Bioaerosols Associated with Biomass to Energy - Worker Exposure and Health Hazards

26th April 2017

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What this talk will cover

- Bioaerosols and bioaerosol exposure;
- Bioaerosols in the context of waste and recycling;
- Results from HSL projects relevant to biomass to energy;
- Practical implications – how can we reduce the exposure of our workforce to dust and bioaerosols?
Sources of bioaerosols

• Bioaerosols always naturally present from various sources – dust, water, vegetation, animals;

• Range in numbers and predominant species – seasonal, geographic, local sources;

• Further influenced by human activities – agriculture, construction, vehicles.
Bioaerosols in the context of waste & recycling

• Waste & recycling – economic, conservation and legal drivers;

• Some areas of work automated, but some manual input;

• Waste & recycling involving organic materials – energy input to processes will generate dust and bioaerosols.
The current challenge in biomass to energy industry

• Adoption of ‘new’ processes after years of coal only;

• Not only dust but also biological component – requiring new risk assessment approach;

• Rohr et al (2015) identified that “potential occupational health impacts of biomass combustion in power generation remain poorly defined”.

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Why are bioaerosols a problem in biomass waste to energy?

• Biomass can provide nutritional and physical requirements for microbial growth;
• Fungi and bacteria naturally present → food – water – temperature → → multiplication;
• Movement of biomass generates bioaerosols.
Why are we concerned about bioaerosols and health?

- No occupational exposure limits;
- Limited dose-response data;
- **But** - evidence as potential respiratory hazard
- Implication – under COSHH control to ALARP
Waste & recycling bioaerosols and health – *Aspergillus fumigatus* and endotoxin

- Workers’ exposure to bioaerosols;
- Dispersion → neighbours (other workplaces, passers by, residents).

**Why are we concerned about *Aspergillus fumigatus*?**
- Prolific spore producer;
- Spores are respirable;
- Allergen, opportunistic pathogen.

**Why are we concerned about endotoxin?**
- Gram –ve bacterial cell wall;
- Immunotoxic;
- Cause inhalation fever.
Danish biofuel plant study (Madsen, 2006)

Workers’ personal exposure to inhalable airborne fungi, bacteria, endotoxin at five biofuel plants
Danish biofuel plant study (Madsen, 2006)

Workers’ personal exposure to inhalable airborne fungi, bacteria, endotoxin at five biofuel plants:

- Total bacteria - median = $4.8 \times 10^5$ cells/m$^3$;
- Total fungi - median = $2.1 \times 10^5$ spores/m$^3$;
- Endotoxin - median = 55 EU/m$^3$;
- Exposure levels differed between the plants, attributed to different process equipment, tasks and the biofuel handled.
- For example, endotoxin higher concentrations at straw plants than at wood-chip plants, while the fungus *Aspergillus fumigatus* greatest concentration at wood-chip plants;
- Also endotoxin found to be in significant concentrations in all size dust fractions (Madsen and Nielsen, 2010).
Indirect microbiological hazards from stored wood

• Microbiological activity in stored wood releasing volatile chemicals, carbon dioxide;

• Oxygen depletion in confined spaces and asphyxiations hazard.
HSL study data (Simpson et al 2016)

• Small scale storage of wood pellets and chips for community/domestic use (6 sites) and 1 pellet warehouse;

• Wood chips more microbiologically contaminated than pellets;

• Combination of chemical decomposition and microbial activity could create oxygen depleted atmospheres in confined spaces.
Other HSL study data (unpublished)

- Palm kernel and olive pulp imported into UK and used either for animal feed or biomass for co-firing with coal;
- Very susceptible to microbial colonisation;
- Evidence of visible microbial growth and clumping of material in automated feed;
- *Aspergillus* and actinomycetes isolated.
Dust and bioaerosol measurement in biomass to energy – the value of monitoring

• Personal sampling – health relevant exposure measurement in breathing zone;
• Fixed point – general overview of emissions, identification of source;
• Simple culture-based analysis with enumeration and characterisation;
• Data to support risk assessment.
Read-across data - Materials Recycling Facilities (MRF)

- Materials reception;
- Some automatic sorting......

HSL: HSE’s Health and Safety Laboratory
Materials Recycling Facilities (MRF)

• .....But a lot of manual sorting;

• Some LEV but not always.
HSL study in MRFs – what we did

- Occupational hygiene surveys at seven MRFs. Each visit aimed to measure task-related exposures to dust and bioaerosols at all stages of the recycling process mainly by personal monitoring;

- In addition, exposure control strategies assessed including management systems (COSHH assessments, operator training etc.), engineering controls and the PPE regime.
Workers’ potential microbial exposure

- Exposure to inhalable bacteria up to $10^5$ cfu/m$^3$ and 73% samples greater than $10^4$;
- Exposure to inhalable fungi up to $10^5$ and 81% samples greater than $10^4$;
- Exposure to *Aspergillus fumigatus* up to $10^5$. 12% samples greater than $10^4$ and further 14% greater than $10^3$;
- Endotoxin up to 2399 EU/m$^3$; 34% above proposed limit of 90 EU/m$^3$ mostly associated with high energy sorting machinery.
### Table 3: Typical power plant tasks and exposures.

<table>
<thead>
<tr>
<th>Job Type</th>
<th>Tasks</th>
<th>Potential Exposures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucker</td>
<td>Transport of biomass to site (road/rail)</td>
<td>Biomass dust and bioaerosols generated during biomass loading and discharge</td>
</tr>
<tr>
<td></td>
<td>Loading and discharge of material</td>
<td>Ash dust generated during loading and discharge</td>
</tr>
<tr>
<td></td>
<td>Transport of ash</td>
<td>Diesel exhaust from vehicles</td>
</tr>
<tr>
<td>Fuel Handling Plant operative</td>
<td>Transport of biomass through the site Storage of biomass Fuel preparation (milling etc.)</td>
<td>Biomass dust and bioaerosols generated during biomass handling and milling Off-gases from storage Direct contact with moldy biomass</td>
</tr>
<tr>
<td>Cleaner</td>
<td>Removal of dust deposits from plant</td>
<td>Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Potential for direct contact with moldy biomass</td>
</tr>
<tr>
<td>Maintenance engineer</td>
<td>Maintenance of plant equipment during normal operation</td>
<td>Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Potential for exposure to combustion gases</td>
</tr>
<tr>
<td>Outage contractor</td>
<td>Repair of plant items during shutdown periods (particularly within the boiler)</td>
<td>Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Direct contact with ash deposits within the boiler (often confined spaces)</td>
</tr>
<tr>
<td>Ash handling plant operative</td>
<td>Removal of ash from the boiler Transport to storage</td>
<td>Direct contact with ash</td>
</tr>
<tr>
<td>Other plant personnel</td>
<td>Various</td>
<td>Fugitive dusts from fuel and ash handling plants Combustion gases</td>
</tr>
</tbody>
</table>

Protection afforded by vehicle cabs

- Measured bioaerosols inside and outside cabs;
- Bioaerosol levels reduced inside cabs – variable but with a median value of a four-fold reduction;
- Suggests need for further examination;
- If used as control = LEV - importance of proper fitting, use & maintenance of air filters.
## Dust from cleaning & maintenance

- More read-across data from HSL studies of dust exposure;
- Cleaner; maintenance engineer; outage contractor (Rohr et al, 2015);
- Think about cleaning & maintenance practices!

<table>
<thead>
<tr>
<th>Activity</th>
<th>Number of reports</th>
<th>Number of data points</th>
<th>Median exposure $\text{mg/m}^3$</th>
<th>Average (arithmetic mean) exposure $\text{mg/m}^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressed air blowing</td>
<td>12</td>
<td>38</td>
<td>26.4</td>
<td>58</td>
</tr>
<tr>
<td>Dry sweeping</td>
<td>20</td>
<td>30</td>
<td>12.8</td>
<td>27.2</td>
</tr>
<tr>
<td>Vacuum cleaning</td>
<td>12</td>
<td>15</td>
<td>3.8</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Case study - brickmaking

- Respiratory Crystalline Silica exposure 0.83 mg/m³ (70 minutes) - enough to exceed 8 hour TWA WEL
- Cleaning contributed 45% of daily dose – no RPE!
Case study – waste and recycling

Inhalable Dust Assessment – materials recycling facility

<table>
<thead>
<tr>
<th></th>
<th>Number of measurements</th>
<th>Number &gt; 10 mg/m³</th>
<th>Mean Exposure (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSE 2010</td>
<td>17</td>
<td>5</td>
<td>7.1</td>
</tr>
<tr>
<td>Company 2011</td>
<td>6</td>
<td>0</td>
<td>1.2</td>
</tr>
<tr>
<td>HSE 2014</td>
<td>15</td>
<td>6</td>
<td>13.2</td>
</tr>
</tbody>
</table>

- Company assessment under-estimated risk because didn’t include end of shift clean down
- Task specific dust exposures at other plants > 100 mg/m³ during cleaning
Bioaerosol exposure for different shifts

- HSL currently completing exposure study of workers in biomass handling – municipal waste transfer stations, mechanical-biological treatment plant materials handling areas;
- At one, compared day shift routine work with night shift cleaning and maintenance;
- Daytime : endotoxin from 127 - 210 EU/m$^3$; bacteria 4.0 x 10$^3$ – 4.4 x 10$^4$ cfu/m$^3$; fungi 8.0 x 10$^4$ – 1.0 x 10$^5$ cfu/m$^3$;
- Night-time : endotoxin from 117 - 1040!! EU/m$^3$; bacteria 2.6 x 10$^4$ – 3.6 x 10$^5$ cfu/m$^3$; fungi 1.1 x 10$^5$ – 4.0 x 10$^5$ cfu/m$^3$. 
Effective LEV for dust & bioaerosol removal

• Microbiological activity in stored wood releasing bioaerosols, volatile chemicals, carbon dioxide;

• Oxygen depletion in confined spaces and asphyxiation hazard.
Making better use of LEV

Smoke is an excellent way of visualising complex and turbulent airflow patterns whether in an open or enclosed space.
Use of smoke machines

Review of smoke machines:

www.hse.gov.uk

or Search fog machines on the internet
Summary

• Bioaerosol emissions associated with bulk biomass to energy - need more data;

• Some read-across from previous exposure assessment to dust and bioaerosols in waste and recycling;

• Assess controls in place and what can be done to mitigate exposure;

• Don’t forget to assess maintenance work;

• WISH Forum Bioaerosols Group – simple generic guidance being drafted.
Any questions?

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