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Seasonal Variability of Indoor Environment Parameters in Children Day Care Centers

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Abstract

*Children attending day care centers have been reported to be more prone to infectious diseases when compared with those cared for at home, and are exposed to conditions that may increase the risk of allergies and asthma. Several studies revealed poor ventilation conditions associated with high levels of carbon dioxide to be common in schools and are often related with a high accumulation of many other indoor pollutants as a consequence. Nine children day care centers were selected randomly to participate in this study. Fifty two classrooms were assessed for building characteristics and for house dust mites, total bacteria, particulate matter and carbon dioxide both in spring and winter seasons. Outdoor measurements were also conducted for comparison. Indoor bacteria and carbon dioxide concentrations were higher than their reference values in both seasons and suggest a correlation possibly related to overcrowded classrooms and inefficient ventilation. Outdoor concentrations are lower than indoor in both seasons showing prevalence of indoor sources ($P=0.01$). In the winter season the allergen which concentration is higher than the reference level is *Der f 1*. Nevertheless the correlation coefficients between allergens, particles and bacteria were not statistically significant. These data will help to evaluate the effectiveness of current building operation practices in children day care centers regarding indoor air quality and respiratory health.*

Keywords - bacteria; particulate matter; house dust mites; children day care centers; indoor health assessment

1. Introduction

Exposure and sensitization to indoor allergens are important risk factors for asthma and allergic respiratory diseases, playing a key role in triggering and exacerbating allergy and asthma symptoms in children [1]. While children's greatest exposure to indoor allergens is at home, other public places where they spend a large amount of time, such as school and day care centers (DCCs), may also be sources of significant allergen encounters [2]. Moreover, the role of human occupancy as a source of indoor biological aerosol is poorly understood. Size-dependent particle behavior often can be

associated with specific chemical and biological components of particulate matter. The strong signal of human microbiota, as airborne particulate matter is concerned, in an occupied room demonstrates that the aerosol route can be a source of exposure to microorganisms emitted from the skin, hair, nostrils and mouths of their occupants [3]. The goal of this research was to determine human associated emission rates of bacteria and their possible relation with house dust mite, particle matter and carbon dioxide (CO₂) concentration in occupied DCCs classrooms.

2. Materials and Methods

2.1. Sampling Sites

This study was design to be accomplished in Porto DCCs planned in two different phases. The phase I include a randomly selected sample of 27 public DCCs. In all DCCs was performed a health characterization by the ISAAC questionnaire and a first environmental characterization. In this phase was made a preliminary study to characterize the buildings construction, as well as CO₂, temperature and relative humidity (RH) monitoring, indoor and outdoor air. In phase II were selected (cluster analysis) 9 DCCs from those studied in phase I. In those selected buildings were performed a more detailed monitoring for house dust mites, total bacteria, particulate matter up to 10 micrometers in size (PM10) and CO₂. All the DCCs rooms were included in the assessment within 7 nurseries (< 1 year old children) and 45 kindergarten (1 to 5 year old children) classrooms. The monitoring phase included daytime air sampling (starting at 9 am and continuing for at least 4 h during normal activities) conducted in a discreet fashion in order not to disturb occupants' normal behavior.

2.2. Environmental Assessment Methods

The assessment was carried out in 52 DCCs classrooms located in Porto urban area, both in spring/summer (March – May 2011) and winter (November 2011 – February 2012) seasons, along one year study. Outdoor measurements were also conducted for total bacteria, CO₂ and PM10 monitoring in each campaign to compare with indoor levels.

Dust was collected in every room during routine activities, using the same collection protocol in all sites. Samples were collected using a common vacuum cleaner equipped with a *Dustream* Collector. About 1m² area, in the middle of the classroom, was vacuumed for an average period of 2 minutes. The selected areas had student activity or traffic. Samples were assayed for dust mite allergens, *Dermatophagoides pteronyssinus* (Der p 1) and *Dermatophagoides farinae* (Der f 1) using a two-site monoclonal antibody ELISA(Indoor Biotechnologies, Cardiff, UK).

PM₁₀ samples were collected using polytetrafluoroethylene (PTFE) filters on Personal Environmental Monitors (PEM) and Gilian personal pumps working at a flow rate of 2.0 L.min⁻¹, following US Environmental Protection Agency (EPA) Method 10-A [4]. Pumps were calibrated and checked prior and after each sample, respectively, using a Gillian Gilibrator-2 Air Flow Calibrator. At least one field blank per sampling event was used. Exposed and unexposed filters were transported, protected from dust and sunlight, and kept away from air in a closed filter holder. Each filter was weighed under controlled temperature (19 to 22°C) and relative humidity (45 to 62%) before and after sampling using an electronic microbalance (Sartorius M5P with 0.001 mg of precision). Static charges were eliminated from filters using a non-radioactive, ionizing air blower (EXAIR, Model No. 7907). After weighting and before sampling, filters were stored in a desiccator. Concentrations were calculated by the filter weight and the respective sample air volume.

Air sampling was carried out with a microbiological air sampler (Merck Air Sampler MAS-100) using the culture media Tryptic Soy Agar (TSA) for total bacteria. It followed the National Institute for Occupational Safety and Health (NIOSH) 0800 Method - Bioaerosol Sampling (Indoor Air). Air was drawn at a rate of 100 L.min⁻¹ at 1-1.5 m height; two different volumes of air (100 and 250 L) were drawn, according to the characteristics and hypothetic contamination of each room. Samples were collected both indoor and outdoor, in sequential duplicates, as well as one field blank per day. All samples were carried out during DCCs routine activities. Quantification of the collected samples was performed by naked eye count, after 48h incubation at 37°C. The concentrations obtained were expressed as number of colony forming units per cubic meter of air (CFU/m³).

CO₂, temperature and RH were determined using a portable IAQ monitor (GasData, model PAQ) during the occupied period. Short-term measurements (30 min average) were made in each room. After the 10 min equipment stabilization, measurements were recorded continuously using PCLogger 32 V3.0 software.

Descriptive statistics were calculated for allergens, bacteria, PM10 and CO₂ by season. Uncertainty was reported as 95% confidence intervals based on error propagation of multiple samples and instrumental uncertainty. Paired t-tests were used to test for seasonal effects differences and Pearson correlation test to identify possible associations between the analyzed parameters. A 0.05 level of significance was used for all analyses. All data were analyzed using IBM SPSS 20.0.

3. Results and Discussion

The 52 classrooms analyzed were all naturally ventilated and 12 classrooms (23% from total) had AVAC systems. The number of occupants by classroom was in average 17 with a range of 5-29. The mean classroom area was 35 m² with a range of 12-59 m². Concerning physical parameters, the spring/summer results for indoor temperature varied between 16°C to 25°C (average 19°C) and the RH varied from 30% to 79% (average 57%), with a mean air velocity of 0.04 m.s⁻¹. The winter indoor physical parameters ranged as followed: 13°C to 25°C (average 19°C) for temperature, 28% to 83% (average 56%) for RH and mean air velocity of 0.12 m.s⁻¹.

In our study the mean levels of bacteria and CO₂ are the ones of concern (Table 1). Indoor total bacteria average concentration is above the Portuguese reference levels, being 58 and 50 times higher than outdoors, both in winter and spring/summer respectively, showing prevalence of indoor sources (P=0.01) which is in accordance with Hospodsky et al. [5], revealing that human occupancy is a dominant factor that contributes to the concentration of indoor airborne bacterial. Both resuspension from carpet and direct human shedding contributed to significantly elevate bacterial concentrations above background concentrations.

Table 1. Environmental assessment descriptive statistics

| | Range | Mean | Std. Dev. | Reference | Outdoor (Mean) |
|--|------------|-------|-----------|---------------------|----------------|
| Bacteria <i>S/S</i> * (CFU.m-3) | 510-18 770 | 4 998 | 3482 | 500 ⁽⁶⁾ | 104 |
| Bacteria Winter (CFU.m-3) | 190-52 560 | 5 785 | 9 296 | | 100 |
| CO2 <i>S/S</i> * (mg.m-3) | 642-5647 | 2677 | 1206 | 1850 ⁽⁶⁾ | - |
| CO2 Winter (mg.m-3) | 699-4953 | 2621 | 1112 | | 712 |
| Der f 1 <i>S/S</i> * (µg/dust) | 0.4-4.1 | 0.8 | 0.9 | 2 ⁽⁷⁾ | - |
| Der f 1 Winter (µg/dust) | <0.1-249 | 5 | 35 | | - |
| Der p 1 <i>S/S</i> * (µg/dust) | 0.4-1.5 | 0.6 | 0.3 | | - |
| Der p 1 Winter (µg/dust) | 0.4-11 | 1 | 2 | | - |
| PM ₁₀ <i>S/S</i> * (mg.m-3) | 0.04-0.4 | 0.14 | 0.08 | 0.15 ⁽⁶⁾ | 0.11 |
| PM ₁₀ Winter (mg.m-3) | 0.01-0.1 | 0.08 | 0.03 | | 0.03 |

* *S/S* - Spring/Summer

In the winter season the allergen which concentration is higher than the reference level is Der f 1. Nevertheless the correlation coefficients between allergens, particles and bacteria were not statistically significant.

Figure 1a. and 1b. present the range of bacteria concentrations between the nurseries and the kindergarten classrooms which indicate high median level of bacteria in nurseries than in kindergarten classrooms. Also the levels of CO₂ are 3 times (winter) and 1.4 times (spring/summer) above recommendations. Moreover there is a significant correlation in spring/summer season ($r_{\text{Bacteria/CO}_2} = 0.3$; $P=0.03$) between bacteria and CO₂ levels.

These concentrations of CO₂ are indicators of occupancy and ventilation in the study areas. Some guidance is given by the Finnish Society of Indoor Air Quality and Climate, suggesting 1300 mg/m³ for 'very good', 1650 mg/m³ for 'good', and 2200 mg/m³ for 'satisfactory' indoor air quality [8].

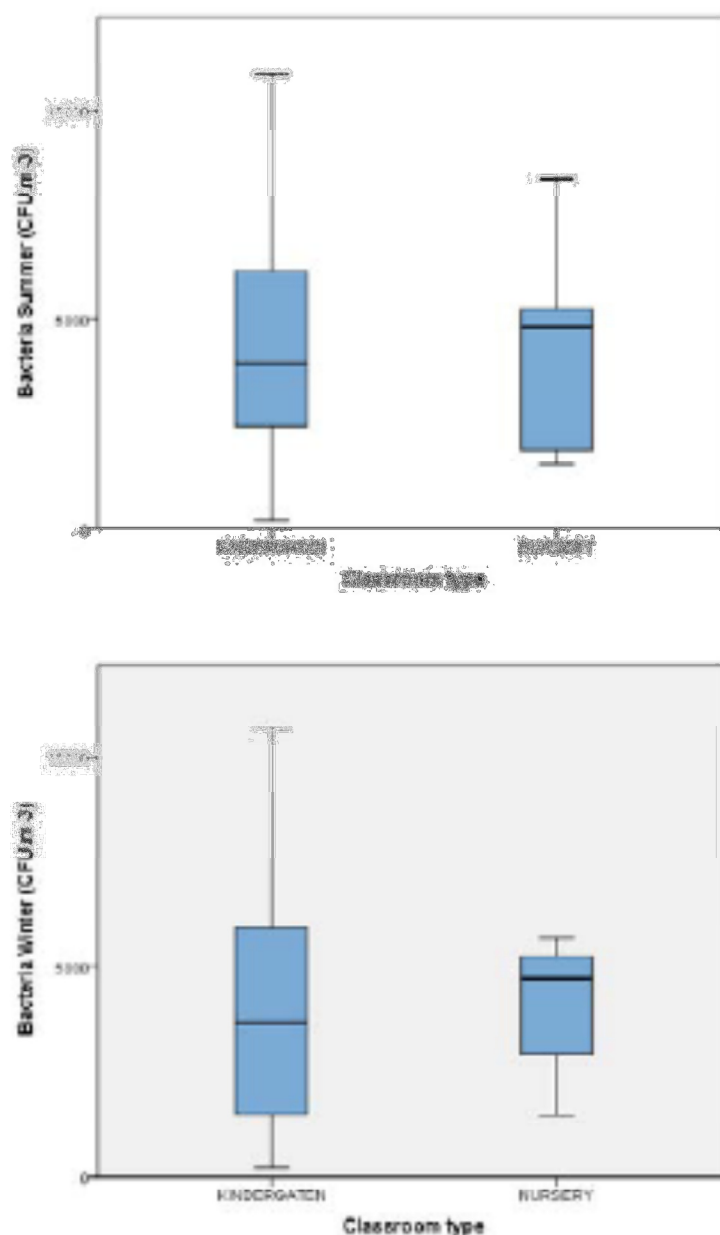


Figure 1a. and 1b. Bacteria concentrations between the nurseries and the kindergarten classrooms

4. Conclusion

Our results provide insights of inadequate indoor bacteria levels most likely due to human source contaminants that accumulate in the rooms. Nevertheless allergens and particles were not related with this biological indoor pollutant. Improvement in hygiene and ventilation measures may be advised to decrease the CO₂ and total bacteria levels in order to achieve a healthier indoor environment for children attending DCCs.

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