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Occupational exposure to particulate matter and fungi in a composting plant—case study in Portugal

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ABSTRACT: The handling of waste can be responsible for occupational exposure to particles and fungi. The aim of this study was to characterize exposure to particles and fungi in a composting plant. Measurements of particulate matter were performed using portable direct-reading equipment. Air samples of 50 L were collected through an impaction method with a flow rate of 140 L/min onto malt extract agar supplemented with chloramphenicol (0.05%). Surfaces samples were also collected. All the samples were incubated at 27°C for 5 to 7 days. Particulate matter data showed higher contamination for PM_5 and PM_{10} sizes. *Aspergillus* genus presents the highest air prevalence (90.6%). *Aspergillus niger* (32.6%), *A. fumigatus* (26.5%) and *A. flavus* (16.3%) were the most prevalent fungi in air sampling, and *Mucor* sp. (39.2%), *Aspergillus niger* (30.9%) and *A. fumigatus* (28.7%) were the most found in surfaces. The results obtained claim the attention to the need of further research.

1 INTRODUCTION

Composting is an important process of solid waste management and it can be used for treatment of a variety of different wastes (green waste, household waste, sewage sludge and more) (Duquenne et al., 2012). This is a natural self-heating process involving the biological degradation of organic matter under aerobic conditions. Installations for composting vary greatly in size (from domestic to large-scale facilities), degree of enclosure (open, partially enclosed, enclosed facilities), design (static windrow systems, aerated static piles, bioreactors, etc.) and the type of wastes composted (Swan et al., 2003).

The handling of waste and compost that occurs frequently in the process (compost turning, shredding, and screening) has been shown to be responsible for the release of dust and airborne microorganisms and their compounds in the air of the composting facilities. Therefore, dust, mesophilic and thermophilic microorganisms as well as volatile organic compounds, endotoxins and glucans compose the bioaerosols in those settings and have been found at high levels in numerous composting facilities and may present an exposure hazard especially for workers (Marchand et al., 1995; Duquenne et al., 2012). Consequently, several microorganisms and thermophilic fungi, such as *Aspergillus fumigatus* have been reported (Swan et al., 2003; Duquenne et al., 2012). Furthermore, this kind of contamination in composting facilities has been associated with increased respiratory and dermal pathologies among compost workers (Bünger et al., 2000, 2007).

In spite of the several published studies, exposure to bioaerosols and dust in composting facilities located in Portugal is still insufficiently characterized. Taking this in consideration the aim of the present study was to characterize and s the exposure to particulate matter and fungi totally indoor composting plant located in ıgal.

ɪATERIALS AND METHODS

Description of the composting plant

:apacity of the studied plant is of 40 thousand of biowaste per year and can go until 60 thou- tons per year. The facility consists in a build- ı which the different composting operations erformed. In this building there is no sorting ıse all the waste sorting process is done in a ·ent plant. Waste is unloaded in a reception which is confined and prepared to receive s with the waste and to avoid the emission lors for the outdoor environment. First phase e process is a waste pretreatment that intends move undesirable materials from the process ;, rocks, plastics, metals...). The next phase ıerobic digestion and after dehydration there ·set composting action, followed by an open ›osting with forced aeration. All the process thirteen weeks.

Particulate matter

ıeasurement of Particulate Matter (PM) was rmed in 7 workplaces (Maintenance work- Centrifuges, Maturation Park, Pre-treat- , Control Room, Waste screw and Cabinet of orklift) using a portable direct-reading equip- (Lighthouse, model 3016 IAQ) to measure 'erent sizes ($PM_{0.5}$; PM_1; $PM_{2.5}$; PM_5; PM_{10}). option was considered because the differenti- between particle's size fractions is important ɔer to estimate with more detail the possible ration of dust into and within the respiratory n (WHO, 1999; Brunekreef and Forsberg, ı. Measurements were conducted near the ers nose and during tasks performance. The ia follow for chosen the measurement places the ones where the workers spend more time. neasurements were conducted continuously duration of 5 min and were considered the , maximum and minimum values obtained ıch particle size.

Fungal contamination

ımples of 50 L were collected from 6 indoor ling sites (Maintenance workshop, Centri- , Maturation Park, Pre-treatment, Control , Waste screw) were collected through an :tion method with a flow rate of 140 L/min malt extract agar (MEA) supplemented with chloramphenicol (0.05%), using the Millipore air Tester (Millipore). An outdoor sample was also collected since this was the place regarded as reference.

Surfaces samples were collected by swabbing the surfaces of the same indoor sites, using a 10 by 10 cm square stencil disinfected with 70% alcohol solution between samples according to the International Standard ISO 18593 (2004). The obtained swabs were then plated onto MEA.

All the collected samples were incubated at 27°C for 5 to 7 days. After laboratory processing and incubation of the collected samples, quantitative (colony-forming units—CFU/m^3 and CFU/m^2) and qualitative results were obtained with identification of the isolated fungal species. For species identification, microscopic mounts were performed using tease mount or Scotch tape mount and lactophenol cotton blue mount procedures. Morphological Identification was achieved through macro and microscopic characteristics as noted by Hoog et al. (2002).

3 RESULTS

3.1 *Particulate matter*

Particulate matter data showed that the workplace "Room Process Control" presented the lowest values of contamination. In opposite, the workplace with higher contamination was Forklift Cabinet for $PM_{2.5}$, PM_5 and PM_{10} sizes. In the case of $PM_{0.5}$ and PM_1 the Maintenance Workshop presented the higher values (Figure 1). The particles concentration obtained in all workplaces were significantly different ($p < 0.05$) with exception for results obtained in: Room Process Control and

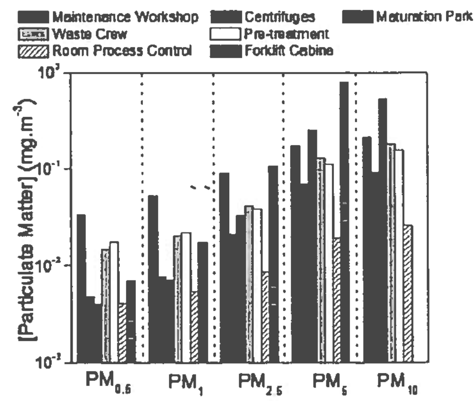

Figure 1. PM mean values distribution by workplace. The results are presented in mg · m^{-3}.

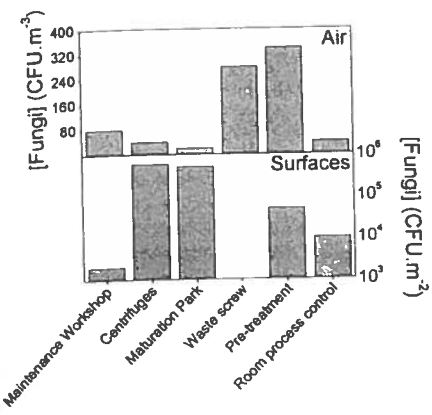

Figure 2. Fungal load distribution in the different workplaces.

Maturation Park in $PM_{0.5}$ (p = 0.07); Pre-Treatment and Maturation Park in PM_5 (p = 0.35); and Maintenance Workshop and Maturation Park in PM_{10} (p = 0.12).

3.2 *Fungal contamination*

Pre-treatment and Waste screw were the sampling sites with the highest fungal load in air and Centrifuges and Maturation park has the highest fungal load in surfaces samples (Figure 2).

Besides both sampling sites with higher air fungal load, also Maintenance Workshop presented more $CFU.m^{-3}$ than the outdoor sample.

Nine different species of filamentous fungi were identified in air samples with a total of 982 isolates. *Aspergillus* genus presents the highest prevalence (90.6%). *Aspergillus niger* (32.6%), *A. fumigatus* (26.5%) and *A. flavus* (16.3%) were the most prevalent fungi in air sampling, but A. *sydowii*, *A. versicolor* and *A. glaucus* were also isolated. *Neosartorya fumigata* was identified in air sampling. *Mucor* sp. and *Penicillium* sp. were also identified.

Four different species were isolated in surfaces samples with a total of 1810000 isolates. *Aspergillus* genus also presents the highest prevalence (60.8%). *Mucor* sp. (39.2%), *Aspergillus niger* (30.9%) and *A. fumigatus* (28.7%) were the most found, but *A. flavus* was also isolated.

4 DISCUSSION

Depending on the waste treatment technology employed, aerosol formation capable of transporting breathable particles with microorganisms has already been published. Regarding composting plants several hazardous agents may be released during the waste composting process (Kummer and Thiel, 2008; Nadal et al., 2009).

Concerning PM data it was possible to measure 5 different sizes that can be distinguished either in the inhalation fraction (PM_5 and PM_{10}) and respiratory fraction ($PM_{0.5}$; PM_1 and $PM_{2.5}$) (WHO, 1999; Brunekreef and Forsberg, 2005). Moreover, studies developed in waste management setting consider normally only the inhalable dust or total dust and do not distinguish or provide data related with the respiratory fraction (Wouters et al., 2006; Park et al., 2011).

In this study, high values of contamination were observed with particular emphases in Forklift Cabinet and Maturation Park. In this last case, the contamination found is probably due to the constant movement of forklifts in this area promoting re-suspension of PM. There are negative health effects related with this type of exposure demonstrated in literature, namely penetration into the gas exchange region of the lung (PM_5) and also the possibility to produce disease by impacting in the upper and larger airways below the vocal cords (PM_{10}) (Vincent and Mark, 1981; Brunekreef and Forsberg, 2005). But $PM_{2.5}$ is also a concern in the Forklift Cabinet and in the Maintenance Workshop, being already in the respiratory fraction this particle size can penetrate in the alveolar region and be involved in systemic effects (Brunekreef and Forsberg, 2005).

In the Maintenance Workshop $PM_{0.5}$ and PM_1 have also some expression probably due to the type of work develop that can involve activities such as sanding, drilling and cutting and not so much waste management activities. However, these workers spend a great part of their time in the places where waste management operations are done, and therefore, the exposure is very diverse during the day and it is dependent of many factors, such as the task developed, materials and equipment used, environmental conditions and also work practice (Eduard and Bakke, 1999).

The same tendency in particle's size distribution was found in other research work developed in different occupational settings that involves exposure to organic dust, namely in swine and poultry production (Basinas et al., 2013; Viegas et al., 2013a,b). In those settings, and with similar values of contamination by PM, it was possible to observe respiratory health effects related with exposure (Donham et al., 1989; Viegas et al., 2013a).

It is important to refer that only one measurement of 5 minutes was taken in each workplace, and variations in PM results can be expected along the day, related with the waste characteristics and also with the tasks being developed. Nevertheless, the measurements were performed during a "normal" day in what concern with the process and the amount of waste that was being handled.

Besides mass concentration, there are other aspects that must be contemplated when considering PM health effects: chemical characteristics and number of particles. Additionally, particles may act as a carrier and a source of nutrients for fungi (such as *Aspergillus*, *Penicillium* and *Mucor* genus) (Seedorf et al., 1998), and bacteria (Halstensen et al., 2013). PM is also rich in endotoxins from the cell wall of gram-negative bacteria and is also associated with mycotoxins produced by several fungi (Mayeux, 1997). These biologically active compounds adhered to PM, along with coexisting toxicant gases that can be carcinogenic, allergic and irritant, promote concern regarding exposure to mixtures and possible additive and synergistic health effects (Von Essen and Donham, 1999).

As stated by Spencer and Alix in 2006: "Composting operations are industrial facilities, like factories. As such, the same reasoning and concepts of industrial hygiene that apply to any other type of factory also apply to compost factories." Some of the preventive and protective measures that can me mentioned are for instance: pave roads; keep roads, areas and equipment clean; dampen loads; enclose and ventilate potentially dusty process areas; maintain closed cabin door or windows from forklifts; provide masks for workers; consider spraying and much others (Spencer and Alix, 2006).

In this kind of industry it is impossible to eliminate all fungi, not only because the permanent bioaerosol generating operations carried out inside the facilities (Marchand et al., 1995), but also due to the high amounts of waste, that is the perfect subtract for fungal growth and development in suitable levels of temperature and humidity (Wouters et al., 2000). When waste is handling in indoor environments, the bioaerossol's exposure is higher (Wouters et al., 2006), increasing the potential health effects due to fungi exposure.

With respect to the health risks derived from exposure to fungi, nowadays, there are no guidelines set by the National Institute of Occupational Safety and Health (NIOSH) concerning the allowable load at the workplace (Vilavert et al., 2009). The World Health Organization (WHO) considers the value of 150 $CFU.m^{-3}$ as a reason for concern, especially when potentially pathogenic species of fungi are present (Goyer et al., 2001) as the ones most prevalent in our study. Pretreatment and Waste Screw sampling sites surpass the WHO value. Moreover, 3 from the 6 sampling sites presented higher fungal load than outdoor sample meaning that there are sources of indoor fungal contamination, such as waste (Wouters et al., 2000).

Besides the quantitative assessment, is crucial to analyze the fungal species present, since adverse health effects dependend on fungal species (Rao et al., 1996; Hoog et al., 2000). According to the American Industrial Hygiene Association (AIHA 1996) in the *Field Guide for the Determination of Biological Contaminants in Environmental Samples*, the identification of the species *A. flavus* and *A. fumigatus*, both of them identified in the analyzed plant, requires implementation of corrective measures.

Mycotoxins occur in occupational environments whenever fungi are present (Mayer et al., 2008) and the results obtained were useful to confirm the relevance to assess toxinogenic strains, from *A. flavus* and *A. fumigatus* in future research. Additionally, knowledge regarding the presence of mycotoxins in bioaerosols from composting facilities is still widely uncertain and is very wide the possibilities of toxins and metabolites that can be present needing to be consider for additional research work (Fischer et al., 1999). In agreement with this, Brera and colleagues (2002) found aflatoxin in airborne dust samples from different occupational settings. Previously, also Autrup and colleagues (1991) measured aflatoxin levels in dust samples from animal-feed production. More recently, some published work developed in Portugal (Viegas et al., 2012, 2013c) has shown that there is occupational exposure to aflatoxin B1 in environments where there is exposure to organic dust concomitantly to high fungal contamination, like in the studied composting plant.

5 CONCLUSIONS

The results obtained in this study claim the attention to the need of further research regarding occupational exposure in composting plants. Additionally, these results allowed the definition of more detailed sampling strategies to better characterize exposure to the risk factors.

Despite the need of more detailed data, the information obtained claims attention to the need for applying adequate preventive and protective measures.

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