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Indoor and outdoor bioaerosol levels at recreation facilities, elementary schools, and homes

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Abstract

One major deficiency in linking environmental exposure to health effects is the current lack of data on environmental exposure. Therefore, to address this issue, the present study measured the bacterial and fungal concentrations in the indoor and outdoor air from two types of recreation facility (42 bars and 41 Internet cafes), 44 classrooms at 11 elementary schools, and 20 homes under uncontrolled environmental conditions during both summer and winter. No major environmental problems were reported at the four microenvironments being investigated during the entire study period. Bacteria and fungi were found in all the air samples, and the environmental occurrence of individual fungi was in the order of *Cladosprium*, *Penicillium*, *Aspergillus*, and *Alternaria*. The six parameters surveyed in the present study were all found to influence the indoor and outdoor bioaerosol levels: microenvironment type, sampling time in elementary school classrooms, agar type for measuring the fungal species, seasonal variation, facility location, and summer survey periods. The indoor and outdoor air concentrations of bacteria and fungi found in this study were comparable to those in other reports, with GM values for the total bacteria and total fungi between 10 and 10^3 colony-forming units per cubic meter of air (CFU m^{-3}). The fungal concentrations found at most of the indoor environments fell within the specified guidelines of the American Conference of Government Industrial Hygienists (ACGIH), between 100 and 1000 CFU m^{-3} for the total fungi. However, the indoor bioaerosol concentrations at most of the surveyed environments exceeded the Korean indoor bioaerosol guideline (800 CFU m^{-3}). Consequently, the current findings suggest the need for reducing strategy for indoor microorganisms at the surveyed microenvironments.

Keywords: Bacteria; Fungi; Fungal species; Microenvironments; Season

1. Introduction

Individual exposure to bioaerosols has become a subject of concern over recent years due to the related adverse health effects. Several studies have reported that exposure to large concentrations of airborne microbes is often associated with asthma and rhinitis (Beaumont, 1988), hypersensitivity pneumonitis (Siersted and Gravesen, 1993), and sick-building syndrome (ACGIH, 1989; Dales et al., 1991). However, the health effects of bioaerosols are only not limited to allergic diseases, as there may also be an association with a number of other health effects, including infections (Dales et al., 1991; Ren et al., 1999). Consequently, the last decade has seen a significant increase in scientific data on nonoccupational exposure as well as occupational exposure to

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bioaerosols in many developed countries for the purpose of evaluating the relationship between exposure and health effects (Górny and Dutkiewicz, 2002). However, for Korea, there is only a limited amount of information currently available on individual exposure to bioaerosols, including a few reports on certain public access facilities, such as hospitals and subway stations (Hong et al., 2003; Lee et al., 2004).

Due to their ubiquitous presence in nature, the presence of bioaerosols is almost inevitable in most enclosed environments (Ren et al., 1999; Jones and Harrison, 2004). In Korea, bars and Internet cafes (or PC room), both enclosed environments, are two of the most popular recreation facilities. A good proportion of bars are located below ground level and their customers invariably complain of a mold odor due to a damp environment, whereas most of Internet cafes are above ground. Internet cafes, where customers can enjoy various Internet services, including online games and chatting, have recently become very popular in Korea for both children and adults. For example, there are currently over 25000 Internet cafes in Korea with the number continuing to growing, and most cafes claim a daily 70% occupancy until 2 a.m. Human beings are an important source of airborne microorganisms in indoor environments (Pastuszka et al., 2000). Thus, it is reasonable that such recreation facilities with a high human occupancy should be investigated as regards the exposure of the customers to bioaerosols, and the results used to evaluate the relationship between exposure and health effects.

In addition, elementary schools are an important facility associated with the environmental exposure of children, and where they spend a large portion of their weekday time. Children are also considered as potentially more vulnerable than adults, as their health is more susceptible to environmental exposure (Guzelian et al., 1992; Aprea et al., 2000). Accordingly, the current study was designed to examine the bioaerosol levels in the indoor and outdoor air at elementary schools and two types of recreation facility (bars and Internet cafes). In addition, households selected from typical residential areas were also surveyed for their indoor and outdoor bioaerosol concentrations. The current study was conducted in Daegu, the third largest city in Korea with a population of 2.5 million and density of 2812 people km^{-2}.

2. Methods

2.1. Survey protocol

The present study measured the bacteria and fungi concentrations in the indoor and outdoor air of two types of recreation facility (bars and Internet cafes), elementary schools, and households under uncontrolled environmental conditions between June 2003 and August 2004. Information on the surveyed recreation facilities and elementary school classrooms is shown in Table 1. Forty-two bars, 41 Internet cafes, and 44 classrooms from 11 elementary schools were surveyed. Twenty homes selected from typical residential areas were also surveyed. An effort was made to geographically disperse the sampling sites throughout the city. The bars were equally classified into two groups (above ground and below ground). The same bars participated in both the summer and winter studies. Furthermore, the summer bar study period was subdivided into two periods (SRFP and NRFP), and all the bars participated in both summer studies. It was expected that the SRFP would provide a more favorable humid environment for microbial growth, resulting in different bioaerosol levels between the two summer periods. Most of the Internet cafes were located on the second floor, with a range from the first to the fifth floor. The Internet cafes and schools were only surveyed during winter, whereas the homes were only surveyed during summer. Similar to the bar study, the household study period was subdivided into two periods (SRFP and NRFP), and all the households participated in both study periods.

Table 1
Information on surveyed recreation and classroom environments

Facility/ school	Sampling season	No. of facilities/ classrooms[a]	No. of occupants[b]	No. of air conditioners operated[c]
Bar	Winter & Summer	42	22.5 (10.9)	34
Internet cafe	Winter	41	28.8 (11.1)	NA
School	Winter	44	37.6 (2.3)	NA

[a] Number of recreation facilities and classrooms surveyed.
[b] Average number of occupants in recreation facilities and classrooms during sampling period; value in parenthesis is standard deviation.
[c] Number of bars operating air conditioners during summer sampling periods; NA, not available.

The indoor and outdoor air measurements were taken concurrently or consecutively at each measurement site. For the recreation facilities and households, the majority of indoor air measurements were taken from the middle of the facility or living room at breathing height, while the outdoor air measurements were taken from outside a window of the surveyed facility or room. The air sampling was performed during regular evening hours (between 19:00 and 22:00) on weekdays (Monday thru Thursday). The classroom samples were collected from the rear of the classroom to minimize the class interruption, and the classroom sampling was performed during morning class time and break times between