# Hospital admission and risk assessment associated to exposure of fungal bioaerosols at a municipal landfill using statistical models

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**Abstract.** The object of this research to determine the statistical relationship and degree of association between variables: hospital admission days and diagnostic (disease) potentially associated to fungal bioaerosols exposure. Admissions included acute respiratory infections, atopic dermatitis, pharyngitis and otitis. Statistical analysis was done using Statgraphics Centurion XVI software. In addition, was estimated the occupational exposure to fungal aerosols in stages of a landfill using BIOGAVAL method and represented by Golden Surfer XVI program. Biological risk assessment with sentinel microorganism A. fumigatus and Penicillium sp, indicated that occupational exposure to fungal aerosols is Biological action level. Preventive measures should be taken to reduce the risk of acquiring acute respiratory infections, dermatitis or other skin infections.

**Keywords:** fungal aerosols, biological risk assessment, hospital admission, respiratory infections, landfill.

## 1 Introduction

Some activities, there exist no deliberate intention to manipulate biological agents, but these ones are associated to the presence and exposure to infectious, allergic or toxic biological agents in air [1]. Bioaerosols consist of aerosols originated biologically

such as metabolites, toxins, microorganisms or fragments of insects and plants that are present ubiquitously in the environment [2]. Bioaerosols play a vital role in the Earth system, particularly in the interactions between atmosphere, biosphere, climate and public health [3]. Studies suggest adverse health effects from exposure to bioaerosols in the environment, especially in workplaces. However, there is still a lack of specific environmental-health studies, diversity of employed measuring methods for microorganisms and bioaerosol-emitting facilities, and insufficient exposure assessment [4], [5]. Bioaerosols exposure does not have threshold limits to assess health impact/toxic effects; reasons include: complexity in their composition, variations in human response to their exposure and difficulties in recovering microorganisms that can pose hazard during routine sampling [4], [8]. Occupational exposure to bioaerosols containing high concentrations of bacteria and fungi, e.g., in agriculture, composting and waste management workplaces or facilities, may cause respiratory diseases, such as allergies and infections [3]. Also, there is no international consensus on the acceptable exposure limits of bioaerosol concentration, too [4].
More research is needed to properly assess their potential health hazards including inter-individual susceptibility, interactions with non-biological agents, and many proven/unproven health effects (e.g., atopy and atopic diseases) [2]. Consequently, the aim of this research was to evaluate if the exposure to fungal bioaerosols becomes a risk factor that increases the number of landfill operator's hospital admission.

## 2 Material and Methods

### 2.1 Site selection and fungi aerosol collection

Bioaerosol sampling is the first step toward characterizing bioaerosol exposure risks [9]. Samples were collected for 12 months (April 2015 - April 2016) in a municipal landfill located near Barranquilla, Colombia. Landfill has a waste discharge zone, where the waste deposited is compacted (active cell), there are some terraces with cells are no longer in operation (passive cells) and a leachate treatment system divided into three treatment steps: one pre-sedimentator, two leach sedimentation ponds and biological treatment pond. Sampling stations were located in the passive cell 1, the passive cell 2, the leachate pool and the active cell. In each sampling station, samples were collected once a month by triplicate in two journeys, morning (7:00 to 11:00) and afternoon (12:30 to 18:00). Fungi aerosol collection procedures and methodology are described in researches recently published [10].

### 2.2 Analysis data

Chi-square analysis was performed to determine the significative statistical relationship and degree of association between variables: hospital admission days and diagnostic (disease) with 95% confidence ($p < 0.05$) [11] using Statgraphics Centurion XVI software. Hospital admission reported diseases were acute diarrheal disease, acute respiratory infections, atopic dermatitis, pharyngitis, otitis and tropical diseases. Analysed period was January 2015 – July 2016. The landfill has 90 workers, while 50 are operators [12]. So, the research was done just with the operators.

### 2.4 Risk assessment: estimation of the occupational exposure to fungal aerosols in a landfill

Technical guide for the evaluation and prevention of risks related to exposure to biological agents [8] and the Practical Manual for the evaluation of biological risk in various work activities BIOGAVAL were used to the estimation of the occupational risk of non-intentional exposure to fungal aerosols. Calculation of the level of biological risk (R) was done with the following equation (1):

$$R = (D \times V) + T + I + F \quad (1)$$

Where:
R is the level of biological risk, D is Damage, D* is Damage after reduction with the value obtained from the hygienic measures, V is Vaccination, T is Transmission way, T* is transmission way (having subtracted the value of the hygienic measures), I is Incidence rate and F is Frequency of risk activities.
For the interpretation of biological risk levels, after validation, two levels were considered: Biological action level (BAL) and Biological exposure limit (BEL). BAL: from this value preventive measures must be taken to try to reduce the exposure. Although this exposure is not considered dangerous for the operators, it constitutes a situation that can be clearly improved, from which the appropriate recommendations will be derived. (BAL) = 12, higher values require the adoption of preventive measures to reduce exposure. BEL: It must not be exceeded. BEL=17, higher values represent situations of intolerable risk that require immediate corrective actions. To establish the distribution of the risk in the landfill, risk level map was made using the Golden Surfer 11 program.

### 2.5 Operator type vs exposure time

Exposure operator time in active cell and leachate pool corresponded to 12 hours for 5 days, except the mechanical technician.

## 3 Results and discussion

### 3.1 Sentinel microorganism

Results of air samples showed more prevalence of *Aspergillus.* Species reported were *A. fumigatus, A. versicolor, A. niger and A. nidulans.* The highest concentration corresponds to *A. fumigatus* during study period [10] microorganism associated to toxins production with cytotoxic properties. *A. fumigatus* has been reported as allergic and toxic microorganism in working environments [1], [7]. Other taxa reported in this study, although in lower concentration during the sampling period, was *Penicillium sp*, associated with dermatitis and respiratory conditions [1], [17], [18]. Airborne fungi causing respiratory infections and allergic reactions include *Penicillium, Aspergillus, Acremonium, Paecilomyces, Mucor* and *Cladosporium* [19]. Most infections, specifically Aspergillosis can occur in immune compromised hosts or as a secondary infection, which is caused due to inhalation of fungal spores or the toxins

produced by *Aspergillus* fungus [20]. In addition, for the sentinel microorganism exposure, *Aspergillus fumigatus* and *Penicillium* sp are contemplated in the Technical Guide for the evaluation and prevention of risks related to exposure to biological agents in Appendix 14. Biological Risk in Waste Disposal Units [8].

### 3.2 Risk assessment

Table 1 presents the damage quantification data, according to the Manual of Optimal Times of Work Disability [13]. The damage of acute respiratory infections and atopic dermatitis corresponds to temporary disability less than 30 days but that may have sequels about the patient.

**Table 1.** Damage rating

| Sentinel microorganism | Manual of optimal times of work incapacity | Damage | Score |
|---|---|---|---|
| Respiratory infections, bronchitis, pharyngitis, or other. *A. fumigatus* | 10 Days | Days of absence <30 days, sequels | 3 |
| Atopic dermatitis, allergic urticaria, *Penicillium sp* | 14 Days | Days of absence <30 days, sequels | 3 |

*A. fumigatu*s and *Penicillium* sp have the highest score according to the transmission route due to their aerial dispersion. In addition, the health threats from bioaerosol exposure can be also greatly enhanced by airborne transmission of infectious agents breathing via [9]. The risk assessment was applied between April 2015 and April 2016, corresponding to the months of monitoring analyzed. For atopic dermatitis and urticaria, the data to calculate the incidence rate correspond to the number of disability cases in relation to the number of operators according to the previous year, the study period was March 2014 to March 2015, and the organization provided information.

**Table 2.** Results incidence rate in the population

| Sentinel microorganism | Incidence rate | Incidence / 100.000 habitant | Score |
|---|---|---|---|
| Respiratory infections, bronchitis, pharyngitis, or other. *A. fumigatus* | 16.000 | ≥ 1000 | 5 |
| Atopic dermatitis, allergic urticaria, or other *Penicillium sp* | 12.000 | ≥ 1000 | 5 |

Percentage of time in which operators are in contact with the different biological agents under analysis was calculated, ignoring the total of the working day (12 hours) and the time spent on breaks (1 hour); obtaining a grade of 5 for presenting a percentage of habitually> 80% of the time. Vaccination variable was classified as 5 since there is no completely effective vaccine for the conditions evaluated. Hygienic

Measures Adopted was used as a corrective value of -2, according to 83.2% of affirmative responses, as results of the survey hygienic measures adopted.

### 3.3 Biological risk level

The following is the calculation of the risk level of exposure to sentinel microorganisms in operational area, personnel who work in Active Cell and leachate pool, or personnel who works 12 hours per day.

**Table 3.** Biological risk level of operator

| Sentinel microorganism | D | T | Corrective value | D* | V | T* | I | F | R |
|---|---|---|---|---|---|---|---|---|---|
| *A. fumigatus* | 3 | 3 | 2 | 1 | 5 | 1 | 5 | 5 | **16** |
| *Penicillium* sp | 3 | 3 | 2 | 1 | 5 | 1 | 5 | 5 | **16** |

According to Biogaval method, the biological risk assessment with sentinel microorganism *A. fumigatus* and *Penicillium* sp, indicates that occupational exposure to fungal aerosols is in Biological action level (BAL). Preventive measures should be taken to reduce the risk of acquiring pharyngitis, bronchitis or other acute respiratory infections; preventive measures should also be taken to reduce the risk of dermatitis or other skin infections. Fig 1 shows the risk level map according to biological risk level in stages of the landfill and the time exposure; active cell is the stage of the landfill that presents the greatest risk of exposure to bioaerosols fungi, followed by the Leachate pool.

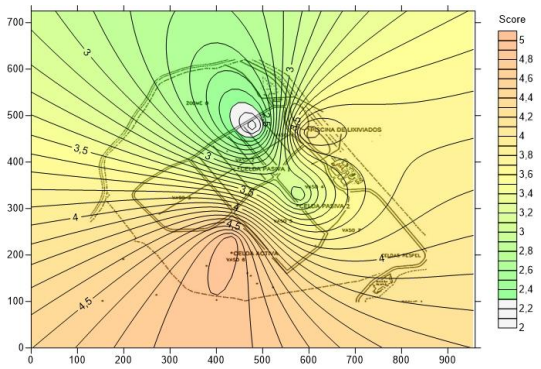


**Fig 1**. Biological risk level map – exposure to fungal aerosols in the landfill.

### 3.4 Chi-square analysis

Chi-square analysis are shown in Table 4. Chi-squared statistic established a p-value less than 0.05, means statistical significance relationship between the hospital admission days and the diagnosed diseases (95% confidence). Figure 2 establish the sense of the relationship between the operator days and diagnostic hospital admissions. Acute respiratory diseases contribution had representation when the

hospital admissions day was one, two or three days (Figure 2). Moreover, otitis generated a significant number of days, whereas pharyngitis and dermatitis had a lower contribution of days (2). Acute diarrheal disease was represented on (1), (2) and (3) day of admission.

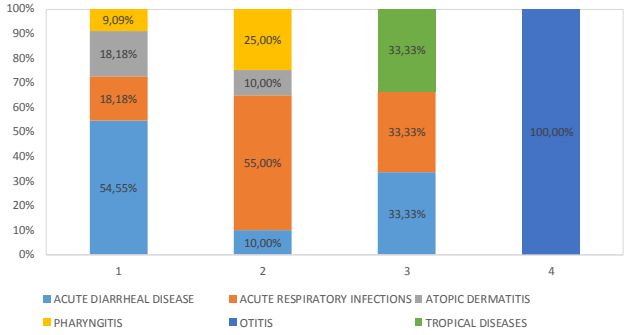


**Fig 2**. Chi-square contribution for each number of hospital admission days.

**Table 4.** Chi-squared analysis

| *Test* | *Statistic* | *Gl* | *P Value* |
|---|---|---|---|
| Chi-square | 56,089 | 15 | 0,0000 |

Non-hazardous waste landfilling has the potential to release biological agents into the air, notably mould spores. Some species, such as *Aspergillus fumigatus*, may be a cause of concern for at-risk nearby residents [21] because aerodynamic diameter (AED) of single and aggregated spores could be from 1.9 µm to 2.7 µm [22]. Chi-square results support the results obtained in the sampling carried out [10] and the risk analysis based on BIOGAVAL method. Hospital admission are potentially associated to operator exposure of fungal aerosols by topic and respiratory via. Other hospital admission disease reported was tropical disease (chikungunya) not associated to fungal aerosols.

According to epidemiological studies of highly exposed populations, diarrhoea is one of the symptoms associated with fungal spore exposure, similar association with endotoxins (acute diarrheal disease) [22]. Endotoxin associated with ambient PM (particulate matter) has been linked to adverse respiratory symptoms, but there have been few studies of ambient endotoxin and its association with co-pollutants and inflammation [23]. The highest concentration corresponds to *A. fumigatus*, but the reported value is lower than those reported by other studies who reported geometrical averages of 9300 CFU / $m^3$ [12]. But it exceeds the values by The Health and Welfare Department in Canada [2], [24], [25].

## 4 Conclusion

The concentrations of bioaerosols did not show a major difference at a reference distance of 200 m, stating that this distance was not enough to reduce the microorganisms to background levels [26]. Environment Agency recommends a limit

distance of at least 250 m, to ensure that composting plants do not have any adverse impact on the health of people living in the area of influence [27]. However, other authors have measured higher than background concentrations, at a distance of 550 m or more of composting sites [24], showing that the radius of action for the decay of the concentration in a natural way may require a wide distance [26].
Statistical analysis of the disease and days hospital admission provided objective information on the potential effect of the operator's bioaerosols exposure indicated changes in working hours urgently, according to risk assessment and results of the sampler campaigns [10]. Looking at the concerns and risks associated with bioaerosols, the area demands a substantial research culminate personal exposure to bioaerosol, formation, distribution, and its validation.

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