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Int. J. Hyg. Environ.-Health 209 (2006) 249–255
International Journal of Hygiene and Environmental Health
www.elsevier.de/ijheh

Temporal variation of airborne fungi concentrations and related factors in subway stations in Seoul, Korea

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Received 4 January 2005; received in revised form 11 July 2005; accepted 31 October 2005

Abstract

This study was performed to assess the levels of fungi concentration in subway stations in Seoul, Korea, and to investigate factors contributing to these concentrations. Ninety air samples were collected hourly over the course of a day from five different subway stations. In addition, five settled dust samples and 12 stagnant water samples were collected to investigate these as potential sources of fungi contamination. The number of passengers and frequency of passing trains were also determined during the sampling periods, as they were considered potential factors influencing the airborne fungi concentrations at a given time during the day. The airborne fungi concentrations, as a function of time, were log-normally distributed. The airborne fungi concentrations measured during the morning and evening commute hours (during which the number of passengers and frequency of passing trains was highest) were significantly higher than those measured during non-commute hours. High concentrations of fungi were found in the settled dust samples, suggesting that the settled dust may have been the main source of airborne fungi concentration. The air movement generated mainly by passengers and additionally by trains might have played a role in suspending the fungi from the settled dust. It was also found that stagnant water might be a potential source of airborne fungi.

Keywords: Airborne fungi; Subway stations; Temporal variation; Passengers; Trains; Settlled dust

Introduction

Since the first line of the Seoul Metropolitan Subway System was introduced in 1974, a total of nine lines have been constructed and installed over the past 30 years. Currently, approximately 5.5 million people, including children, workers, and senior citizens, use the subway system daily. Thus, the air quality in the subway system is very important for the health of the general public. It was reported that allergic alveolitis and febrile reactions to inhaled mold dust were associated with high exposure levels of fungi (Malmberg et al., 1993). Although there is some information on airborne fungi concentrations in schools, swine confinement buildings and biowaste-handling facilities, the information on airborne fungi in subway stations is very limited (Duchaine et al., 2000a, b; Fischer et al., 2000; Awad, 2002).

The objectives of this study were: (1) to evaluate temporal variation of airborne fungi concentrations in

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doi:10.1016/j.ijheh.2005.10.001

subway stations, and (2) to investigate the factors affecting the temporal variation of these airborne fungi concentrations.

Materials and methods

Sampling and analysis of air samples

In the spring of 2003, a total of 90 air samples were collected every hour from 8:00 to 19:00 from five subway stations in Seoul to evaluate the temporal variation of airborne fungi concentrations. The samples were taken from heights of 70 to 100 cm from the floor at the center of the subway platforms. At each sampling location two simultaneous samples were taken. Air samples were collected using polycarbonate membrane filters (diameter 37 mm, pore size 0.4 μm, Nuclepore Corp., Cambridge, MA) at a flow rate of 3.0 l/min (2.97–3.16) for 60 min (Palmgren et al., 1986). The samples were delivered to an analytical laboratory within 24 h after sampling and analyzed immediately on arrival.

To extract the fungi from the filter samples, 1.5 ml of sterile peptone water (0.1%, w/v, containing 0.01% Tween 80) were inoculated onto the support pad through the outlet of the cassette, after which the connection was plugged up (Dillon et al., 1996). Five milliliters of sterile peptone water was transferred through the inlet hole, and the cassette was re-plugged and vigorously shaken for more than 30 min (at approximately 400 rpm on a shaker table). The cassette was unplugged and the suspension was pulled with a syringe. A portion of the suspension was utilized for the determination of viable fungi by a plate count technique (Palmgren et al., 1986).

A malt extract agar (MEA) with chloramphenicol was used to culture the mesophilic airborne fungi (Macher, 1999). After incubating the MEA plates at room temperature (25 °C) over 7 days, colony forming units were determined. The concentration of airborne fungi was expressed as colony forming units per cubic meter of air (cfu/m^3). The relative humidity and temperature in the subway stations were measured three times, at the 10th, 30th, and 50th minute, respectively, during each 1-h-sampling period.

Samples of settled dusts and stagnant water

A total of five settled dust samples were collected from five subway stations at a flow rate of 19.4 l/min (15.0–25.0 l/min) for 20 min, using a pre-weighed 37 mm diameter, 0.4 μm pore size polycarbonate membrane filter (Macher, 1999, 2001). The sampling was carried out on the surface of the platform and at the lower part between the rail beds to capture the settled dust (Donham et al., 1986). The filter samples were delivered to the laboratory for analysis within 24 h of sampling. The polycarbonate membrane filters were removed from the cassette holders and weighed to determine the total dust mass. The samples were suspended in sterile distilled water and inoculated onto MEA plates (Macher, 1999). All plates were incubated at 25 °C and examined over 7 days.

A total of 12 water samples were collected from stagnant water using 10 ml syringes from three of the five subway stations and one other station. Stagnant water was present near the lower part of the rail beds and at the gutters of the platforms. The samples were taken and delivered to the laboratory for analysis within 24 h of sampling. A portion (0.1 ml) of the water sample was inoculated onto MEA media, cultured at 25 °C, and examined over 7 days.

Statistical analyses

A *W*-test (Shapiro–Wilk test) was employed to determine the type of distribution of airborne fungi concentrations. A *t*-test was employed to evaluate whether the temporal variation of airborne fungi concentrations within a day was significant. Pearson correlation coefficients were calculated to evaluate the relationship between concentrations of airborne fungi and other factors, such as the number of passengers and the frequency of trains passing in a given hour. A regression analysis was performed to confirm which factor was more powerful. All statistical analyses were conducted using the statistical package SPSS 10.0.

Results

Classification of fungi

Results of fungi examination indicated that *Penicillium* spp., *Penicillium janthinellum*, *Aspergillus* spp., *Aspergillus niger*, *Aspergillus nidulans*, *Cladosporium* spp., *Cladosporium cladosporioides*, and *Mucor* spp. were identified from the air samples.

Temporal variation of airborne fungi concentrations in subway stations

Results of the *W*-test indicated that the airborne fungi concentrations in four (Stations A, C–E) of five subway stations were log-normally distributed ($p < 0.05$). Table 1 and Fig. 1 present temporal variations of airborne fungi concentration from 8:00 to 19:00 from five subway stations. Average concentrations by hour ranged from 663 to 1574 cfu/m^3, with an overall mean of 1023 cfu/m^3.