and between 2.1 and 3.6×10^2 CFU/m^3 for moulds and yeasts (Table 7). However, the values in the vicinity of Facility C, located in the midst of an industrial site, with much construction activity, were significantly higher ($P < 0.05$). At a distance of 150 m upwind of the facility near a main road, median values of approximately 1.4×10^3 CFU/m^3 both for bacteria and moulds were determined on three observation days. At a distance of 300 m downwind of the facility on a construction site, median values of approx. 8.6×10^3 CFU/m^3 for bacteria and 6.9×10^2 CFU/m^3 for moulds and yeasts were observed during construction work with intensive dust formation (Table 6). In the case of bacteria, the predominant proportion (> 90%) were aerobic spore-forming organisms (*Bacillus* spp.) and *Cladosporium* spp., *Penicillium* spp., and *Alternaria* spp. were the most abundant fungi.

Compared to the relatively low yearly or half-yearly median values (Facility A and B), highly elevated counts were observed on individual days depending on climatic influences (especially wind) and operating conditions of the facilities.

Emission and transmission of moulds, predominantly *A. fumigatus*, was verified in the vicinity of Facility B (Table 9): in the period shortly before 18 May, the compost containers in Facility B were open for several days due to a technical operating trouble and the exhaust air was released directly to the external environment in an unfiltered state. Whereas on 3 May, at roughly the same climatic conditions and during routine operation, median values for moulds were between

Table 7
Concentrations of outdoor airborne microorganisms near Facility B[a]

Sampling site	Bacteria			Moulds and yeasts		
	Median	Maximum	Minimum	Median	Maximum	Minimum
5 m W	255	790	110	210	930	83
50 m W	280	1300	88	230	540	110
110 m W	330	730	130	340	670	97
140 m W	255	1100	120	360	2600	79
220 m N	210	770	53	210	540	27
400 m E	190	330	110	255	2000	70
400 m NE	265	460	100	315	550	95
2km NE	140	450	100	225	580	45

[a] 10 Sampling days; $n = 72$ individual counts per sampling location (all values in CFU/m^3).

Table 8
Concentrations of outdoor airborne microorganisms near Facility A[a]

Sampling site	Bacteria			Moulds and yeasts		
	Median	Maximum	Minimum	Median	Maximum	Minimum
5m S (upwind)	740	1400	31	290	1235	2
5m N (downwind)	1625	3800	100	680	2800	15
150 m S	475	1700	27	135	1250	16
300 m S	210	900	35	110	540	10
500 m W	215	650	40	95	340	9
550 m S	177	625	30	78	220	10
600 m S	233	350	30	75	280	8
650 m NW	265	562	35	110	250	10
700 m SW	225	580	30	85	220	10
30 km[b]	165	275	20	45	155	5

[a] 12 Sampling days; $n = 81$ individual counts per sampling location (all values in CFU/m^3).
[b] Sampling site in an urban 'clean air' area.

0.8 and 5.8×10^2 CFU/m^3 and the proportion of *A. fumigatus* between 3 and 20%, on 18 May at a distance of 140 and 400 m downwind the values for moulds were up to 2.6 and 2.4×10^3 CFU/m^3. The proportion of *A. fumigatus* was also significantly higher and reached values of > 90% at some sampling locations (Table 9).

4. Discussion

There is still disagreement regarding the measurement of different groups of microorganisms and/or toxins in counts of airborne microorganisms. Bacteria and moulds are mostly referred as 'total counts', meaning the number of culturable microorganisms in order to be able to judge the total emission potential for concentrations of airborne organisms of a study site. Frequently, the proportion of thermophilic Actinomycetes and *Aspergillus* spp. is investigated as some species may cause organ mycosis and allergic reactions in diseased or immunosuppressed individuals. The possibility for comparison of data from a number of different studies gathered from garbage-processing facilities is limited because of the lack of standardisation, and the studies can vary in method and statistical evaluation. The various measuring systems used have different disadvantages in accordance with the devices used. In this study, only a part of all potential microorganisms contained in the ambient air were collected using the Andersen sampler. Especially larger particles (> 6 μm) are poorly registered by this system. However, allergenic responses may be caused by any inhalable particle (Griffiths and DeCosemo, 1994; ISO, 1995). Moreover, the Andersen can overload very quickly, and in low concentrations where sampling has to be carried out for long periods some less-robust microorganisms can be damaged (Decker and Buchanan, 1969; Griffiths and Boysan, 1996; Griffiths et al., 1996, 1997).

Counts of airborne microorganisms on one and the same sampling site may yield different results, owing to different parameters and several parallel measurements should be conducted on each site. Wind direction and speed (not registered in this study) can have a large effect on the collection efficiency of aerosol samplers (May et al., 1976; Upton et al., 1994).

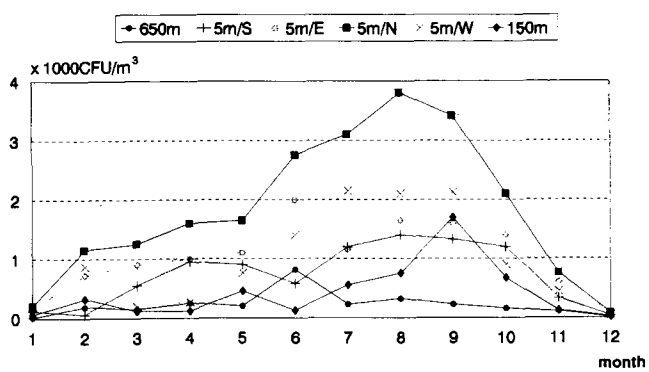

Fig. 2. Airbourne bacterial counts at composting Facility A: single values/sampling day.

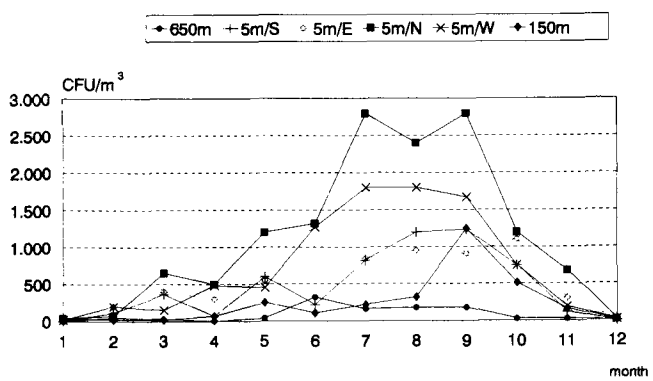

Fig. 3. Airbourne fungal counts at composting Facility A: single values/sampling day.

Table 9
Concentrations of airborne microorganisms in Facility B. Proportion of *Aspergillus fumigatus* of total counts of moulds and comparison of the single values on 2 sampling days, 3 May and 18 May (all values in CFU/m^3)

Sampling site	3 May		18 May	
	Moulds	*Aspergillus fumigatus* (%)	Moulds	*Aspergillus fumigatus* (%)
5 m W	169	8 (5)	840	117 (14)
50 m W	177	9 (5)	539	485 (90)
110 m W	141	9 (6)	371	350 (95)
140 m W	168	18 (11)	2600	317 (12)
220 m N	88	17 (20)	415	261 (63)
400 m E	83	8 (19)	2410	245 (10)
400 m NE	105	9 (9)	176	26 (15)
2 km NE	580	17 (3)	440	33 (8)

4.1. Facility-related counts

The highest concentrations of airborne microorganisms were determined predominantly in those areas where materials are moved, for example in the turning of windrows, grinding, blending of compost etc. These findings correspond to those of other authors (Clark et al., 1983; Jager et al., 1994). The total airborne concentration during the composting process and the sorting for recycling is reported to be between 10^5 and 10^7 CFU/m^3 for moulds and between 10^3 and 10^6 CFU/m^3 for bacteria (Seidl, 1995) or even up to 10^9 CFU/m^3 for moulds inside the enclosed facilities (Grüner, 1994). The quantitative differences reported by the authors, which are caused by the different types of facilities and different sampling locations, as well as different measuring systems, are conspicuous.

High counts of potentially pathogenic microorganisms are generally to be expected in the area of industrial composting with temperatures between 30°C up to approximately 50°C, especially high spore counts of *A. fumigatus*. In the present study, the largest proportion of *A. fumigatus* was 64% (median for moulds 1.1×10^5 CFU/m^3) in the composting area in the enclosed Facility C during intensive decomposition process. Göttlich (1995) found maximum counts of *A. fumigatus* in composting areas of up to 9×10^6 CFU/m^3. No occupational exposure limits exist for airborne microorganisms. Malmros (1990) suggested limit values for work sites in composting facilities to be set at 10^4 CFU/m^3 for culturable bacteria, and 10^3 CFU/m^3 for Gram-negative bacteria. Rylander (1986) has found that the spore concentration necessary for a sensitisation in humans must be at least 10^8. Other authors set relevant fungal spore and Actinomycetes concentrations in the range between 10^6 and 10^{10} CFU/m^3 (Lacey et al., 1972). From the point of view of occupational medicine, potential allergies against moulds and Actinomycetes are most important. For allergic diseases such as extrinsic allergic alveolitis and allergic bronchial asthma, exposure frequency and concentrations are significant in addition to individual constitutional factors. Since the development of occupational allergic asthma is highly dependent on individual susceptibility, it may not be possible to suggested tentative occupational exposure limits for fungal spores in relation to this disease (Poulsen et al., 1995). The bacterial and spore load to employees in composting facilities has so far hardly been studied. Stalder (1994) investigated the antibodies against different Actinomycetes and moulds in 30 employees of composting facilities and compared these findings to a control group not subjected to this exposure. Significantly higher antibody titers against Actinomycetes were found in employees in composting facilities. However, the titers were significantly below those titers associated with patients suffering from extrinsic allergic alveolitis (EAA). Also, there were no pathological findings in the employees of the composting facilities studied. In a different study, it was determined that in 6 of 11 employees the symptoms fatigue, headaches, fever and diarrhoea occurred significantly more frequently than in a control group (Lundholm and Rylander, 1980). In preliminary studies of employees of sorting or composting plants, Marth et al. (1996) found no elevated frequency of the antigen-specific IgE-antibodies. Subjectively, employees indicated a significantly higher degree of headaches than individuals in a control group.

In spite of the uncertainty of the effects of fungal spores on the respiratory system, it is recommended that adequate respiratory protection be used during certain types of work in composting (i.e. high efficiency particulate air filters (HEPA) in machines turning windrows). Important measures to be taken from the occupational medicine point of view are adequate allergological examination prior to employment. Millner et al. (1994) suggest that future worker studies should include systematic assessments for mucus membrane irritation, organic dust toxic syndrome (ODTS), HP (extrinsic allergic alveolitis), and related disorders in

low, chronic exposure situations, i.e. situations in which exposures of 10^4–10^5 CFU/m^3 are generally present.

4.2. Counts related to neighbourhood residents

With regard to neighbourhood residents, only the counts from Facilities A and B can be used. For Facility C, we only have outside counts from 3 days. However, the data for Facility C suggest that the very busy streets and the major construction site in the vicinity of the facility are sources of dust emission, and therefore also for bacteria and moulds, in their own right. Furthermore, bacteria and mould emissions in the area immediately adjacent to the facility in the area of the biofilter are significantly higher than in the case of the other facilities. However, in comparison to the counts inside the facility, *Cladosporium* spp. spores rather than *A. fumigatus* spores predominate. *Cladosporium* spp. spores are generally abundant in the outdoor air and may also multiply in the biofilter (rind material).

The counts in the neighbourhood of the other two facilities (A and B) are more representative as the number of observation days was higher (12 and 10 days, respectively). The counts show that median values for bacteria and moulds in the area of the open Facility A are constant at distances in excess of 150 m. Similarly, this is also true of Facility B, although the median values for moulds are twice as high compared to Facility A. This discrepancy can be explained with the fact that counts in Facility B were only conducted during the warm summer months, whereas Facility A counts also included the winter months during which counts of airborne microorganisms are lower. Counts in 14-day intervals over a period of 1 year in the unpolluted outside air show median values between 0.8 and 3.3×10^2 CFU/m^3 for bacteria and between 1.0 and 1.9×10^2 CFU/m^3 for moulds (Schlacher et al., 1996). These are counts which are roughly comparable with those of the areas surrounding Facilities A and B. However, as shown in the case of Facility B, higher counts, especially of *A. fumigatus*, can be expected in cases of poor operation (e.g. technical problems) and under specific climatic conditions (wind). The counts of bacteria and moulds are not relevant for the determination of the health hazard for neighbourhood residents as total concentrations of microorganisms of $> 10^4$ CFU/m^3 also exist in everyday situations (e.g. inside spaces with many people, busy streets etc.) (Daschner, 1995). *A. fumigatus*, however, which occur in large numbers in the ambient aerosol in the compost in the composting process, can be used as a parameter for a potential health hazard. Millner et al. (1977) showed in their investigations that the volume of *A. fumigatus* spores in composting sites, which are similar to the results of this study, can be up to 70% of the total microflora found. This proportion declines to 2% at distances of 320 m to 8 km. Thus, *A. fumigatus* can be considered as indicator for counts of airborne microorganisms both in the facility itself and in the neighbourhood of composting facilities. This is also true of thermophilic Actinomycetes (e.g. *Saccharopolyspora* spp., a pathogen causing farmer's lung) which also multiply in the termophilic process of composting. However, it is difficult to determine the health risk to neighbourhood residents in the case of the operating trouble of Facility B resulting in high counts *A. fumigatus* (e.g. 3.2×10^2 CFU/m^3 at a distance of 140 m). There are no studies regarding the effects of short-term or chronic exposure of 100–500 spores of *A. fumigatus* on a healthy body (in the case of immunocompromised individuals, significantly lower numbers may lead to disease). Horn (1994), who found an average of 100 spores of *A. fumigatus*/m^3 at a distance of 540 m from a composting plant, could not find any diseases related to *A. fumigatus* among neighbourhood residents. Moreover, much higher values must be expected in agricultural activities in rural areas such as in haylofts when turning hay (from 4×10^3 to 2×10^6 CFU/m^3) (Lacey et al., 1992; Mark, 1992), in stables (1×10^3 CFU/m^3) or on mushroom farms (9×10^4 CFU/m^3) (Clark et al., 1983).

Regarding the hazard to neighbourhood residents and according to the results of the present study, no elevated load should be expected beyond a distance of 150 m from the facilities during normal operation. The distance legally prescribed for Austria, 300 m, is therefore sufficient to avoid high levels of microorganisms in the neighbourhood. In the case of poor operation and especially under specific climatic conditions (wind), higher counts can be expected at distances in excess of 300 m. In view of the possible release of high airborne concentrations of *A. fumigatus* during failures in composting plants, hospitals and health-care facilities should be sited at distances in excess of 300 m from such facilities. Moreover, odour complaints, which were not subject of this study, will in many cases be more significant than the bacteria and mould content of the outside air.

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