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Airborne microbiological characteristics in public buildings of Korea

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Abstract

Characteristics of airborne bacteria and fungi were surveyed in the public buildings regulated in Korea, with the six-stage cascade impactor. The total concentrations of airborne bacteria and fungi were averaged to 404 and 382 cfu m^{-3} in hospital, 931 and 536 cfu m^{-3} in kindergarten, 294 and 334 cfu m^{-3} in elderly welfare facility, and 586 and 371 cfu m^{-3} in postpartum nurse center. Mean respirable concentrations of airborne bacteria and fungi were 194 and 292 cfu m^{-3} in hospital, 358 and 347 cfu m^{-3} in kindergarten, 134 and 266 cfu m^{-3} in elderly welfare facility, and 254 and 289 cfu m^{-3} in postpartum nurse center, respectively. Based on this results, total and respirable concentrations of airborne bacteria and fungi were significantly highest in kindergarten and lowest in elderly welfare facility ($p<0.05$). The ratios of indoor and outdoor concentration for airborne bacteria and fungi were below 1.0 in all the investigated public buildings regardless of size distribution. The dominant genera identified in the public buildings were *Staphylococcus* spp., *Micrococcus* spp., *Corynebacterium* spp., and *Bacillus* spp., for airborne bacteria and *Penicillium* spp., *Cladosporium* spp., and *Aspergillus* spp., for airborne fungi, respectively. Size distributions of airborne bacteria and fungi in terms of the dominant genera were not observed consistently except for *Staphylococcus* spp., which was detected mainly on the first stage (>7.0 μm) and second stage(4.7–7.0 μm), and *Penicillium* spp., and *Cladosporium* spp., showing the highest collection rate at stage 3 (3.3–4.7 μm) regardless of the kind of the public buildings.

Keywords: Airborne bacteria; Airborne fungi; Public building; Six-stage cascade impactor; Korea

1. Introduction

Increasingly the health problems of residents provoked by exposure to various indoor air contaminants have social concerns all over the world because contemporary people spend most of the day in confined indoor spaces. One of indoor air contaminants is a bioaerosol, defined as an airborne particle that is living or originate from living organisms [1]. Airborne bacteria and fungi, also included in bioaerosols, are generally recognized to cause respiratory diseases such as rhinitis, asthma, and pneumonia and can even lead to death especially for those who are physiologically sensitive to them [2–5]. The potential of health risk caused by exposure to airborne bacteria and fungi can occur in workplaces and residential spaces at any time. Moreover, a severity of health problem related to exposure to them can be highlighted still more on indoor spaces where residents like patients, infants and old people, having relatively poor immunity to infections, get along in a group [6–9].

To prevent the spread of such diseases, The Korean Ministry of Environment announced The Act of Indoor Air Quality Management in August 2004. According to the act, the Korean public buildings, hospital, childcare center, elderly welfare facility and maternity recuperation center, which brought about many environmental problems based on sanitary aspect, were regulated in regard to threshold limit value of 800 cfu/m^3 for total airborne bacteria [10]. Until now, there is no country which established lawfully regulated standards related to airborne microorganisms except Korea. Only the reference standards of indoor

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airborne microorganisms for workplace or residential space have been recommended by some foreign governments [11–13] or proposed by researchers [14]. In addition, no domestic study has been conducted to evaluate whether the current standard is pertinent.

Thus, this study was performed to investigate the level and characteristics of airborne bacteria and fungi according to size distribution in hospital, childcare center, elderly welfare facility and maternity recuperation center which were regulated by law in Korea and to present fundamental data that are available to assess validity of the current standard and are necessary for reducing indoor air contamination by airborne bacteria and fungi.

2. Materials and methods

2.1. Subjects

As shown in Table 1, this field study was conducted by visiting hospitals, childcare centers, elderly welfare facilities and maternity recuperation centers located at the southern part of Kyunggi-do province in Korea. They were investigated twice, once in spring (March–May) and autumn (September–November), respectively, in 2004. The subjects were randomly selected among the buildings that belonged to the range as regulated by the The Act of Indoor Air Quality Management and that gave an approval to our phone or written requests for cooperation with this study. The places and times in each building where most of the activities of the residents were carried out were chosen as the measuring points.

2.2. Measurement and analysis

The six-stage viable particulate cascade impactor (Model 10–800, Andersen Inc, USA) at the flow amount of 28.3 l/min was used for sampling airborne bacteria and fungi, and the aerodynamic diameter range for each stage are as follows: 1stage ($>7.0\,\mu m$), 2stage (4.7–7.0 μm), 3stage (3.3–4.7 μm), 4stage (2.1–3.3 μm), 5stage (1.1–2.1 μm), and 6stage (0.65–1.1 μm) [15]. Air sampling has been done for 8–12 min according to the environmental situation of the measurement locations. Measurement was taken at the height of about 1.0 m twice at the same measuring point. For comparison with the outdoor concentration, measurement was conducted simultaneously once at one spot located within 1 m from each building. Before sampling, the inside of the sampler was disinfected with 70% alcohol and then was inserted with the agar plate according to collection stage. Trypticase soy agar (Lot 2087730, Becton Dickinson and Company, USA) where cycloheximide 500 mg was added to suppress the growth of fungi, was used as bacterial culture medium. For fungal culture, Malt extract agar (Lot 3111376, Becton Dickinson and Company, USA) was used where cycloheximide 100 mg was applied to suppress the growth of bacteria. The culture media for which sample collection were finished were immediately taken to the microbe laboratory and were cultured in the incubator for 1–2 days under a 37 °C condition for bacteria and for 3–5 days under a 20–25 °C condition for fungi. The concentration of airborne bacteria and fungi, i.e. cfu/m^3 was calculated by dividing by air volume (m^3) the value obtained from counting the colonies formed on the culture medium after the process of culturing (Eq. (1) and (2)). The total number of the samples was 480 for airborne bacteria and fungi, respectively (Eq. (3)).

$$\text{CFU (Colony Forming Unit)}/m^3 = \text{Colony counted on agar plate}/\text{Air volume}(m^3) \quad (1)$$

$$\text{Air volume}\,(m^3) = 28.3\,\text{l/min} \times \text{sampling time (min)}/10^3 \quad (2)$$

$$\text{Total number of samples} : \langle \text{Measuring spots}(28) \times \text{repetition}\,(2) + \text{outdoor}\,(24)\rangle \times \text{Size stages of sampler}(6) = 480\ \text{units} \quad (3)$$

The genera of all the cultured airborne bacteria were identified according to the classification method of Bergey's manual and, after dying the bacteria by Gram's method, additional identification was carried out by conducting biochemical test through the automated microbial identification system, VITEK (Model VITEK 32 system, bioMerieux Inc., France). On the other hand, the airborne fungal genera were identified according to the classification

Table 1
Characteristics of subjects investigated in this study

Site	Selection bias[a]	Ventilation type	Measurement		No.[b]
			Location	Time	
Hospital	$\geqslant 2000\,m^2$ (area) or $\geqslant 100$ (ward)	Mechanical	Hall	10:30 am–12:00 pm	10
Childcare center	$\geqslant 1000\,m^2$ (area)	Natural	Corridor	11:30 am–1:00 pm	10
Elderly welfare facility	$\geqslant 1000\,m^2$ (area)	Natural	Corridor	11:30 am–1:00 pm	10
Maternity recuperation center	$\geqslant 500\,m^2$ (area)	Mechanical	Hall	11:00 am–1:00 pm	10

[a]Based on The Act of Indoor Air Quality Management regulated in Korea.
[b]T he number of public buildings investigated in each type.