FINAL REPORT

Occupational Risk Assessment of Workers in Composting Facilities in British Columbia

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Executive Summary

The purpose of this risk assessment is threefold: (1) to identify hazards (and dose-response levels, if possible) from working in publicly- and privately-owned composting facilities in British Columbia (BC); (2) to identify potential short- and long-term health issues for workers at these composting facilities; (3) to identify health and safety measures that may be taken to minimize the effects of identified hazards. This risk assessment is being conducted at the request of CUPE BC to assess these issues. Workers, in composting and parallel industries like agriculture, may experience health concerns, some of who may file claims with workers' compensation boards.

The main research methods employed for this report were document review of peer-reviewed and grey literature, key informant interviews, and a site visit of a municipal composting facility.

There are 46 composting facilities in British Columbia that are both publicly- and privately-owned and operated. Composting facilities recycle a variety of raw waste material. Organic matter waste forms include biosolids (e.g., wastewater and septic tank sludge), fish and food waste, plant matter, wood residuals and yard waste, among others (Forgie, Sasser & Neger, 2004). Most facilities in British Columbia compost organic matter composed of non-biosolids. Exposure levels to airborne hazards vary between indoor and outdoor composting facilities, composting methods, and climates. The two most commonly used composing methods in BC are windrow and static aerated piles. Windrows are elongated, relatively narrow, low piles with a large exposed surface area ideal for passive aeration and drying. They are usually outdoors and front-end loaders are used to turn the piles. Static aerated piles are often used for biosolids or wet feedstock. The compost piles are placed overtop of perforated pipes. Instead of turning methods to introduce oxygen, fans or blowers are used to pump air in

and out of the piles. The organic material produced is rich in nutrients and sold for commercial and public purchase.

Our research identified numerous potential hazards for workers at composting facilities. These hazards include pesticides/herbicides, thermophilic bacteria, endotoxins, beta d-glucan, *aspergillus fumigatus*, and methane. Workers may be exposed to these hazards through a variety of tasks performed in routine work practices, such as the grinding, blending, mixing, sieving, and storing of feedstock. Constructing, agitating, and turning windrows also create exposures to bioaerosols. Workers in confined spaces (e.g., indoor composting facilities) and those working outside the cabs of equipment are at higher risk of exposure to hazards. The aforementioned hazards have the potential to cause short- and long-term health issues for workers at composting facilities. Health conditions vary depending on the hazard to which workers are exposed. The main health risks are various respiratory illnesses which may be acute or chronic; health effects also vary based on the immune system of the worker.

Fortunately, there are many preventive measures that can be taken to minimize exposure to composting biohazards. Our recommendations include various hazard control measures, policy changes, and further research. Hazard control measures include engineering controls, such as the use of enclosed cabs on equipment (e.g., front-end loaders), and the installation of filtration, ventilation, and air conditioning units on cabbed equipment. We also recommend the use of appropriate filtration and ventilation systems in indoor composting facilities. Maintaining windrow moisture content at 50-60%, using sprinkler systems in dry climates, and keeping surfaces in indoor facilities wet to reduce bioaerosol levels, are also recommended.

Other hazard control measures include administrative controls like the education of workers on potential health risks as well as how to control dust and bioaerosol levels.

Scheduling worker rotations and hygienic procedures (e.g., hand washing) are also recommended as administrative controls. The use of personal protective equipment, like masks, for tasks with high risk of airborne hazard exposure (e.g., mixing, blending, working outside equipment's cabs) is also recommended. We further recommend that many of these hazard control measures should be mandatory with appropriate policy changes across all composting facilities in BC and ideally, all of Canada. Finally, we recommend continued research specific to the hazards associated with composting facilities, such as the dose-response relationships between bioaerosol exposures and health risks, and the use of hazard controls by workers.

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1.0 Purpose and Overview of this Risk Assessment

The purpose of this risk assessment is threefold: (1) to identify hazards (and dose-response levels, if possible) to workers in publicly- and privately-owned composting facilities in British Columbia (BC); (2) to identify potential short- and long-term health issues for workers at these composting facilities, and; (3) to identify health and safety measures that may be taken to minimize the effects of identified hazards.

Workers, in composting and parallel industries like agriculture, may experience health concerns, some of who may file claims with workers' compensation boards. This risk assessment is being conducted at the request of the Canadian Union of Public Employees' (CUPE) BC regional office to assess these issues.[1]

This risk assessment is consistent with The Canadian Centre for Occupational Health and Safety (CCOHS)(2006) definition, for it describes a process where hazards are identified, the risk associated with the hazard is analyzed or evaluated, and appropriate ways to eliminate or control the hazard are determined. Risk assessments tend to be conducted on individual facilities with the goal being the creation of a safer and healthier workplace (CCOHS, 2006). Since our risk assessment is a broad overview of all municipal composting facilities in British Columbia and uses secondary data analysis, caution with respect to the application of these findings to specific composing facilities is prudent. Accordingly, we recommend the use of this report to *inform* future risk assessments of individual or multiple composting facilities that use the collection of original (location specific) data.

In the remainder of this report, we will:

[1] The authors of this report are not receiving any remuneration from CUPE, nor does CUPE have a say in the evaluation of this report, so the authors do not foresee any possible conflicts of interest.

- Discuss the research methods employed (i.e., document review of peer-reviewed and grey literature, key informant interviews and a site visit of a municipal composting facility);
- Provide background information on the composting industry, such as its extent in BC and Canada, types of composting facilities (e.g., indoor, outdoor), the most common methods of composting (windrow and static aerated piles), and composting regulations in Canada;
- Define the main hazards reviewed (pesticides/herbicides, thermophilic bacteria, endotoxins, beta d-glucan, *aspergillus fumigatus*, and methane), and for each hazard, we will provide an explanation of how exposure is possible, possible health effects of exposure, and information on dose-response levels, if available;
- Identify preventive measures which may be taken to reduce exposure to biohazards;
- Discuss the strengths and limitations of this risk assessment, and finally;
- Provide recommendations on how to reduce exposure to hazards in the composting industry, as well as outline policy and regulatory measures, and further research that should be undertaken.

2.0 Methods

The main research methods employed for this report were document review of peer-reviewed and grey literature, key informant interviews, and a site visit of a municipal composting facility. The collection of original (new) data is beyond the scope of this risk assessment.

Special effort was made to review Canadian and British Columbian documents and websites by regulatory and advisory bodies. Documents from international sources were also sought. *Key* search terms included "municipal composting," "worker safety," "health effects," "dose response," "pesticides," "herbicides," "*aspergillus fumigatus*," "endotoxins," "methane," "beta D-glucan" and "thermophilic bacteria."

We conducted a semi-structured, key informant interview with Dr. Karen Bartlett, a professor of environmental and occupational hygiene at the University of British Columbia. Dr. Bartlett has expertise in the health effects of municipal composting on workers in British Columbia (Bartlett, et al., 2009).

We also conducted a semi-structured interview with four staff members of the City of Vancouver's landfill site in Delta, British Columbia. These staff members included Lynn Belanger, manager; Dave Robertson, superintendent; Nicole Steglich, project engineer; and George Twarog, environmental technician.

The five researchers also conducted a site visit of the composting facility at the aforementioned landfill with Mr. George Twarog, the site's environmental technician. For more information of the site, visit: http://vancouver.ca/files/cov/2011-vancouver-landfill-annual-report.pdf .

3.0 Background

Municipal composting is increasingly used throughout the world as it reduces the amount of organic waste being disposed of in landfills or incinerated. Composting has wide public support; however, over the last twenty years concerns have been raised over the occupational health and safety in industries where workers may be exposed to airborne biohazards (i.e., microscopic particulate of biologic origin) (Bartlett, Atwater & Chow, 2009).

3.1 *Extent of Composting in British Columbia*

In 1998, the Compost Council of Canada (CCC) identified 344 centralized composting facilities in Canada – 92 additional facilities than two years prior (2010). At that time, British Columbia had 46 centralized composting facilities, both publicly and privately operated facilities. In 1998, composting facilities in Canada processed a combined 1,650,000 metric tons of organic material (CCC, 2010). The composting industry generates a profit from the recycled organic matter that they produce, which is sold as fertilizer products to landscape companies and farmers, as well as directly to the general public.

3.2 *Types of Compost Materials, Tasks and Methods*

Composting facilities recycle a variety of raw waste material otherwise known as feedstock. Organic matter waste forms include biosolids (e.g., wastewater and septic tank sludge), fish and food waste, plant matter, wood residuals, and yard waste among others (Forgie, Sasser & Neger, 2004). Most facilities in British Columbia compost organic matter composed of non-biosolids; however, each facility has permits that regulate the type of raw material they are able to compost.

There are several types of composting methods, but the most commonly employed in BC are windrow piles and static aerated piles (CCC, 2010). Windrows are elongated, relatively narrow, low compost piles with a large exposed surface area ideal for passive aeration and drying. Open windrow piles are turned over a 15-day period or longer at 55 degrees Celsius to break down organic matter (Forgie et al., 2004). They may be turned by either high-technology equipment (i.e., a straddle turner) or by more economical low-technology equipment (i.e., front-end loader) (Bartlett et al., 2009). Job tasks included in this method are blending (i.e., biosolid slurry is mixed with wood chips) and grinding the feedstock material, building windrow piles, turning piles, moving the pile after the

thermophilic phase, and screening the final product (Bartlett et al., 2009). Workers may perform several of these tasks throughout the day, or be in close proximity to areas where these tasks are being carried out.

Static aerated piles, on the other hand, are not turned with any device to introduce oxygen to the pile (Forgie, et al., 2004). Instead, these piles are placed overtop of perforated pipes, and fans or blowers are used to pump air in and out of the piles. Static aerated piles are often used for biosolids or wet feedstock.

There are different composting processes/tasks, and each one may affect worker exposure to biohazards to varying degrees. The methods and technology employed for windrow and aerated static piles are not standardized in the province.

3.3 *Composting Regulations in British Columbia*

Composting and composting facilities are regulated by legislation under the British Columbia Waste Management Act (1986). In 2002, The Ministry of Land, Water and Air Protection in BC created the *Organic Matter Recycling Regulation* (OMRR). This regulation governs the construction and operation of composting facilities in BC and was intended to provide guidance to protect soil and water quality, and to beneficially use organic material (Ministry of Environment, 2012,). However, if private, non-municipal facilities do not sell their products to the public, they do not have to comply with these regulations (Bartlett, personal communication, October 16, 2012). OMRR abides by the Workers Compensation Board (WCB) guidelines on worker physical safety, as well as safety from microorganisms which may cause ill health in sensitive workers (Forgie, et al., 2004). It is unclear however, what, if any, guidelines WCB provides *specifically* with respect to composting facilities, let alone microorganisms and human health. We searched WCB's website ("health and safety by topic"), but it did not produce significant findings related to composting or other related industries like agriculture. Regions can chose to adopt additional bylaws to supplement BC's OMRR legislation.

Our key informant interviews reaffirmed the lack of regulations and policy for protective measures of workers at composting sites beyond safety vests and steel-toed work boots. It is left to the discretion of the worker to use additional protective equipment such as safety glasses, hearing protection, and respiratory masks (Belanger, et al., personal communication, November 7, 2012). While the use of respiratory equipment is not a formal requirement for staff to wear in the composting industry, some jurisdictions require the use of half-mask respirators for all staff inside transfer stations (indoor facilities) due to high levels of bioaerosols in the air (Belanger, et al., personal communication, November 7, 2012).

3.4 *Types of Composting Biohazards*

Bioaerosols are defined as "airborne particles, large molecules, and volatile compounds that are living or were released from a living organism" (Environmental Agency, UK, 2009, p.1). Organic matter composting facilities are primarily concerned with endotoxins, *Aspergillus fumigatus* (fungus) and Thermophilic actinomycetes (biologic dust) (Bartlett et al., 2009; Prasad et al., 2004; Environmental Agency, UK, 2007). The composting tasks/methods mentioned above produce (aerosolized) particulate matter that contained Gram negative bacterial components (endotoxins), fungal spores (1-3) β D glucan), *Aspergillus fumigatus* (fungal) and Thermoactinomycetes (bacterial) spores.

(See section 4.0-9.0 for further details on hazards, health effects and dose response)

3.5 Exposures: Factors Affecting Levels of Airborne Hazards

As organic material breaks down during composting using open windrow or static aerated piles, bioaerosols are released into the air. There are a number of factors which may affect the concentration of airborne hazards during the composting process, such as the climate in which the composting site is located, the type of material being composted, and the type of equipment being used in the composting process (Bartlett, et al., 2009). Bartlett et al. (2009) found that a compost facility located in a desert climate in the interior of British Columbia had the highest concentration of dust and endotoxins. Exposures are also greater during warm weather (spring and summer seasons) because wet weather reduces the risk of hazards becoming airborne.

Biohazards and their respective levels may be affected by the composting tasks and methods employed. Blending was associated with the highest geometric mean concentration of *Aspergillus fumigatus* in Bartlett and her colleagues' research (2009). The highest geometric concentration of thermoactinomycetes was associated with grinding feedstock. They also found that windrow piles which composted only biosolid feedstock had the highest endotoxin exposure as well as the highest exposure to dust, endotoxins, and glucan compared to static aerated piles.

3.6 *Potential Health Effects Related to Composting*

The major concerns related to health in the composting industry are both short and long-term respiratory related illnesses. Bioaerosols have been determined to impact human health and they are the major agents most commonly detected at composting facilities. The most damaging biohazards to human health are *Aspergillus fumigatus* (fungus and bacteria) and thermophilic actinomycetes (biologic dust). (Environmental Agency, UK, 2007; Recycling and Organics Unity, 2003). Bioaerosols vary significantly in size ranging from 0.02 to 100 μm in diameter (Environmental Agency, United Kingdom, 2009). Microorganism particles within bioaerosols disperse and settle within the human body; the extent to which they disperse and settle is dependent on the physical size of the particle. Particles less than 6 μm can settle in the lungs and reach alveoli as well as bronchi, which cause irritation and possible negative health outcomes (Environmental Agency, United Kingdom, 2007).

3.7 *Dose-Response Relationships*

The health effects of bioaerosols are dependent upon the type of bioaerosol, the host, as well as the dose level (Composting Association of Ireland, 2004). This means that workers may experience variations in health effects at different dose exposure levels (e.g., low dose exposure to one individual can create a response that will not occur, or differ in another individual exposed to the same dose level). Dose-response is extremely difficult to measure and the literature in this area is inconsistent and sparse (Douwes, Thorne, Pearce, Heedrik, 2003; Skyes et al, 2009). Exposure assessment at composting sites is relatively common, but testing methods are unstandardized and threshold values in the literature are inconsistent (Douwes et al, 2003; Environmental Agency UK, 2009).

4.0 Pesticides and Herbicides

4.1 *Definition*

In order to ensure the healthy development of desired plants, pesticides and herbicides can be used to kill unwanted pests or weeds. It is predicted that these substances remain in the biological waste matter when it enters a composting facility for processing due to the fact no bylaw restricts the use of these chemicals on private lands and homeowner property in BC (International EcoGen Inc., 2010).

4.2 *Exposures*

Herbicide and pesticide exposure is associated with activities at composting facilities that result in the distribution of the organic matter being composted into the air, such as working outside the cab, using a front-end loader, pile construction, and screening (whenever piles are disturbed) (Bartlett et al., 2009; Prasad et al., 2004; Sykes et al., 2004). Exposure can also occur in a situation where the organic compost matter comes in direct contact with a worker's skin or eyes (Recycled Organics Unit, 2003).

4.3 *Health Effects*

Pesticides and herbicides exposures have been shown to be linked to both carcinogenic and non-carcinogenic health effects. In a study conducted by Ji et al. in 2001, pancreatic cancer rates significantly increased as the rate of exposures to pesticides grew. Although this study could not illustrate a casual relationship between the exposure and the disease, the trend was strong enough for authors to urge for continuing research in this area. Non-carcinogenic health effects include damage to eyesight and in some cases permanent impairment of vision, skin irritation, and anemia (Cox, 1998). Some studies also demonstrated a possible link between Parkinson's disease and pesticide exposures, although more research is required in this area (Berry, LaVecchia & Nicotera, 2010). Animal studies focused on the health outcomes of herbicide exposure also produced results linking exposure to negative liver, blood, and body weight effects (Cox, 1998).

4.4 *Dose-Response Relationship*

There is not enough conclusive research in this area to determine a dose-response relationship. Future studies should be conducted in order to generate conclusions in this area.

5.0 Thermophilic Bacteria

5.1 *Definition*

Thermophilic bacteria are present in composting sites. The most common thermophilic bacteria are from the phyla *Actinomycetes*, and more specifically the genera *Thermoactinomycete* and *Saccharopolyspora* (formerly known as *Micropolyspora*).

5.2 *Exposures*

The average temperatures of compost sites provide ideal conditions for *Actinomycetes* to thrive, for they grow well in warm humid compost sites at temperatures between 30-60 degrees Celsius (Sykes et al., 2007). A study in Korea, identifying thermophilic species distributions in composting sites, found that *Actinomycetes* made up 14.6% of all microbial species, demonstrating relatively high emissions levels of thermophilic bacteria (Byeon et al., 2009).

Exposure levels of *Actinomycetes* also vary throughout the composting process. Levels of this pathogen rise during the processes that require high temperatures (Deportes et al., 1995). Thermophilic bacteria emissions are highest during the reception and fermentation stages. Studies have shown that levels of thermophilic bacteria tend to also vary by season – in reception it was higher during the summer, while during fermentation it was higher during the winter (Deportes et al., 1995).

5.3 Health Effects

Thermophilic bacteria can cause workers exposed to these bacteria to suffer health consequences. The health outcomes of exposure to these bacteria are predominantly related to respiratory illnesses. Thermophilic bacteria are known to be allergens that cause irritations to the lungs; however, there is currently limited knowledge on the dose-response association between thermophilic bacteria and lung diseases. *Actinomycetes* are able to enter the lungs and deposit themselves into the alveolar region due to their small diameters (<1.5 p m) (Rautiala et al., 2003). *Saccharopolyspora rectivirgula* and *Thermoactinomycetes vulgaris* have been identified as causing the allergens responsible for farmer's lung (Pepys et al., 1990). Farmer's lung is a type of hypersensitivity pneumonitis, which is an inflammation of the alveoli in the lungs.

Identifying the true effect of thermophilic bacteria on composting site workers would require further studies establishing a precise dose-response effect of *Actinomycetes* amongst compost workers. Average emission levels of these bacteria in composting sites will likely vary depending on the local climate, as well as the type of compost processed at that site. Long-term health consequences of exposure to this pathogen have not yet been established.

5.4 *Dose-Response Relationship*

It is known that there is a direct relationship between exposure to *Thermoactinomycetes* and risk of hypersensitivity pneumonitis; however, there is insufficient data to establish the exact dose-response relationship. A number of studies estimate that a sudden exposure of between 10^6 cfu/m^3 and 10^8 cfu/m^3 can initiate an allergic reaction or other related respiratory illnesses in workers of compost sites (Desportes et al., 1996; Lavoie and Allie 1997).

6.0 Endotoxins

6.1 *Definition*

Endotoxins are the cell wall constituents of gram-negative bacteria (Bartlett et al., 2009). They are composed of lipopolysaccharides, proteins and lipids, with lipopolysaccharides being most responsible for their biological properties (Prasad et al., 2004). Endotoxins are found airborne among dust particles, and as parts of bacteria they are prevalent in the presence of organic matter (Bartlett et al., 2009).

6.2 *Exposures*

Similar to other bioaerosols, higher levels of endotoxins are associated with activities at composting facilities that disturb the organic matter being composted. Any activities involving the movement of waste, such as agitation of the compost piles, pile construction, screening, as well as the use of high energy windrow turners, result in increased levels of endotoxins in the air (Bartlett et al., 2009; Prasad et al., 2004; Sykes et al., 2004). Dry conditions, such as spring and summer climates, as well as inadequate moisture in facilities, are also associated with significantly higher concentrations of endotoxins in the air (Bartlett et al., 2009; Epstein et al., 2001). Working conditions, specifically working outside a cab or with open windows/doors inside cabs, result in significantly higher personal exposure to endotoxins (Bartlett et al., 2009; Epstein et al., 2001). Sykes et al. (2010) found minimal differences between the personal exposure of working outdoors and working indoors in a ventilated, filtered air cab.

6.3 *Health Effects*

Adverse health effects from exposure to endotoxins have been documented in many occupational settings. Michel *et al.* (1997), exposed normal subjects to high doses of endotoxins (similar to those in occupational settings), and observed acute symptoms including fever and dyspnea. Endotoxin exposure in occupational settings, including composting facilities, has been associated with symptoms such as cough, mucous membrane irritation, fever, malaise, dyspnea, wheezing, headaches, chest tightness, airway inflammation, airway flow restriction, and nose and throat irritations (Douwes and Heederik, 1997; Health Council of Netherlands, 2010; Heederik et al., 1991; Prasad et al., 2004). The production of inflammatory markers (cytokines) after inhalation of endotoxins causes the non-allergic respiratory effects in those affected (Douwes et al, 2000; Health Council of Netherlands, 2010).

Long-term exposure to endotoxins has been associated with non-atopic chronic obstructive pulmonary disease in the farming and animal feed industries (Schwartz et al., 1995; Smid et al., 1992); flu-like respiratory illness (Prasad et al., 2004); and, symptoms of chronic bronchitis, asthma, and reduced lung function, resulting from chronic inflammation (Health Council of Netherlands, 2010). Endotoxin exposure has also been linked to increased severity of asthma and prevalence of asthma in those chronically exposed (Michel et al., 1996; Prasad et al., 2004; Thorne et al., 2005).

6.4 *Dose-Response Relationship*

Dose-response relationships between endotoxins and adverse health effects have not been adequately studied. Some reasons for this are the inconsistent measuring methods for endotoxin exposure and the difficulty of conducting animal studies on effects of endotoxins which are generalizable to humans (Health Council of Netherlands, 2010). There have been small studies documenting dose related increases in health effects associated with endotoxins in normal (non-occupational) participants (Michel et al., 1997). Lower doses of 0.5 μg (500ng) and 5 μg (5000ng) of lipopolysaccharide (LPS- pure endotoxin) resulted in no clinical symptoms, but neutrophils and C-reactive protein concentrations increased, of which the later has been associated with the risk of developing lung disease in those chronically exposed (Michel et al., 1997). Five μg LPS was the threshold value for an acute significant risk in blood C-reactive protein concentrations, while the threshold value for no acute response in sputum inflammatory cells was <0.5 μg (Michel et al., 1997). The highest exposure (50 μg) was associated with acute clinical symptoms such as fever and dyspnea (Michel et al., 1997).

In a five year study on animal feed workers, Post *et al.* (1998) found a dose-response relationship between endotoxin exposure (measured as dust exposure) and FEV1 decline to be – for every increase in ng/m^3 ($10EU/m^3$) resulted in a decline of 0.33 ±0.14 ml (in FEV1). Kennedy *et al.* (1987) looked at a purer sample of endotoxins in dust and also observed a decrease (-0.052ml) in FEV1 among cotton workers.

Based on existing data, the Health Council of the Netherlands has established health-based recommendations for limits of occupational exposure to airborne endotoxins (Health Council of Netherlands, 2010). They suggest that the maximum personal inhalable endotoxin exposure should be 90 EU/m^3 measured as an eight hour time-weighted average (Health Council of Netherlands, 2010).

7.0 Beta D-glucan

7.1 *Definition*

Beta glucans are glucose monomers which link in glycosidic bonds to form polysaccharides found in the cellulose of plants, the bran of grains, cell wall of yeast, and certain fungi, mushrooms, and bacteria (Akremiene et al., 2007). They are recognized by the innate immune system, and can help initiate an immune response within the body to invading pathogens (Akremiene et al., 2007).

7.2 *Exposures*

As with other bioaerosols discussed in this report, beta glucan exposure is associated with activities at composting facilities that result in the distribution of the organic matter being composted into the air, such as being outside the cab, using a front-end loader, pile construction, and screening (Bartlett et al., 2009; Prasad et al., 2004; Sykes et al., 2004).

7.3 *Health Effects*

Although glucans can strengthen the response of the immune system to pathogens, these interactions can also damage the ability of the body to control these processes (Akremiene et al., 2007). Beta D-glucans can damage the normal reactions of the lung to other agents such as endotoxins and antigens, leading to inflammation resulting in mucous membrane irritation (MMI) and organic dust toxic syndrome (ODTS) (Recycled Organic Unit, 2003). MMI can develop after several weeks of low exposure to organic dust or bioaerosols, and consists of itching and watering of the eyes and nose, as well as throat irritation (Recycled Organics Unit, 2003). ODTS can occur after heavy exposure to organic dust, appearing as flu like symptoms, and including a wide range of diseases and/or allergic reactions (Recycled Organics Unit, 2003). When the allergic reaction occurs predominantly in the airways or breathing tubes, the result is asthma, where as when the reaction occurs in the alveoli and very small airways, the result is hypersensitivity pneumonitis (Recycled Organics Unit, 2003). Pneumonitis' symptoms include fevers, chills, cough, and shortness of breath which occur a short time after exposure, or a cough and shortness of breath which develop more gradually (Recylced Organics, Unit, 2003). Both MMI and ODTS often go unrecognized due to the fact only serious cases or clusters are brought to a physician's attention (Recycled Organic Unit, 2003).

7.4 *Dose Response*

Although there is no specific number set for beta D-glucan exposures, some literature provides the rates of different health issues between those exposed to beta glucans and a control group. In a study conducted by Adhikari et al. (2011), greenhouse workers exposed to beta glucan experienced significantly higher levels of wheezing, phlegm, hay fever, and cough compared to a control group. This data was collected using concentrations of inhalable (1→3)-β-D-glucan in three greenhouses ranging from 7.7 to 71.2 ng m^{-3} in winter and 16.9 to 26.4 ng m^{-3} in summer per shift (Adhikari et al., 2011). These numbers are much lower than the average personal exposure during a shift for a compost worker in BC, which has been recorded as high as 229 micrograms m^{-3} in research conducted by Bartlett, Atwater & Chow (2009).

8.0 *Aspergillus fumigatus*

8.1 *Definition*

Aspergillus fumigatus is an airborne saprophytic fungi which grows on, and is involved in, the processing of organic matter (Latge, 1999). It is one of the most widely found fungi in the world, and is associated with soils, crop plants, grasses, hay, compost, and wherever molds grown (Prasad et al., 2004), meaning most individuals are constantly exposed to its airborne conidia (Latge, 1999). The fungus releases its conidia through disturbances in the environment and strong air currents (Latge, 1999). Conditions with particularly high airborne levels are dry conditions where dust is maintained in the air, as *A. fumigatus* is found within dust (Prasad et al., 2004). Being able to live at temperatures greater than 45 degrees Celsius, *A. fumigatus* is a thermotolerant fungus with compost piles providing an ideal environment (Bartlett et al., 2009).

8.2 *Exposures*

Activities within composting facilities that are most responsible for the presence of *A. fumigatus* include: transportation; grinding, mixing, sieving, and storing feedstock; blending, turning and building the compost piles (Bartlett et al., 2009; Prasad et al., 2004). Prasad et al. (2004) showed that surface concentrations of *A. fumigatus* are highest in the least frequently turned windrows, while Bartlett et al. 2009 showed that blending the feedstock, and using front-end loaders, resulted in the highest exposure to *A. fumigatus.* It is also important to note that composting material that is too dry – often a result of insufficient moisture conditions in dry hot weather months – increases dust concentrations and consequently, *A. fumigatus* conidia concentrations (Prasad et al., 2004).

8.3 *Health Effects*

The conidia of *A. fumigatus* enter the body through inhalation into the respiratory tract and can potentially cause a number of respiratory symptoms. Most of the associated adverse health effects are observable only in immune-compromised individuals, with healthy individuals' respiratory immune system being able to clear the fungi conidia after they enter the body (Browne et al., 2001; Latge, 1999).

Adverse health effects caused by *A. fumigatus* are classified under the umbrella of Aspergillosis. Health effects that have been connected with immune-compotent individuals are chronic forms of pulmonary aspergillosis, although Millner *et al.* (1994) showed that aspergillosis is rare in these individuals including those in occupational settings who work with higher concentrations of the fungi (Latge, 1999), as well as allergic responses that appear as asthma and sinusitis (Latge, 1999).

In immune-compromised individuals, especially those with atopic asthma, cystic fibrosis, or those with preexisting cavities in their lungs (e.g. post-tuberculosis), exposure to *A. fumigatus* can result in conditions such as aspergilloma (when the fungi form a ball in the airways), allergic bronchopulmonary aspergillosis, and invasive aspergillosis (a rapidly progressive and often fatal disease) (Latge, 1999).

8.4 *Dose-Response Relationship*

Information specific to dose-response for *A. fumigatus* is sparse and tends to focus on cell culture studies or animal studies (not generalizable to humans) (Hebart et al. 2002; Simonen-Jokinen et al., 2005).

9.0 Methane

9.1 Definition

Methane is an odorless, colourless gas at room temperature and standard pressure. It becomes flammable when it has a concentration of 5 to 15% in the air. During composting, methane is produced by micro-organisms during anaerobic respiration (i.e., in situations with little to no oxygen). Methane's chemical formula is CH_4, and it is produced from the reaction between carbon dioxide and hydrogen, with water as a side product [$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$].

9.2 Exposures

During composting, methane is produced when there is not enough oxygen due to a lack of air circulation or if the compost material is not turned over often enough (United States Environmental Protection Agency, 1994). During composting, anaerobic conditions produce hydrogen sulfide and amines, which caused more odors to be released (United States Environmental Protection Agency, 1994).

Methane production can be reduced when the composting process is aerated frequently. This can be done by composting outdoors and by turning over the compost regularly. Anaerobic conditions not only increase potential hazards, but they also slow down the composting process, as aerobic conditions increase the speed of composting 10 to 20 times (United States Environmental Protection Agency, 1994).

9.3 Health Effects

At high levels, methane acts as an asphyxiant, causing difficulty in breathing, as oxygen is displaced (CCOHS, 2006). Harmful effects will occur if oxygen levels go below 18% (CCOHS, 2006), in which case it may cause drowsiness or narcosis (unconsciousness). Additionally, high levels of methane can be explosive (New South Wales Department of Environment and

Conservation, 2003). Presently there is little evidence that the oxygen levels in composting facilities actually reach those levels.

9.4 Dose-Response Relationship

Illness due to methane varies with the concentration of oxygen present in the air. Table 9.1 lists the health effects of oxygen deprivation depending on concentration (CCOHS, 2006):

Oxygen level	Health effects
12-16%	Lack of coordination, along with increased pulse rate
10-14%	Fatigue, exertion, and uneasy respiration
6-10%	Lack of consciousness, nausea, difficulty in movement, and possible collapse
<6%	Convulsions, panting, possibly death

Figure 9.1 Health Effects of Oxygen Deprivation

Methane and oxygen levels need to be monitored more frequently in order to assess the danger. High methane levels are more likely to affect indoor composting facilities, as there is less air circulation. In these situations, biofilters can be used to treat this gas (European Commission, 2007).

10.0 Conclusion

Composting is a rapidly growing industry in British Columbia, the rest of Canada and throughout the world. Formative preliminary work has been conducted in BC regarding composting workers' occupational health and safety (i.e., exposure to bioaerosols) (Bartlett, et al., 2009). This work is also being undertaken in many other jurisdictions including (but not limited to) the United Kingdom, Ireland, and Australia (Composting Association of Ireland, 2004; Environmental Agency, United Kingdom, 2009; Recycling and Organics Unit, [Australia], 2003). This report continues to highlight issues of concern for composting workers, as well as provides key recommendations to mitigate health risks.

In this risk assessment, we: (1) identified hazards (and dose-response levels, when possible) from working in publicly- and privately-owned composting facilities in British Columbia (BC); (2) identified potential short- and long-term health issues for workers at these composting facilities, and; (3) identified health and safety measures that may be taken to minimize the effects of identified hazards. This risk assessment was conducted at the request of CUPE BC because workers in composting, and parallel industries like agriculture may experience health concerns, some of who may file claims with workers' compensation boards. Most of the health effects to workers from composting biohazards are respiratory-related illnesses, which may affect workers to varying degrees depending on the worker's immune system, as well as the toxicity of the biohazards, etc.

Our main research methods were document review of peer-reviewed and grey literature, key informant interviews, and a site visit of a municipal composting facility.

11.0 Strengths and Limitations

Since our risk assessment is a broad overview of all municipal composting facilities in British Columbia, and uses mostly secondary data analysis, caution with respect to the application of findings to specific composing facilities is prudent. Accordingly, we recommend the use of this report to *inform* future risk assessments of individual or multiple composting facilities that use the collection of original (location specific) data.

Unfortunately, scientific research and government regulations have not kept up with increasing concerns over the range of hazards to which workers in the composting industry may be exposed. Our review of the literature noted (especially) a profound lack of information on dose-response relationships. Difficulties in conducting generalizable scientific research is compounded by the range of composting facilities (i.e., indoor and outdoor), methods (e.g., windrow and aerated static piles), tasks (e.g. blending, transferring), equipment (e.g., enclosed cabs), as well as the local climate – each one may affect the exposure of workers to biohazards to varying degrees. There is little standardization or regulation in the province, and facilities are both publicly- and privately-owned and operated.

The possible health effects and related concerns, from odours etc., that may permeate neigbourhoods, business districts and ecosystems close to composting facilities will also be an increasing cause for concern with the rapid growth of the composting industry, and require more scientific and regulatory action.

Fortunately, there are a number of preventive measures that workers and employers can undertake to reduce workers' exposure to these hazards, which we outline in the next section, "Recommendations." Moreover, if new composting facilities purchase modern equipment, worker's exposure to hazards will also be reduced, while simultaneously being able to compost more organic matter.

12.0 Recommendations and Preventative Measures

Our recommendations are based on current findings in the scientific and grey literature, key informant interviews, and a site visit of a municipal composting facility. Despite research about the hazards that workers may be exposed to in the composting industry, the findings pertaining to dose-response are limited. While no two composting workplaces will be the same, various worker tasks (e.g., mixing, blending) may heighten workers' exposure to hazards, and workers' health remains a concern in occupational settings where exposure to airborne hazardous material is present. Based on our findings, the research team has a number of recommendations for future work in this area.

12.1 *Hazard Control Measures*

Hazard control measures encompass four main types: engineering controls; administrative controls; personal protective equipment; and elimination/substitution (CCOHS, 2006). Although the elimination of hazards in the workplace is preferable, this is not possible with the hazards identified because they originate naturally from the composted material itself. Fortunately, exposure to hazards can be reduced/minimized.

Engineering controls are "involved in the design or modification of plants, equipment, ventilation systems, and processes that reduce the *source* of exposure" (CCOHS, 2006). We recommend the following engineering controls:

- The installation and use of enclosed cabs on equipment, like front-end loaders, with ventilation units and filtration at the point of air-entry. Bartlett et al. (2009) found that irrespective of the type of compost facility, dust and endotoxin exposures were reduced on average 10-fold inside air-conditioned cabs on front-end loaders. (See Figure 2 in the Appendix)
- The installation and use of appropriate ventilation and filtration systems in indoor facilities.
- Maintaining moisture content in windrows at 50-60% to reduce dust exposure (Prasad et al., 2004); and using sprinkler systems in dry climates to keep dust levels low.
- Keeping surfaces in indoor facilities wet. This can be accomplished through the use of an appropriate vacuum or "wet method," instead of dry sweeping (with a broom), to control dust and reduce inhalation hazards.

- Windrows should be built high to increase the height at which bioaerosols are released, which in turn would increase their dispersion into the air at an elevation which reduces the level of exposure to workers (Prasad et al., 2004).

Administrative controls "are those that alter the way work is done, including timing of work, policies, and other rules, and work practices such as standards and operating procedures" (CCHOS, 2006). <u>We recommend the following administrative controls</u>:

- Periodic training and worker education for compost workers on how to control dust and bioaerosol exposures (e.g., keeping surfaces wet, keeping cab doors and windows closed, and use air-conditioning when necessary and available).
- To improve compliance with hazard control measures, workers should be educated about the hazards to which they are being exposed, the health consequences which can arise from these exposures, and how control measures will protect them from these hazards.
- Scheduling worker rotations to ensure that exposure to potentially high bioaerosol-generating activities is minimized.
- Encourage worker hygienic practices, such as hand washing before eating and drinking, providing and laundering workers' uniforms, and providing change room with showers.
- Education and training should also be provided to supervisors/managers about 'best practices' at events, like the Compost Council of Canada conferences.
- All protective equipment and filters should be readily available and well-maintained.

Personal protective equipment is another hazard control measure. We recommend the use of the following personal protective equipment:

- NIOSH Class N-95 masks/disposable respirators (see Figure 3 in the Appendix) (filters at least 95% of airborne particles) for tasks with high airborne hazard exposure risk (e.g., mixing, blending, working outside the cab). The use of these masks should be a minimum *requirement* for these tasks. In enclosed or highly dusty areas, workers should be required to wear half-mask respirators (see Figure 4 in the Appendix).
- Workers should wear work gloves and uniforms at all times. This equipment should be left at the workplace at the end of each shift.
- Safety glasses should also be provided.

12.2 *Policy and Regulatory Measures*

Fortunately, there are many control measures to reduce exposure to occupational hazards in the composting industry. Many of the hazard control measures mentioned in the previous section are voluntary. We recommend the following policy and regulatory measures:

- The measures outlined in section 13.1 should be mandatory and gradually implemented, and 'best practices' guidelines should become *required* regulations with appropriate penalties for non-compliance.
- All composting facilities should be required to comply with the *Organic Material Recycling Regulations*, and should be accountable/liable to a provincial or federal regulator, such as The Compost Council of Canada.

- For hazards with sufficient research to date, we recommend the creation of regulations around maximum exposure limits.
- All new composting facilities, or facilities in need of new equipment, should be required to purchase modern equipment, which in addition to handling more compost material, have better safety measures.

12.3 *Further Research*

Composting is a growing industry worldwide, yet there are many unanswered questions about the effects on workers' health. Further research will help with primary and secondary prevention of health issues related to the exposures of hazards in the composting workplace. It will also assist with providing necessary evidence for worker claims with workers' compensation boards. We recommend the following research:

- A prospective cohort study to establish possible causation and dose-response relationships related to the exposures of various hazards and health outcomes in composting facilities.
- Standardization of testing methods to compare endotoxin levels within different environments, and research to establish health-based threshold exposure limits (i.e., maximum allowable values for various endotoxins).
- A survey of workers at composting facilities across Canada regarding possible health effects of various hazards, and the use of hazard controls (e.g., closed cabs).

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Appendix: Tables and Figures

Table 1. An Overview of Composting Hazards, Health Risks , and Dose-Reponse Relationships

Hazard	Tasks: Potential Harm	Health Risk	Dose Response
Pesticides and Herbicides	Being outside the cab (i.e., activities which allow for direct exposure)	Non-carcinogenic: -May increase risks of Parkinson's disease -Damage to eye sight -Skin irritation -Anemia -Liver, blood, and body weight effects (animal studies) Carcinogenic risks increase with exposure	Not enough research to determine
Thermophilic Bacteria	During handling of the fermenting compost	-Allergen -Respiratory illnesses -Lung irritation -Farmer's lung (hypersensitivity pneumonitis	Direct relationship between exposure and health effects. Sudden exposure of between 106-108 cfu/m3 can initiate allergy or other respiratory illnesses
Endotoxins	Being outside the cab; using a front-end loader; using high energy windrow turners; pile agitation, construction, and screening	-Mucous membrane, nose and throat irritations -Increased severity and prevalence of asthma -Chronic obstructive pulmonary disease -Symptoms of chronic bronchitis, and reduced lung function -Cough, fever, malaise, dyspnea, wheezing, headaches, chest tightness, airway inflammation, airway flow constriction -Lung constriction and dyspnea -Organic dust toxic syndrome	• < 5,000 ng causes no clinical symptoms • 5,000 ng is threshold for increased risks of developing lung disease • 50,000 ng is associated with acute fever and dyspnea -Other endotoxins • Studies have shown a linear relationship between exposure and disease
Beta D-glucan	Being outside the cab; using a front-end loader; pile construction and screening (whenever piles are disturbed)	-Irritation of the mucous membrane -Organic dust toxic syndrome -May cause diverse allergic reactions -Asthma -Hypersensitivity pneumonitis	Not enough research to determine
Aspergillus fumigatus	Grinding feedstock, blending the pile, turning the piles; Mixing, sieving, processing and storing of feedstock or finished product; turning windrows (least frequently turned have the highest surface concentrations)	Immune-compromised individuals: -Pulmonary aspergilloma -Allergic bronchopulmonary aspergillosis -Invasive aspergillosis Immune-competent individuals: -Chronic forms of pulmonary aspergillosis -Allergic responses appearing as asthma and sinusitis	Not enough research to determine
Methane	Indoor composting facilities; Anaerobic environments	-Lack of coordination and increased pulse rate	12-16% oxygen level
		-Fatigue, exertion, and uneasy respiration	10-14% oxygen level
		- Lack of consciousness, nausea, difficulty in movement, possible collapse	6-10% oxygen level
		-Convulsions, panting, possibly death	<6% oxygen level

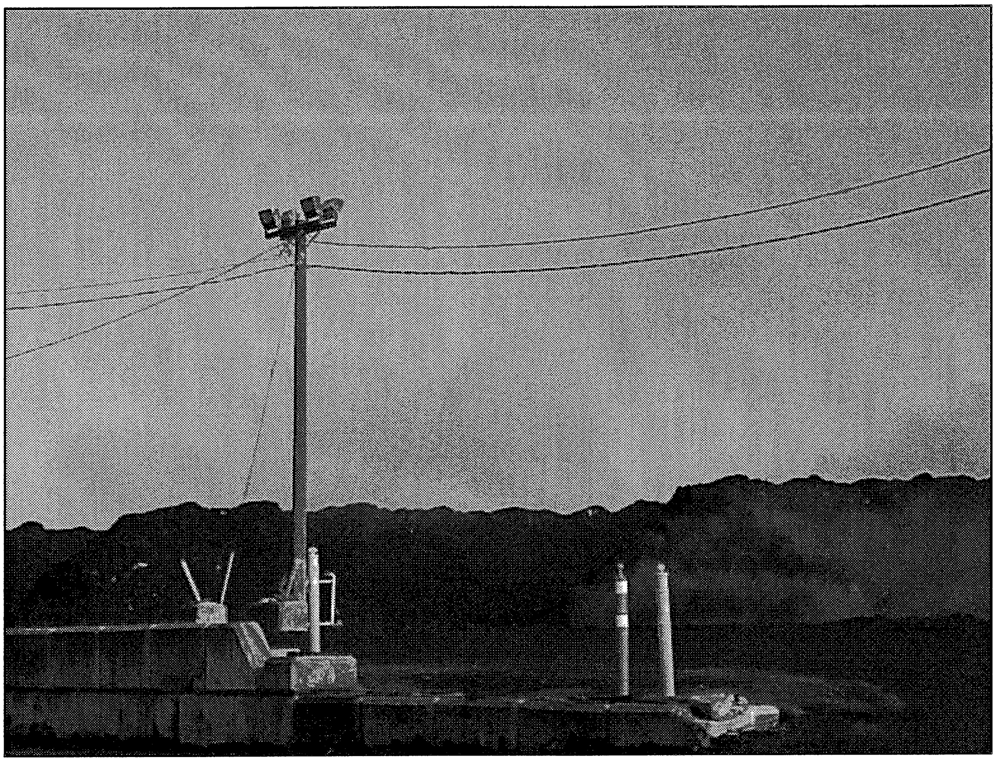

Figure 1. Windrows at an outdoor yard waste and wood composting facility.

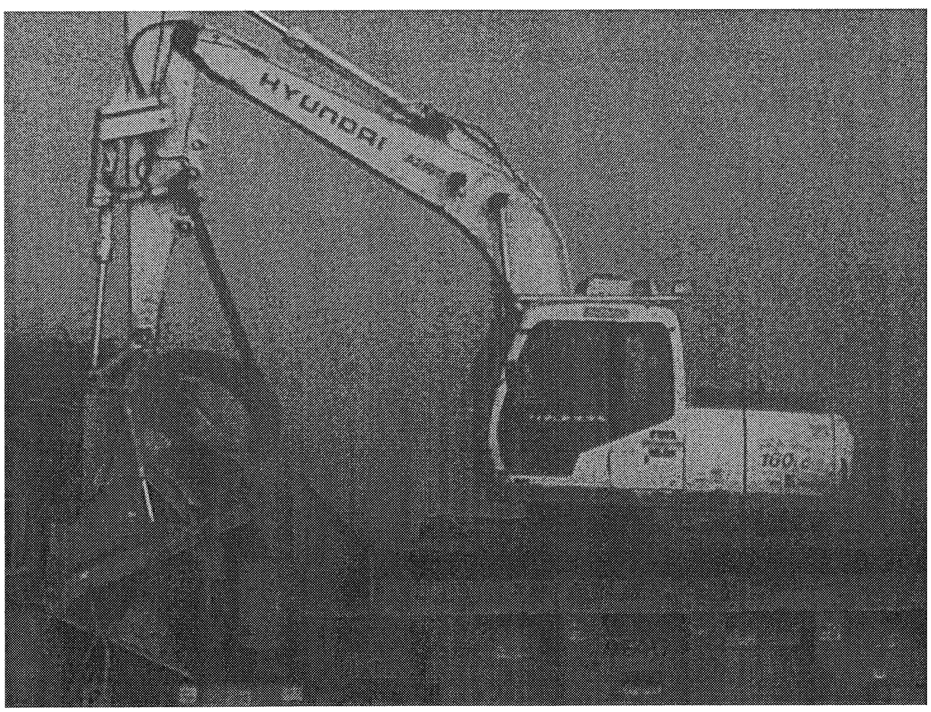

Figure 2. Composting facility employee working in a closed and ventilated cab.

Figure 3. NIOSH N95 Mask / Disposable Respirator

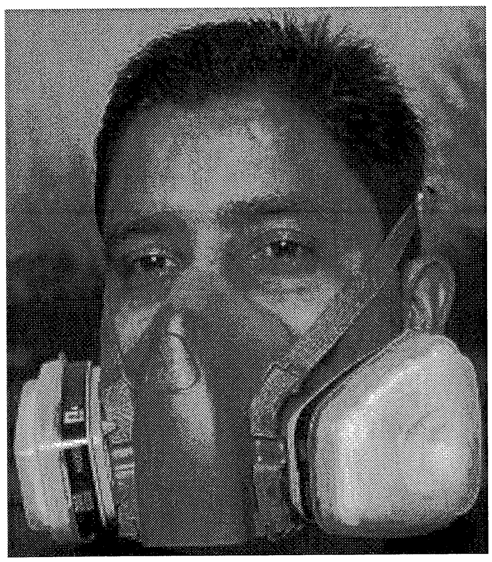

Figure 4. Half Mask Respirator