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Effects of bioaerosol polluted outdoor air on airways of residents: a cross sectional study

C E W Herr, A zur Nieden, M Jankofsky, N I Stilianakis, R-H Boedeker, T F Eikmann

BACKGROUND: Bioaerosol pollution of workplace and home environments mainly affects airways and mucous membranes. The effect of environmental outdoor residential bioaerosol pollution, for example, livestock holdings, farming, and waste disposal plants, is unclear.

AIMS: To investigate the perceived health of residents living in areas with measurable outdoor bioaerosol pollution (for example, spores of Aspergillus fumigatus and actinomycetes), and effects of accompanying odours.

METHODS: In a cross sectional study, double blinded to ongoing microbial measurements, doctors collected 356 questionnaires from residents near a large scale composting site, and from unexposed controls in 1997. Self reported prevalence of health complaints during the past year, doctors’ diagnoses, as well as residential odour annoyance were assessed. Microbiological pollution was measured simultaneously in residential outdoor air.

RESULTS: Concentrations of >10^4 colony forming units of thermophilic actinomycetes, moulds, and total bacteria/m^3 air were measured 200 m from the site, dropping to near background concentrations within 300 m. Positive adjusted associations were observed for residency within 150–200 m from the site versus unexposed controls for self reported health complaints: “waking up due to coughing”, odds ratio (OR) 6.59 (95% confidence interval [CI] 2.57 to 17.73); “coughing on rising or during the day”, OR 3.18 (95% CI 1.24 to 8.36); “bronchitis”, OR 3.59 (95% CI 1.40 to 9.4); and “excessive tiredness”, OR 4.27 (95% CI 1.56 to 12.15). Reports of irritative airway complaints were associated with residency in the highest bioaerosol exposure, 150–200 m (versus residency >400–500 m) from the site, and period of residency more than five years, but not residential odour annoyance. Lifetime prevalence of self reported diseases did not differ with exposure.

CONCLUSIONS: Bioaerosol pollution of residential outdoor air can occur in concentrations found in occupational environments. For the first time residents exposed to bioaerosol pollution were shown to report irritative respiratory complaints similar to mucous membrane irritation independently of perceived odours.

Bioaerosols occur ubiquitously as inhalable mixtures of air and microorganisms, parts of microorganisms, or organic substances of microbial and plant origin. In the outdoor air, exposure bioaerosols (for example, containing Aspergillus fumigatus) can occur from natural or anthropogenic sources. When evaluating health effects of bioaerosols (organic dusts), their composition, concentration, and measurement methods applied must be considered. Individual susceptibility, for example, atopy, allergic sensitisation, or immunodeficiency, also plays an important role in the risk assessment. Health based threshold levels for microorganisms for outdoor, indoor, or workplace air have not been established. It is, however, known that infectious, allergic, or toxic disturbances triggered by bioaerosols originate mostly in moulds, thermophilic actinomycetes, Gram negative bacteria, and viruses.

Besides livestock breeding and farming, the increasing number of large scale composting facilities for sewage sludge, and yard and solid waste being established within the scope of modern disposal concepts can release bioaerosols. Health relevant moulds (Aspergillus fumigatus) and actinomycetes accumulated in compost material become airborne as vegetative cells or spores through movement of the material. Workers on composting sites have higher rates of airway related mucous membrane complaints and diseases. In these workers, specific antibodies against actinomycetes, as well as airway inflammation (or mucous membrane irritation (MMI)) have been reported. Severe cases of general disease, for example, hypersensitivity pneumonia or severe toxic reactions (toxic pneumonitis or organic dust toxic syndrome (ODTS)) were reported in workers and one private person following direct contact with compost.

Worldwide several thousand of these often malodorous sites are operating. However, their health effects on nearby residents have not been investigated sufficiently. A study in residents living within 500 m of a site showed no clear evidence of health changes. In a case report, an asthmatic, living 80 m from a composting site (52% of the year in the wind direction), was found to have an allergic bronchopulmonary aspergillosis (ABPA).

There is an urgent need to evaluate pollution due to bioaerosols (organic dusts), which can also occur in indoor air, as far as the general public health is concerned. This is particularly important as an increasing fraction of the general population in industrialised countries must be classified as a risk group (for example, atopics) in the context of bioaerosol pollution.

This cross sectional study aimed to relate self reported health to measurable bioaerosol pollution in the residential outdoor air. Prevalence of perceived complaints and self
reported doctors’ diagnoses of residents living very close (150–200 m) to a composting site were compared to those in the same neighbourhood living further away (>400–500 m) and to a corresponding unexposed control group without a residential source of bioaerosols. Measurements of viable airborne microorganisms in residential air were performed during the ongoing epidemiological study and were known neither to interviewers nor to the study subjects at that time. Reports of annoying residential odours were also assessed, as they are known to be of relevance to reported health.²⁻⁴

METHODS
Assessment of exposure to cultivable microorganisms in the outdoor air of the residential area
The aim of the measurements was to assess location specific “worst case” conditions with regard to released bioaerosols into the neighbourhood. This concerned periods of intense microorganism releasing work activity, previously defined meteorological conditions at the time of measurement, as well as topographical aspects. Because of the ubiquity of the microorganisms under research, especially the thermophilic microorganisms releasing work activity, previously defined meteorological conditions, comparative quantitative measurements of background concentrations were taken upwind of the site.

The concentrations of three fractions of culturable microorganisms were determined in three repeated measurements. These were collected with filter based samplers (MD 8 Sartorius, Goettingen, Germany, flow rate 8 m³ h⁻¹, collection time 10 min) 1.5 m above ground level, with subsequent indirect plating method after filtration and precipitation on gelatine filters.²⁻⁴

- Total bacteria (R2A agar (oxoid), 25°C)
- Moulds (dichloran-glycerine-(DG18)–(oxoid), 25°C)
- Thermophilic and thermodurant actinomycetes (glycerine-arginine-agar, 50°C).

As results of single microbial measurements are known to vary considerably, results of the three consecutive measurements are given as maximum and minimum concentrations in table 2 and not mean values.

Epidemiological investigation
Study population
A team of doctors, process engineers, microbiologists, and meteorologists selected a composting site which had been in operation for five years and had lead to distress in the neighbouring residents due to odour annoyance and fear of allergies and infection. Considering topographical and meteorological (for example, wind direction) as well as technical aspects (site not completely closed off, processing of yard trimmings and organic waste, a turnover of approximately 12 500 Mg per year), discharge of bioaerosols from the site into the neighbouring residential area was presumed prior to the study. Other sources of bioaerosol exposure (sewage plants, etc) did not exist in the proximity of the residential area.

Together with the local health authority, an unexposed control area was selected in the same governmental district. Criteria for the selection were: similarity of population pattern, residential area (size of households, road traffic, petrol stations, and industrial sites) and the lack of sources of microorganisms in the residential outdoor air.

The residential area next to the composting plant was located at a distance from 150 to 500 m downwind. All persons living there (n = 310) and 411 unexposed inhabitants in the control area were invited to participate in the study. Addresses were collected from the municipal registration of address office.

Questionnaires concerning perceived health and odour annoyance
An environmental health questionnaire was used for the assessment of self reported health: complaints and symptoms as well as lifetime prevalence of doctors’ diagnoses. The questionnaire was developed with items validated and applied in several national and international studies, for example, for occupational medicine.

<table>
<thead>
<tr>
<th>Participant characteristics</th>
<th>Study population</th>
<th>Unexposed controls</th>
<th>Residents of a neighbourhood with bioaerosol pollution of outdoor air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Classified</td>
<td></td>
</tr>
<tr>
<td>Distance from the emitting site</td>
<td>–</td>
<td>150-300 m</td>
<td>Up to &gt;10⁶ CFU* m⁻³</td>
</tr>
<tr>
<td>Bioaerosol pollution in residential air</td>
<td>–</td>
<td>Not measured</td>
<td>Up to &gt;10⁶ CFU* m⁻³</td>
</tr>
<tr>
<td>Participants</td>
<td>n=356</td>
<td>n=142</td>
<td>n=214</td>
</tr>
<tr>
<td></td>
<td>SS† Yes [%]</td>
<td>SS† Yes [%]</td>
<td>SS† Yes [%]</td>
</tr>
<tr>
<td>Female</td>
<td>356 56.7</td>
<td>142 52.8</td>
<td>214 59.3</td>
</tr>
<tr>
<td>Age &gt;50 years</td>
<td>356 43.0</td>
<td>142 36.6</td>
<td>214 47.2</td>
</tr>
<tr>
<td>Duration of present residency &gt;5 years</td>
<td>350 71.7</td>
<td>137 70.8</td>
<td>213 72.3</td>
</tr>
<tr>
<td>Odour annoyance in the residential area</td>
<td>344 59.3</td>
<td>132 25.8</td>
<td>212 80.2</td>
</tr>
<tr>
<td>Separate collection of organic household waste</td>
<td>199 7.5</td>
<td>73 0.0</td>
<td>162 9.3</td>
</tr>
<tr>
<td>Composting in own garden</td>
<td>348 55.5</td>
<td>136 75.0</td>
<td>212 42.9</td>
</tr>
<tr>
<td>Occupation at a composting site</td>
<td>350 67.4</td>
<td>137 65.7</td>
<td>213 68.5</td>
</tr>
<tr>
<td>Environmental tobacco smoke (at home/in the workplace)</td>
<td>337 0.6</td>
<td>136 0.0</td>
<td>201 1.0</td>
</tr>
<tr>
<td>Use of inhalers at home</td>
<td>283 39.6</td>
<td>111 39.6</td>
<td>172 39.5</td>
</tr>
<tr>
<td>Bedroom equipment‡</td>
<td>355 97.5</td>
<td>142 99.3</td>
<td>213 96.2</td>
</tr>
<tr>
<td>Smoking status (smoker and non-smoker &lt;5 years)</td>
<td>324 26.5</td>
<td>132 25.0</td>
<td>192 27.6</td>
</tr>
<tr>
<td>Home &lt;50 m from busy street</td>
<td>356 30.6</td>
<td>142 17.6</td>
<td>214 39.3</td>
</tr>
</tbody>
</table>

*CFU, colony forming units.
†SS, sample size.
‡Bedroom furnishings include one of the following: carpet, furs, eiderdown, horsehair or innerspring mattress, furniture made of chipboard.
§Vapours, gases, dusts, heat, cold, dampness.
ISAAC.\textsuperscript{21} It was designed in particular to record health impairments and diseases of the respiratory tract from air pollution.

Prevalence of respiratory (12 items), eye related (two items), and general (eight items) health complaints, as well as current intake of medicine during the past 12 months were recorded (table 1). Subjects were also asked to state lifetime prevalence of diseases found by their own doctors in 18 categories. Interviewing doctors checked allergic conditions and current medicine intake by inspecting documents stating allergies and medicine supply during the study related house call.

Lifestyle factors and individual exposure to microorganisms from household sources (contact with compost, organic waste collection in the home,\textsuperscript{16} inhalers, soft furnishings) were determined (see table 1). Further questions concerned the occurrence and quality of annoying odours in the residential area.

Epidemiological survey
The survey was carried out after consultation with the state data protection officer. It took place on all school days of one week in July 1997, not during school holidays. A press conference, information by mail, and public event had previously taken place. The selected sample was mailed the questionnaire accompanied by additional information stating, for example, that their participation was voluntary. They were then phoned up to three times in order to arrange appointments for the doctor supported medical history interviews. These interviews took place in their homes and lasted for about an hour per person.

Statistical analysis
Using the LOGISTIC procedure of the SAS/STAT software, version 8.0, a logistic regression modelling approach was employed to analyse the health data of the 356 respondents studied. The model associated odds ratios (OR) and the corresponding 95% confidence intervals (CI) were determined. A p value of 0.05 or less was judged relevant. First a core model in which residents living at different distances (150–200 m, >200–400 m, >400–500 m) from the site were compared to those living beyond 500 m was calculated for both parameters in the core model.

In a second stage the model was calculated for those 214 residents living near the composting site only. Those living in the two distance groups nearest to the site (150–200 m, >200–400 m) were compared to those living at >400–500 m. Fixed covariables were age, odour annoyance, and period of residence in the current home >5 years.

RESULTS
Exposure to culturable microorganisms in the outdoor air of the residential area
In the outdoor air of the residential area 200 m from the plant, concentrations of up to >10\textsuperscript{4} CFU m\textsuperscript{-3} air were recorded for total bacteria, moulds, and thermophilic actinomycetes. Even 320 m from the site differences in concentrations of total bacteria and moulds which were 100 times background levels (10\textsuperscript{-3}–10\textsuperscript{-4} CFU m\textsuperscript{-3} air) were detected. Furthermore, the site characteristic thermophilic actinomycetes which were not found in upwind—background measurements—were still detectable 550 m downwind from the site at a concentration of <10\textsuperscript{3} CFU m\textsuperscript{-3} air.\textsuperscript{27}

These high concentrations of culturable microorganisms close to the plant came down quickly to near background concentrations within 550 m from the plant (table 2). Based on this observation, the exposed population was divided into three groups, dependent on the linear distance of the respective home from the site (150–200 m, >200–400 m, >400–500 m).

Epidemiological investigation
Study population
A total of 356 people took part in the study (see table 1). The response rate in the residential area with bioaerosol pollution was 69%. Selection bias due to low participation rate (35%) in the unexposed group would be characterised by stronger weighing of health concerned subjects perceiving health impairment.

More females and subjects >50 years took part in the exposed group. As stated above an adjustment was made for both parameters in the core model.

In the neighbourhood of the site, residential odour annoyance was reported by 80%, increasing to 95% in residents living 150–200 m from the site. When asked to characterise this odour annoyance, 10% described it as “disgustin”. None of the exposed controls reporting odours from other possible environmental sources stated this kind of odour annoyance. This underlines the specific odour annoyance of the exposed group.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Concentrations of culturable microorganisms [minimum/maximum]* in residential air neighbouring a bioaerosol releasing composting site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample points (by distance and direction to composting site)</td>
<td>Total bacteria [CFU m\textsuperscript{-3} air]</td>
</tr>
<tr>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Upwind</td>
<td></td>
</tr>
<tr>
<td>500 m SE§</td>
<td></td>
</tr>
<tr>
<td>Downwind</td>
<td></td>
</tr>
<tr>
<td>200 m NW**</td>
<td>2.2 \times 10^0</td>
</tr>
<tr>
<td>250 m WNW††</td>
<td>3.9 \times 10^0</td>
</tr>
<tr>
<td>300 m N††</td>
<td>4.4 \times 10^0</td>
</tr>
<tr>
<td>320 m NW</td>
<td>6.8 \times 10^0</td>
</tr>
<tr>
<td>550 m N</td>
<td>8.3 \times 10^0</td>
</tr>
</tbody>
</table>

Sampling conditions

<table>
<thead>
<tr>
<th>Samplers</th>
<th>Collection time</th>
<th>Detection limit</th>
<th>Date and time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter based MD 8 Sartorius, (Goettingen, Germany)</td>
<td>10 min at 1.5 m above ground level with subsequent indirect plating method after filtration and precipitation on gelatine filters</td>
<td>40 CFU</td>
<td>07.08.1997; 00:00–02:15§§</td>
</tr>
</tbody>
</table>

*Minimum (Min) and maximum (Max) values of three repeated measurements. †Kompostwerk Langes Feld, Kassel, Germany. ‡CFU, colony forming units. §SE, southeast. †ND, not detected. **NW, northwest. ††WNVW, westnorthwest. †‡N, north. §§Although there was a cold air flow from the composting site towards the studied neighbouring residential area “worst case” conditions.
### Table 3  Prevalence of reported health complaints in residents in the neighbourhood of a composting site stratified according to the distance between home and composting site respectively, increasing concentration of bioaerosol exposure in residential air and unexposed controls

<table>
<thead>
<tr>
<th>Study population</th>
<th>Unexposed controls</th>
<th>Residents in the neighbourhood of a composting site with bioaerosol pollution of outdoor air</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Distance of home from composting site</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Bioaerosol pollution in residential air</td>
<td>–</td>
<td>Not measured</td>
</tr>
<tr>
<td>Participants</td>
<td>n=356</td>
<td>n=142</td>
</tr>
<tr>
<td>Reported health complaints†</td>
<td>SS‡</td>
<td>SS</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of colds &gt;5/year</td>
<td>352</td>
<td>142</td>
</tr>
<tr>
<td>Hay fever</td>
<td>355</td>
<td>142</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>354</td>
<td>141</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>355</td>
<td>142</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>348</td>
<td>139</td>
</tr>
<tr>
<td>Shortness of breath at rest</td>
<td>343</td>
<td>137</td>
</tr>
<tr>
<td>Shortness of breath following exertion</td>
<td>344</td>
<td>136</td>
</tr>
<tr>
<td>Waking up with chest tightness</td>
<td>338</td>
<td>135</td>
</tr>
<tr>
<td>Waking up due to shortness of breath</td>
<td>341</td>
<td>136</td>
</tr>
<tr>
<td>Waking up due to coughing</td>
<td>338</td>
<td>135</td>
</tr>
<tr>
<td>Wheezing</td>
<td>349</td>
<td>139</td>
</tr>
<tr>
<td>Coughing rising/during the day§</td>
<td>355</td>
<td>142</td>
</tr>
<tr>
<td>Eyes and general health</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Itching eyes &gt;10/year</td>
<td>340</td>
<td>131</td>
</tr>
<tr>
<td>Smarting eyes &gt;10/year</td>
<td>344</td>
<td>136</td>
</tr>
<tr>
<td>Loss of appetite</td>
<td>347</td>
<td>140</td>
</tr>
<tr>
<td>Nausea or vomiting &gt;5/year</td>
<td>343</td>
<td>136</td>
</tr>
<tr>
<td>Diarrhoea &gt;5/year</td>
<td>349</td>
<td>138</td>
</tr>
<tr>
<td>Excessive tiredness &gt;5/year</td>
<td>341</td>
<td>138</td>
</tr>
<tr>
<td>Shivering</td>
<td>353</td>
<td>140</td>
</tr>
<tr>
<td>Fever &gt;5/year</td>
<td>356</td>
<td>142</td>
</tr>
<tr>
<td>Joint trouble &gt;10/year</td>
<td>346</td>
<td>136</td>
</tr>
<tr>
<td>Muscular complaints &gt;10/year</td>
<td>339</td>
<td>135</td>
</tr>
<tr>
<td>Current intake of medicine/vitamins</td>
<td>355</td>
<td>142</td>
</tr>
</tbody>
</table>

*CFU, colony forming units.
†Frequency or occurrence in the past 12 months. If not otherwise stated, rates are for a single occurrence.
‡SS, sample size.
§Criteria of the World Health Organisation for chronic bronchitis.

Regarding exposure to airborne microorganisms from domestic sources, residents near the composting site reported less separate collection of organic household waste. This rate was lowest in those living closest to the site. From this observation, as well as from reports on composting in own gardens, there was no indication of a higher exposure of the residents in the neighbourhood of the site to bioaerosols from domestic waste sources.

Smoking status and exposure to environmental tobacco smoke, occupational exposure, personal use of inhalers, as well bedroom equipment, also gave no indication of a higher burden on the airways of the exposed group. The same applied to the statements on mould or dampness in homes (9% in unexposed controls, also gave no indication of a higher exposure to car traffic related pollutants close to the site. For this reason an adjustment was made in the logistic regression.

**Health effects in a residential area with bioaerosol pollution**

Residents living in the neighbourhood of the composting site reported health complaints, medicine intake, and 11 of the 18 self-reported illnesses ever diagnosed by a doctor more frequently than unexposed controls without a neighbouring composting site. Stratification showed the highest prevalence of complaints in those living closest to the site who were respectively exposed to the highest concentration of bioaerosols measured. Nevertheless, the exposed group living furthest away from the site at a distance of >400–500 m still reported higher rates of health complaints (but not self-perceived diseases) compared to unexposed controls (table 3).

In the core model the unexposed residents without an adjacent composting site were compared with exposed residents in the neighbourhood of the site. For this the exposed group was stratified according to distance between home and composting site, and nine confounders were taken into consideration. Adjusted associations were found between close residency to the site (150–200 m)—highest concentration of airborne microorganisms (up to >10⁵ CFU m⁻³ residential air)—and three of 12 airway related complaints, as well as excessive tiredness and intake of medicine (table 4). For those living further away from the site (>200–400 m), these associations were not observed.

In this core model, duration of present residency (>5 years), respectively duration of exposure was positively associated with “waking up due to coughing” (OR 2.29; 95% CI 1.13 to 4.79) and “bronchitis” (OR 2.37; 95% CI 1.65 to 5.06) during the past 12 months.

In a second step only those living in the neighbourhood of the composting site were studied. This allowed the effects of the bioaerosols (measured concentrations and duration of exposure) and the possible bias due to the specific, in part distracting, residential odour annoyance near the composting site to be analysed more precisely. This comparison of the most highly exposed (up to >10⁵ CFU m⁻³ residential air) with the least exposed (near background concentrations of airborne...
microorganisms) population of the same neighbourhood was positively associated with eight items of reported health (table 5). “Shortness of breath” (“following exertion” and “while at rest”) was most strongly associated with residential exposure to highest concentrations (>10⁵ CFU m⁻³) bioaerosols. Frequency of perceived bronchitis in the past 12 months and two symptoms associated with cough all had positive adjusted OR above 2.5. Sore eyes as well as diarrhoea, excessive tiredness, shivering. Specific odour annoyance did not confound any of the airway related complaints in the neighbourhood of the composting site (table 5).

In this analysis, distance of the home from the site, and duration of residency, as well as residential odour annoyance were not associated with increased reporting of lifetime prevalence of 18 self reported doctor diagnosed illnesses.

**DISCUSSION**

Concentrations of culturable airborne microorganisms, including moulds, measured in the residential air during the study (table 2) at 150 to 320 m from the composting site were 100 000 times higher than those concentrations generally reported as natural background concentrations. Background concentrations for total bacteria and moulds are given as <10³

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**Table 4** Health effects* of bioaerosol pollution in residential outdoor air highly exposed (>10⁵ CFU m⁻³) in the neighbourhood of a composting site compared to unexposed controls without a neighbouring composting site

| Reported health complaints‡§ | Residents with bioaerosol pollution of up to >10⁵ CFU m⁻³ residential air living 150-200 m from the composting site OR** 95% CI†† OR 95% CI OR 95% CI |
|-----------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Bronchitis                  | 262                                            | 3.59                                            | 1.40 to 9.47                                    |
| Waking up due to coughing   | 255                                            | 6.59                                            | 2.57 to 17.73                                   |
| Coughing on rising or during the day†† | 263 | 3.18 | 1.24 to 8.36 |
| Excessive tiredness         | 251                                            | 4.27                                            | 1.56 to 12.15                                   |
| Current medication intake   | 263                                            | 2.64                                            | 1.08 to 6.60                                    |

**Table 5** Health effects* of highest (>10⁵ CFU m⁻³) air versus near background concentrations of outdoor bioaerosol, pollution, duration of present residency, and odour annoyance in a residential area with a neighbouring composting site

<table>
<thead>
<tr>
<th>Reported health complaints‡</th>
<th>Bioaerosol pollution in residential air up to &gt;10⁵ CFU m⁻³</th>
<th>Duration of present residency &gt;5 years</th>
<th>Odour annoyance in the residential area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of colds &gt;5x/year</td>
<td>209 1.94 0.65 to 6.78</td>
<td>4.72 1.19 to 31.83</td>
<td>3.09 0.50 to 60.14</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>210 3.02 1.35 to 7.06</td>
<td>2.91 1.29 to 7.03</td>
<td>1.86 0.71 to 5.54</td>
</tr>
<tr>
<td>Waking up due to coughing</td>
<td>202 2.70 1.23 to 6.10</td>
<td>2.51 1.19 to 5.53</td>
<td>1.95 0.81 to 5.08</td>
</tr>
<tr>
<td>Wheezing</td>
<td>207 1.96 0.84 to 4.82</td>
<td>2.95 1.22 to 7.99</td>
<td>1.97 0.72 to 6.35</td>
</tr>
<tr>
<td>Shortness of breath at rest</td>
<td>203 3.99 1.31 to 15.19</td>
<td>1.50 0.56 to 4.49</td>
<td>1.97 0.59 to 9.02</td>
</tr>
<tr>
<td>Coughing on rising or during the day††</td>
<td>210</td>
<td>2.67</td>
<td>1.17 to 6.10</td>
</tr>
<tr>
<td>Shortness of breath after exertion</td>
<td>205 4.23</td>
<td>1.74 to 11.34</td>
<td>2.03 0.90 to 4.91</td>
</tr>
</tbody>
</table>

*Only the significantly increased complaints from table 3 are listed.
†CFU, colony forming units.
‡Frequency of occurrence in the past 12 months; if not otherwise stated, rates are for a single occurrence.
§SS, sample size.
**OR, adjusted odds ratio comparing the group nearest to the composting site (150–220 m) with the control group in a residential area without a neighbouring composting site adjusted for residential odour annoyance, duration present residency >5 years, composting in own garden, separate collection of organic household waste, distance of home to busy road <50 m, age, gender, smoking, and passive smoke exposure.
††CI, confidence interval.
†‡Distance of home to the emitting site 150–200 m.
§§§§Due to the small number of subjects of this complaint reliable odds ratio could not be determined.
The health complaints found here in association with residential bioaerosol exposure were not accompanied by increased self reports of diseases diagnosed by a doctor. This

controls in a neighbourhood without a composting site) with residency near the composting site (data not shown).

As a result of this, and particularly because of the detection of site typical actinomycetes, a distance dependent influence of the composting site on the residential air could be demonstrated up to 550 m (table 2). In a study conducted in Islip, New York, 16 the bioaerosol related influence of a large scale composting site on a residential area 500 m away could not be excluded. However, this study has methodological shortcomings as far as exposure measurements and health effects are concerned. In other studies, the bioaerosol pollution due to sites could only be demonstrated up to a distance of 200 m. 7

The highest concentrations of total bacteria and actinomycetes (>10^3 CFU m^-3 air) measured, were within the range of those reported in occupational studies of composting sites, 15 16 17 For total CFU bacteria, the measured concentrations of 10^2–10^3 CFU m^-3 air also exceeded occupational threshold levels recommended in Denmark and Sweden. 17 Health effects have been observed in the studies on workplace or indoor environment in association with concentration levels recorded here for total bacteria and moulds (Aspergillus fumigatus). 11 22

These microbiological measurements were performed under meteorological conditions which occur on 50% of the days in a year. Desired “worst case” conditions were not achieved completely during these measurements. Considering this the exposure to airborne cultivable microorganisms in the residential area could at times have been even higher. The additional health burden from non-culturable microorganisms or allergenic and toxic parts of microorganisms, which also occur in bioaerosols, was not even assessable in the scope of the measurements. 5

An association could be demonstrated in the present study between residential bioaerosol pollution (<200 m from the plant) and irritative airway complaints. This association was found when comparing with less exposed subjects living in the same neighbourhood further away from the same site (>400–500 m) and also, to a greater extent, when comparing with unexposed controls as well as least exposed. Furthermore, an association of these complaints with the duration of bioaerosol exposure (>5 years) could also in part be demonstrated. If at least two irritative mucous membrane symptoms are reported in association with chronic exposure to bioaerosols, this is suggestive of airway inflammation. 7

Complaints of airway inflammation are to be expected after frequent exposure to microorganisms in the range of concentration of 10^9–10^10 CFU m^-3 air. 1 These concentrations are similar to those measured 200 m from the site in this study (table 2). Furthermore, due to the meteoro logical and topographical conditions, this exposure is likely to have existed frequently.

Irritative airway complaints (increased frequency of coughing, shortness of breath, and self diagnosed bronchitis) have already been reported in health studies concerning exposure to microorganisms: At workplaces with handling of garbage and compost, increased frequencies of airway related mucous membrane irritation, coughing, and tracheobronchitis, among others, have been reported 15 16; similarly, airway symptoms have been reported in residents of mouldy or damp homes. 17 19

The health complaints found here in association with airborne microorganisms in residential air (200 m from the site), dropping sharply within 300 m and reaching near background concentrations at 550 m. 16

It could be shown that perceived odour annoyance, considered to be a strong bias on self reported complaints, had no influence on these irritative airway complaints (table 5). Odour annoyance was only associated with general complaints. This could have been expected on the basis of previous reports. 16 20 Comparable results were found when studying odour annoyed (90%) neighbours of another composting site. Rates of health complaints showed no association (versus
might have been anticipated, as on the one hand diagnosing
airway irritation related to environmental exposure is not
common by general physicians. On the other hand, higher
rates of diseases with clear laboratory findings or organ
impairment could not have been expected. Nevertheless, sev-
ceral considerations should be made when considering their
relevance as far as public health is concerned. For airway
inflammation related to bioaerosol exposure, a toxic or
non-specific genesis is hypothesised. It can be accompanied
by an increase in bronchial reactivity as a sign of an inflamma-
tory process as well as possibly being the onset of chronic
bronchitis. 2,7 An effect of the bioaerosol concentration in the
residential air with regard to excessive tiredness and shivering
(table 5) was also detected in the present study. At workplaces
with garbage or compost handling, and in homes containing
mould, single general complaints of general disturbances,
for example, toxic pneumonitis, including shivering and tired-
ess, are often observed.10

This study forms the basis for further studies using more
sophisticated designs (for example, prospective panel study)
to study the clinical relevance of these irritative airway symp-
toms. Clinical parameters, for example, lung function exami-
nations could be included, particularly since connections have
been found in the workplace between symptoms of airway
inflammation and changes in lung function.2 Risk groups for
airway effects (for example, children) could be particularly
looked at. Due to the small sample of children this was not
possible in the present study.

Furthermore, mucous membrane lavage could be carried
out to document inflammatory changes and evidence of spe-
cific antibodies in the sense of exposure manifestation.2 11
As the amount of time spent outdoors in the residential area
is relatively small, and therefore exposure to outdoor air only
represents a small part of the day, the possible accumulation in
interior rooms of airborne microorganisms from emission
sources should be measured in the future.

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