RESEARCH ARTICLE

Exposure to aerosolized fungi among collectors of recyclable and mixed residential wastes

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Abstract:

Bioaerosols may contain pathogenic, infectious and toxic live bacteria, fungi and viruses. Fungi constitute an essential part of the solid waste. Waste collectors have a high risk to the exposure of bioaerosols at their working environment. Various health impacts from bioaerosol exposure include allergies, acute toxic effects, respiratory symptoms and cancer. The objectives of this study were to quantify and compare the culturable aerosolized fungi exposure between recycle waste and mixed residential waste collectors, in addition to evaluate the influence of outdoor temperature and relative humidity to the concentration of culturable aerosolized fungi. A total of 40 exposure samples for each category were collected using an air sampling pump attached at the waste collector's body. The colony forming units of culturable fungi were calculated after culture and incubation. Outdoor temperature and relative humidity were also recorded. Waste collectors to both categories of waste were exposed to high levels of culturable airborne fungi, however there was no significant difference between the airborne fungal exposure for recyclable (1.38×10^9 CFU/m^3) and mixed (1.60×10^9 CFU/m^3) residential waste collectors. There was a significant strong positive correlation between fungal concentrations and temperature (*r*: 0.632; r: 0.819), but a negative correlation between fungal concentrations and relative humidity (*r*: -0.594; r: -0.799), for both recyclable and mixed residential waste respectively. The high concentration of aerosolized fungi exposed towards the waste collectors was influenced by several factors including the type of waste collected, collection truck, and manual handling as well as total hours of working and handling wastes.

Keywords: aerosolized fungi, mixed residential waste, recyclable waste, waste collectors

1. INTRODUCTION

There are numerous chemical, biological, physical, and ergonomic health hazards associated with the collection of solid and compostable waste. Malaysia has been experiencing rapid industrialization and urbanization that has changed the characteristics of the Malaysian solid waste generation [1]. Increased population density (i.e., increased waste generation) and new waste management and recycling initiatives have increased the potential for bioaerosol exposures among waste collection workers in industrialized countries. In Malaysia, waste collectors are involved in collecting, sorting, transporting and disposing various types of wastes, such as municipal wastes, industrial wastes, commercial waste, agriculture wastes, institutional wastes and other types of wastes.

Microbiological exposures associated with waste can occur indoors where the waste is stored [2] or outdoors during its collection, and may be influenced by sorting, transferring, and cleaning processes [3,4,5,6]. The microorganisms may already become aerosolized when handling the biodegradable wastes and wastes that is meant to rot also have been colonized by the fungi and bacteria [7]. Exposure to bioaerosols may lead to a high risk of occupational health problems among the waste collectors.

There have been increased incidence rates of occupational pulmonary, gastrointestinal and skin problems among waste collectors [8]. Compostable waste collectors have been shown to suffer from a variety of health effects including mucous membrane irritation, rhinitis, allergy, asthma, bronchitis, conjunctivitis, hypersensitivity pneumonitis, allergic broncho-pulmonary mycosis, dermatitis, and diarrhea [8-14].

An important factor in the Malaysian context, however, is the lack of basic epidemiological data on the health impact of prevailing waste management practices that would motivate and drive the authorities to adopt safer management techniques. Therefore, in this study our objective was to assess airborne exposure levels to culturable fungi among collectors of mixed and recyclable waste.

2. MATERIALS AND METHODS

2.1 Sampling location

Residential areas in Kuala Lumpur were selected in this study because of the growing waste generation every year in the city. The sampling was done for four days with a total exposure sample of 80 for both recyclable and mixed residential waste collectors.

2.2 *in-situ* data collection

Outdoor temperature and relative humidity that influence the colony count also were recorded using the Wet Bulb Globe Temperature (WBGT) during the sampling process.

2.3 Airborne fungal sampling and culture

An air sampling pump consisting of a polycarbonate filter with pore size of 0.8 µm and 37-mm diameter cassette was attached to the waste collector. The cassette was supported by cellulose pads that loaded into close-face of the cassette. The pump was operated at an airflow of 2 L/min for a duration of 30 minutes throughout working hours. According to a previous study, air samples of bioaerosols taken on filters may be preferable to impaction on agar dishes [15]. After the sampling period, the filter was brought to the laboratory for analysis. In the extraction procedure, a 5ml volume of sterile distilled water was added into the cassette filter and shaken for approximately 15 minutes. The extracted sample was diluted 100 times using serial dilution method. Then, 0.1 ml of the diluted fluid was sucked out and plated onto the Potato Dextrose Agar (PDA) in the petri dish and incubated for 5-7 days at 37°C [7,16]. After incubation, the colony was counted under the light microscope. The analytical results for culturable fungi are reported as colony forming units per cubic meter of air (CFU/m^3) and were calculated using the following formula:

$$CFU/m^3 = \frac{\text{No. of colonies on petri dish x extraction volume (mL)}}{\text{spreading volume (mL)}} \times \frac{1}{\text{volume of air sampled } (m^3)}$$

2.4 Preparation of agar plate

Potato Dextrose Agar (PDA) was used to culture the extracted samples. The agar medium was first melted, then cooled to 45 - 47°C. Approximately 15 to 20 ml of agar was poured from the tube to the sterile petri dish using aseptic technique. The petri dish was rotated so that the medium covers the bottom and not moved until the medium solidified. The preparation procedures by Csuros *et al*. [17] was used.

2.4 Statistical Analysis

The significant difference between occupational rxposures for both exposure scenario was assessed by the Mann–Whitney test for non-parametric distributions. The relationship between fungal counts and environmental factors were analysed using Pearsons correlation.

3. RESULTS AND DISCUSSION

3.1 Cultural fungal count and exposure to waste collectors

The mean and standard deviation of the colony count of fungi for each type of waste is depicted in Table 1. The mean colony count of aerosolized fungi for mixed residential waste is 1.6×10^9 CFU/m^3. The waste samples that were collected and analyzed were mostly food wastes where they contributed almost 65% of the overall weight. Waste materials begin the breakdown process when they are deposited within a container, especially the organic and biodegradable materials like food wastes. The materials may be readily colonized by the microorganisms like fungi and it may become aerosolized when the wastes are being handled.

In addition to the food wastes, garden wastes which was also present in the mixed residential waste collected play a big role in displaying a high total colony count of culturable fungi [11]. Some fungal spores that are naturally present in low numbers and flourish in stored organic material may germinate and grow. Fungi can grow at lower water availability [18]. When the garden wastes are left for a few days before collection, the natural biological process of decomposition will occur which is composting. When the waste is being handled and moved around by the waste collectors, the fungi can be aerosolized and this will lead to the exposure towards the waste collectors.

Table 1: Culturable fungal counts

Sample type	Colony count (CFU/m^3)		
	Mean (N=80)	Min	Max
Mixed waste	1.60×10^9	5.2×10^8	2.74×10^9
Recyclable waste	1.38×10^9	3.6×10^8	2.72×10^9

The mean colony count of aerosolized fungi for recyclable waste is 1.38×10^9 CFU/m^3. Although the mean exposure to the mixed residential waste collector is higher than the recyclable waste, the mean value of both wastes have a very small difference and was not statistically significant. The composition of the recyclable wastes was mostly paper, plastic, glass and aluminum. A possible reason for the high exposure of aerosolized fungi from recyclable wastes towards the waste collectors is probably because of the small amounts of food, milk or water that has been contaminated and left in the recyclable wastes especially in the food packaging such as cans, tins, glass bottles and tetrapaks. This contamination could provide a good medium for the microorganisms to grow.

Exposure thresholds to both bacteria and fungi range from 10^3 CFU/m^3 to 10^5 CFU/m^3 [19]. Additionally, the outdoor concentration of airborne fungal spores is usually in the order of 10^3-10^4 CFU/m^3, changing with weather, season and geographical location [11]. The high total count of aerosolized fungi reported is mainly due to the composition of the waste that is present in the waste sample.

The type of collection truck also plays a role in contributing to the high exposure of fungi. Usually, mixed residential waste is collected using the compactor truck in Kuala Lumpur. This is because the wastes get compacted and compressed which make the exposure to aerosolized fungi

higher. In addition, the loading of the compactor truck takes place close to the worker's breathing zone, plus the collectors stand next and near the loading as the wastes get compressed [11]. As waste collectors stand on the platform that is situated near the loading area when travelling from one place to another, exposure to aerosolized fungi for the waste collectors happens for a longer duration.

Another factor that influences the high total count of culturable fungi exposed towards the waste collectors is manual handling which cannot be avoided in certain instances. Households are provided with the standard waste bin by the waste contractor company which is designed to be lifted by the compactor truck. However, based on observations, not all households follow these requirements with most putting the waste outside the bin leading to manually handling by the waste collectors. Furthermore, some households do not separate wastes, thus the waste collector will be the one who separates the unseparated wastes. One of the collector as a 'runner' moving ahead of the truck to collect the recyclable waste and throw it onto the back of the open truck. Another waste collector that stays at the back of the open truck will segregate the unseparated wastes. During this manual handling, the exposure of aerosolized fungi becomes higher.

Moreover, the additional factor that increases the exposure of aerosolized fungi towards the waste collectors is the waste handling period. Waste collectors start their duties at 6.30 in the morning, with certain waste collector crews that service a larger collection area end the collection day at night. During the collection of recyclable waste, the total hours taken for the collection period to be over was an average of 10 hours. Thus, this makes the waste collector spend a longer period handling the wastes and increases the exposure period [15].

3.2 Correlation with environmental factors

Pearson's Correlation was used to calculate the relationship between concentration of aerosolized fungi with outdoor temperature and relative humidity. The results obtained showed that the concentration of aerosolized fungi and outdoor temperature and relative humidity had a positive value and strong relationship with a correlation coefficient of 0.819 and 0.632 for mixed waste and recyclable waste respectively. In contrast, the relationship between the concentration of aerosolized fungi and relative humidity although slightly strong but it was negatively correlated for both mixed waste and recyclable waste with respective coefficients of -0.799 and -0.594 respectively. This shows that the high colony count of aerosolized fungi is influenced by the temperature and relative humidity. The correlation of fungal concentration with environmental factors is shown in Table 2. Although these results are based on few samples, statistically significant differences were found for both the recyclable and mixed waste with the environmental factors.

The concentration of aerosolized fungi increases as the temperature goes higher and the relative humidity become lower during the sampling period. Thus, as the time reaches 12 noon, the temperature is the highest and hottest which makes the concentration of aerosolized fungi become high. Simultaneously, when the temperature is high, the relative humidity becomes lower as the weather become hotter, and the surroundings become dry. A higher concentration of bioaerosols exposure in waste collection during the summer condition has been reported in seasonal countries [3].

Table 2: Relationship between fungal counts and environmental factors

Sample type	Colony count (CFU/m^3)	Correlation coefficient (r)	
		Temperature	Relative humidity
Mixed waste (Mean, N=40)	1.60×10^9	0.819*	-0.799*
Recyclable waste (Mean, N=40)	1.38×10^9	0.632*	-0.594*

* $p < 0.05$

As the time shifts from afternoon to evening, the temperature also is slightly lower and the relative humidity gets a bit higher. Thus, the concentration of the aerosolized fungi also decreases. The temperature that is considered to be optimum for fungal growth is between 25°C and 30°C [20]. Moreover, it is also stated that the fungal activity decreases rapidly when temperature reaches the maximum value of approximately 40°C. In this study, the temperature range is between 25°C and 34°C when the sampling of aerosolized fungi was being conducted, where the fungal activities are 10 times higher than at 0°C [20]. Thus, it resulted in high colony count of culturable fungi for mixed residential waste and recyclable waste.

4. CONCLUSION

The present analysis suggests that the collection of wastes, whether segregated or not may lead to significant worker exposure to culturable fungi. There are several factors that contribute to exposure to the waste collector, such as the type of collection truck involved, the intensity of manual handling by the waste collectors and the total hours working and handling the wastes. Results also showed that the concentration of aerosolized fungi exposed to the waste collectors were influenced by temperature and relative humidity of the surroundings. As this assessment was limited to only a few days, it may not adequately reflect the full range of exposures among waste collectors. In general, these results suggest the need for modifying certain work practices to minimize exposure. Recommendations include automation of waste collection, the use of personal protective equipment including goggles, gloves, and disposable masks, implementation of training programs, and good personal hygiene.

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