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Distribution of Hospital Airborne Microorganisms in Seoul, Korea

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서울시내 종합 병원 공기중의 미생물 분포

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ABSTRACT

This study was carried out to investigate the airborne microbial pollution in hospital environment. Using a mechanical air sampler, microbiological samples were taken from intensive care unit, general ward room, patients waiting room and outdoor of 20 hospitals in Seoul, Korea. The concentration of airborne bacteria and fungi ranged 97-410 cfu/m^3 and 37-77 cfu/m^3, respectively and patients waiting room had highest bacterial count. 18 genera of molds were identified and the most frequently recovered molds were *Aspergillus*, followed by *Penicillium*, *Alternaria* and *Cladosporium*. Among *Staphylococcus* species, *S. haemolyticus* and *S. epidermidis* were predominant and 47% of *Staphylococcus* species were isolated from intensive care unit.

Keywords: Hospital environment, Airborne bacteria count, Fungi count

요 약

서울에 위치한 20개 종합병원의 중환자실, 일반병동 입원실, 환자대기실과 병원 실외 4곳 공기중의 일반 세균수와 곰팡이수를 측정하였으며, 기회 감염균을 검출하였다. 97-410 cfu/m^{3}의 일반세균수와 37-77 cfu/m^{3}의 진균이 검출되었으며 중환자실이 가장 낮은 미생물의 오염도를 보였으며 환자대기실이 가장 높은 오염도를 나타내었다. 18종의 진균이 분리되었으며 *Aspergillus* spp.가 가장 높은 빈도로 검출되었으며, 그 다음으로 *Penicillium*, *Alternaria*, *Cladosporium* 속 등이 검출되었다. *Staphylococcus* spp. 중에서는 *S. haemolyticus*와 *S. epidermis*가 가장 높은 빈도로 검출되었으며 검출된 *Staphylococcus* spp. 중 47%가 중환자실에서 검출되었다.

I. Introduction

The indoor environment can potentially place human occupants at greater risk than the outside environment, because enclosed spaces can confine aerosols and allow them to build up to infectious doses.[1] Ventilation system can pick up contaminated air and distribute infectious microorganisms to other parts of the building. Ventilation system components can become contaminated with pathogenic microorganisms which are subsequently transmitted to the buildings occupants.[2,3]

With the advancement of medical science and technology today, an increasing number of patients are at risk of acquiring infections during the time of hospitalization. Nosocomial infection is a major problem in many healthcare facilities, with approximately 1 in 10 patients acquiring an infection during a hospital stay.[4] These infections cause much misery and are associated with significant

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morbidity and mortality. In addition, the economic impact of nosocomial infection on healthcare systems is considerable. In Korea, the numbers of patients infected in hospitals are over 135,610 per a year and the additional cost of the medical fee is approximately 35 billion won per year.[5]

Hospital indoor air contains a diverse range of microbial population. The significance of these microorganisms is debatable in some quarters, whereas it may be considered significant. The importance of the estimation of the quantity and the types of airborne microorganisms is that these values can be used as an index for the cleanliness of the environment and the source of hospital-acquired infections.[6] The majority of bioaerosols are not pathogenic and cause disease only in sensitized or grossly immunocomprised individuals, but It is well documented that the hospital environment is a source of acquired infections.[7] For this reason, knowledge of the incidence of microorganism in hospitals is important for the understanding of the possible types of infections and allergies that may accrue from them. Furthermore, controlling the microorganisms in these hospital environments may play a role in the prevention of cross infection.

Geographical and regional levels of indoor microorganisms have not been extensively studied in Korea. This study was performed to investigate the contamination level of indoor air from hospital environment. Airborne microorganisms were identified from intensive care unit, general ward, patient's waiting room and outdoor of hospitals located in Seoul, Korea.

II. Materials and Methods

1. Hospital selection

Three types of hospitals in Seoul were randomly selected according to their bed numbers. Total 20 hospitals were classified as follows: 5 small sized hospitals (100-150 beds), 10 medium sized hospitals (400-900 beds) and 5 relatively large sized hospitals (more than 1000 beds).

2. Air sampling

Over a 10 week period (July to August 2001), serial air samples of 1 cubic meter each were directly impacted onto the surface of the pour-plated Petri dishes with a Surface Air System (SAS) sampler (PBI International, Italy). The sampler was generally located in the center of the room away from open windows or doors at 1.5 m above the ground. Microbes were usually collected between 1 and 3 p.m. and air flow rate was 90 *l*/min. Sampling volume was adjusted to 100 *l* according to SAS manual.

3. Microbial Assay Procedures

Tryptic soy agar, Blood plate agar (5% sheep blood), Rose Bengal agar, Sabouraud dextrose agar, Mannitol salt agar and Baird-Parker agar (Difco, USA) were used for the isolation and propagation of the different microbial communities. The bacterial culture plates were incubated at 35°C for 3 days while fungi cultures were incubated for up to 5-7 days at 25°C. The total number of colony forming units (CFU) was enumerated and converted to organisms per cubic meter of air. Bacterial colonies were initially characterized by morphology and microscopic appearance and identified further by biochemical tests. These tests include: 1) oxidase, catalase, coagulase according to FDA Bacteriological Analytical Manual.[8] 2) identification methods in applied and environmental microbiology using other methods such as VITEK (Biomerieux, Marcy IEtoile, France). Fungi were identified according to the Manual of Clinical Microbiology,[9] which is based mainly on gross colony appearance and microscopic examination of the spore and hyphal mycelium.

III. Results

The number of bacteria and fungi populations from the air of 4 different places of hospital environment were shown in Fig. 1 and 2. The highest population of bacteria was found in patient's waiting room with an average of 410 cfu/m^3, and ICU at the lowest with 97 cfu/m^3 regardless of hospital size. The average number of bacteria in ICU in small hospitals (100-150 beds) were 128 cfu/m^3, medium sized hospitals (400-900 beds) had an average of 88 cfu/m^3 and relatively large hospitals (more than 1000 beds) 96 cfu/m^3. The bacteria counts of general ward room and waiting

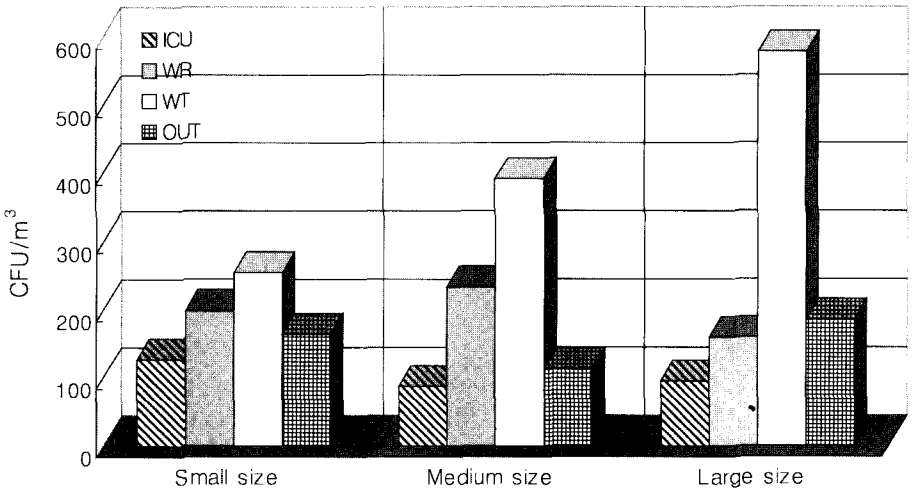

Fig. 1. Bacteria populations of hospitals depending on bed size (ICU : intensive care unit, WR : ward room, WT : patient's waiting room, OUT : outdoor), (Small size : 100~150 beds, Medium size : 400~900 beds, Large size : more than 1000 beds).

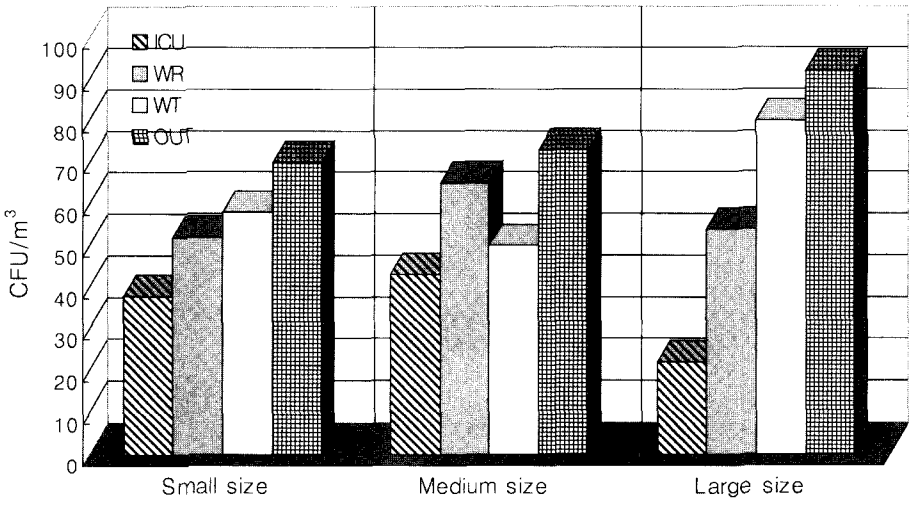

Fig. 2. Fungi populations of hospitals depending on bed size. (ICU : intensive care unit, WR : ward room, WT : patient's waiting room, OUT : outdoor), (Small size : 100~150 beds, Medium size : 400~900 beds, Large size : more than 1000 beds).

room were higher than outdoor air of hospitals, and bacteria count of waiting room was increasing as increasing the size of hospitals because of the large number of patients. Outdoor air of the hospitals showed the higher count of fungi with average 77 cfu/m^3 than indoor air of hospitals. (Fig. 2) The numbers of fungi in ICU of small and medium sized hospitals were showed similar results with an average of 38 cfu/m^3, 43 cfu/m^3, respectively, while those in large hospitals were 22 cfu/m^3, relatively low level of pollution. The results showed that lowest count of bacteria and fungi was observed from ICU of all hospitals and bacteria count of ward room and waiting room were higher than outdoor air.

High-efficiency particulate air (HEPA) filters are rarely used in buildings, even in hospital ventilation systems. We were able to find these devices from

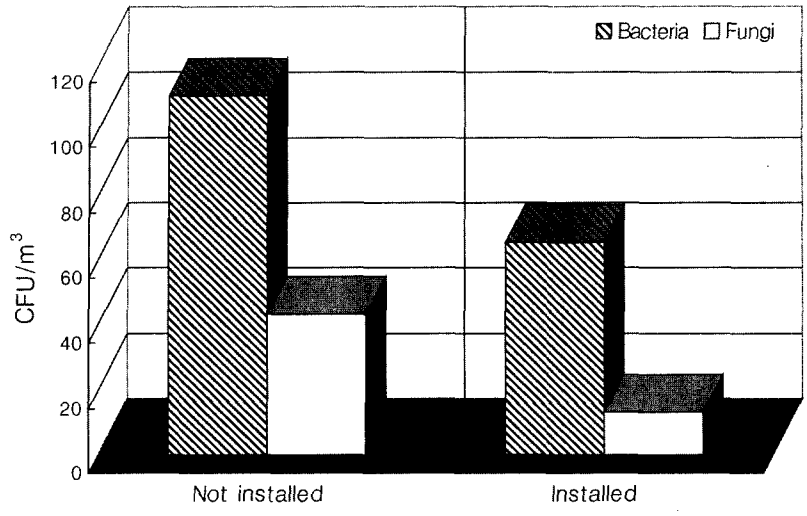

Fig. 3. Microbial distributions of hospitals depending on installation of HEPA filter.

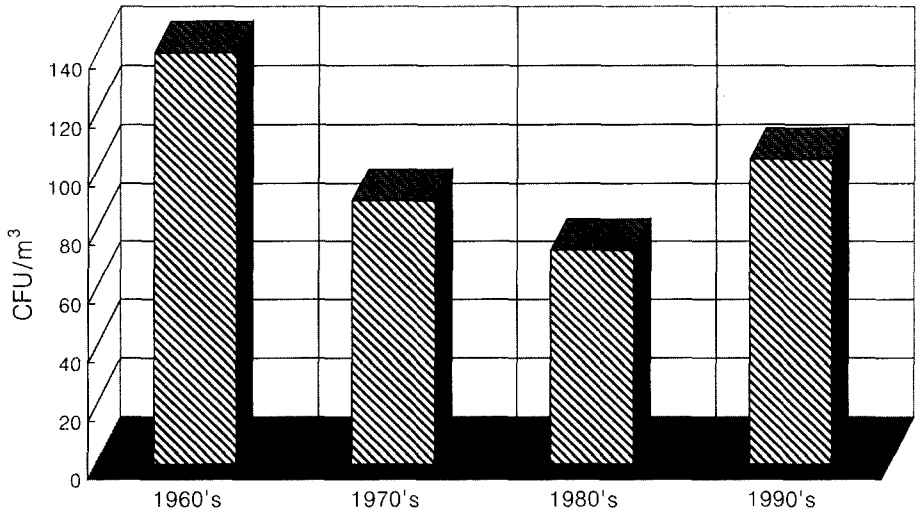

Fig. 4. Microbial populations depending on the construction year of hospitals.

ICU in 4 out of 20 hospitals (20%) that we examined. In ICU with HEPA filter, as far as the bacteria were concerned, it showed 65 cfu/m^3, which was about 40% lower than 108 cfu/m^3 which was found in ICU without HEPA filter. For molds, places with HEPA filter were showed 13 cfu/m^3, about 70% lower than 43 cfu/m^3 shown by ICU without HEPA filter (Fig. 3). In hospitals where HEPA filter was installed, it showed 40%, 70% lower level of bacteria and fungi respectively, compared to hospitals that had no HEPA filter installed. The reason why large sized hospitals have lower air pollution level than other hospitals was considered because of regular cleaning of exhaust devices and the positive effect of installation of HEPA filter device.

In relating count of bacteria in ICU to the construction year of hospitals, two hospitals that were built in 1960's had an average of 140 cfu/m^3, five hospitals that were built in 1970's had an average of 90 cfu/m^3, six hospitals that were built in 1980's had an average of 73 cfu/m^3, while

Table 1. Classification of opportunistic fungi isolated from the different places of hospitals

Microorganism	Number of isolates				
	ICU	WR	WT	Outdoor	Total
Penicillium spp.	20	17	25	10	72
Aspergillus spp.	33	51	47	14	145
Trichoderma spp.	1	2	2	1	6
Cladosporium spp.	6	4	4	5	19
Fusarium spp.	2	3	1	8	14
Alternaria spp.	1	0	4	18	23
Curvularia spp.	2	0	0	8	10
Scopulariopsis spp.	1	0	1	1	3
Monilia spp.	1	1	0	2	4
Yeasts	5	0	2	0	7
Rhizopus spp.	0	3	2	1	6
Scedosporium spp.	0	1	0	0	1
Epicoccum spp.	0	1	0	0	1
Mucor spp.	0	1	1	2	4
Stemphylium spp.	0	0	1	1	2
Phoma spp.	0	0	0	2	2
Chrysosporium spp.	0	0	0	1	1
Paeulomyces spp.	0	0	0	1	1
Chaetomium spp.	0	0	0	1	1
Unidentified	3	9	12	15	39
Total	75	93	102	91	
Average Temperature (℃)	24.8	24.9	24.8	29.2	
Average Humidity(%)	59.3	59.8	59.1	56.8	

Key ; ICU=intensive care unit; WR=ward room; WT= patient's waiting room.

seven hospitals that were built in 1990's had an average of 104 cfu/m^3 (Fig. 4). Although two hospitals that were built in 1960's had a relatively higher pollution level than other hospitals, so did the most recently built hospitals that were constructed in 1990's, which had more bacteria contamination than the hospitals that were built in the 70's and the 80's. At the beginning of this year, a hospital that was built in 1970's modified ICU by installing HEPA filter system and new exhaust devices. And it turned out to be very effective, as it showed lower pollution level than the hospitals that were built quite recently, in the 1990's. Also, it was found that, when the hospitals had an absence of proper ventilating devices, it did not matter whether the hospitals were built recently, because it had a very high pollution level.

The immunocompromised patients are highly susceptible to nosocomial infections caused by organisms such as fungi that were previously considered to be low virulent or non-pathogenic. Table 1 shows hospital fungi isolated from 4 different places of hospital environments. The most common fungi in hospital environment were *Aspergillus* spp. which were accounted for 40% of fungal isolates. The second most common fungi were *Penicillium* spp. (20.3%), followed by *Alternaria* spp. (6.3%) and *Cladosporium* spp. (5.2%). Fungi in the outdoor air was slightly different, with *Alternaria* spp. covering 20%, *Aspergillus* spp. covering 15.5% and *Penicillium* spp. covering 11.1%. From patient's waiting room, one isolate of *A. fumigatus*, 3 isolates of *A. flavus* and 10 isolates of *A. niger* were detected. *A. fumigatus* and *A. flavus*, which are especially virulent, were not detected in ICU and ward rooms, but were detected in patient's waiting room. Therefore, it is vital not to get them exposed to patients who have weak immune systems.

Table 2. Classification of *Staphylococcus* species isolated from hospital environment

Staphylococcus spp.	No. of isolates				
	ICU	WR	WT	Outdoor	Total
S. haemolyticus	8	5	3	4	20
S. epidermidis	11	5	2	-	18
S. saprophyticus	3	3	1	-	7
S. simulans	2	-	1	-	3
S. capitis	3	-	1	-	4
S. cohnii	-	1	-	-	1
S. warneri	-	-	2	-	2
Unidentified	-	1	1	-	2
Total	27	15	11	4	

Key ; ICU=intensive care unit; WR=ward room; WT= patient's waiting room.

There are various different microorganisms which could cause nosocomial infection, but we specifically identified *Staphylococcus* spp. which has become a big issue (Table 2). MRSA (methicillin resistance *S. aureus*) and VRSA (vancomycin resistance *S. aureus*) which are known to be a super - bacteria were not detected, but 57 isolates of CNS were detected. Twenty isolates of *S. haemolyticus*, 18 isolates of *S. epidermidis*, 7 isolates of *S. saprophyticus*, 4 isolates of *S. capitis* and 3 isolates of *S. simulans* were detected. Overall, *S. haemolyticus*

and *S. epidermidis* were predominant CNS. 27 isolates of CNS bacteria were detected in ICU, with 15 in a general ward room, 11 in patient's waiting room, and 4 were detected in outdoor of the hospital. If we look closely, 27 isolates of CNS which was 47% of total CNS were detected in ICU, and this results reflect that in the hospital environment, ICU were contaminated with CNS bacteria more than any other places.

IV. Discussion

Jung (1997)[10] reported that the bacteria count of indoor air in several hospitals in Korea were 282-625 cfu/m^3 and 73% of bacteria were identified as *Staphylococcus* species and 21% were *Micrococcus* species. Total bacteria and fungi counts of indoor air in the houses and apartment in Korea were reported as 420 cfu/m^3 and 130 cfu/m^3.[11] Quantitative study of intensive care unit (ICU) and operating theatre (OT) showed that lower count of bacteria and fungi compared to other area of hospitals, 687 cfu/m^3 in ICU and 473 cfu/m^3 in OT were reported. Most of bacteria identified were CNS in ICU and nearly half of these were *Micrococcus* species in OT.[12] Although there are no established standards for viable or nonviable particulates in the operating room, or in any other hospital area, the number of microorganisms in the OT and the ICU was extremely low.[7] This was anticipated due to the high sanitary standards in these areas, as compared to other hospital areas. The common genera of fungi frequently isolated from the hospital air, *A. niger*, *Chaetomium* species, and an *Alternaria* species have been reported. In air-conditioned homes, there are usually fewer fungi isolates, but a significantly greater number of *Aspergillus* species are present in comparison to the outdoor air.[13]

Quantitative study of 20 different hospitals in this study showed that the patient's waiting room had the highest total count of bacteria and opportunistic fungi such as *A. fumigatus* and *A. flavus* were isolated only from the patient's waiting room. These findings could be explained by many factors including the large number of people in that area. Therefore, in hospital buildings, equal care should be taken when designing and running the ventilation system for patient's waiting room. The contribution made by airborne pathogens to nosocomial infection has often been underestimated. Indeed, it has been calculated that the airborne route of transmission accounts for 10% of all sporadic cases of nosocomial infection. For example. pulmonary aspergillosis results from the inhalation of spores of *Aspergillus* species. The spores are widespread in the outdoor environment and often enter hospital buildings through mechanical ventilation ducts which have inadequate filter protection. Immunocompromised patients are particularly vulnerable to infection from *Aspergillus* species.[14]

Human related organisms or the body normal flora, also found in clothing, are spread through shedding during human activities. The organisms which particularly spread by this way include: *Staphylococcus aureus*, coagulase negative *Staphylococci* (CNS), *Micrococcus* species, alpha haemolytic *Streptococci*, *Diphtheroid* species and Gram negative rods. MRSA is a major problem in many hospitals throughout the world, but MRSA was not isolated in this study. Although infection with MRSA is generally associated with person-to-person contact, airborne transmission of *S. aureus*, including MRSA, has occurred in a variety of settings, including intensive care, burns and orthopedic units.[15-17] Gram positive bacteria such as *Staphylococcus* species possess a peptidoglycan-rich cell wall, which confers relative resistance to desiccation, thus allowing them to survive for considerable periods in the environment and facilitating their distribution around the buildings by air currents.

More information is now available on the level of airborne microorganisms in the hospital environment of Korea. The quantity and quality of microbial population seem to be within reasonable and acceptable limits, but because almost half of CNS isolates in this study were isolated from ICU, it was suggested that standards for air quality in ICU should be established. Concerning the fungi genus identification, *Aspergillus*, *Penicillium* and *Cladosporium*, are the health-related fungi, which are mainly isolated from both indoor and outdoor air.

V. Summary

This study was carried out to investigate the

airborne microbial pollution in hospital environment. Using a mechanical air sampler, microbiological samples were taken from intensive care unit, general ward room, patient's waiting room and outdoor of 20 hospitals in Seoul, Korea. The concentration of airborne bacteria and fungi ranged 97-410 cfu/m^3 and 37-77 cfu/m^3, respectively and patient's waiting room had the highest bacterial count. 18 genera of molds were identified and the most frequently recovered molds were *Aspergillus*, followed by *Penicillium*, *Alternaria* and *Cladosporium*. Among *Staphylococcus* species, *S. haemolyticus* and *S. epidermidis* were predominant and 47% of *Staphylococcus* species were isolated from intensive care unit.

References

1. Samet, J. M. and Spengler, J. D. : Indoor air pollution A health perspective. Baltimore, MD: The Johns Hopkins University Press, 1991.
2. Huddleson, I. F. and Munger, M. A. : A study of an epidemic of brucellosis due to *Brucella melitensis*. *Am. J. Public Health* **30**, 944-954, 1940.
3. Glick, T. H. : Pontiac fever, an epidemic of unknown etiology in a health department. In: Clinical and epidemiologic aspects. *Am. J. Epidemiol.* **107**, 60-94, 1978.
4. Mertens, R. A. F. : Methodologies and results of national surveillance. *Clin. Infect. Disease*, **3**, 156-178, 1996.
5. Woo, J. H., Lee, M. S. and Chung, M. H. : Investigation of nosocomial infection in Korean J. Nosocomial Infect. Cont. **2**, 177-202, 1997.
6. Spendlove, J. C. and Fannin, K. F. : Source, Significance and control of indoor microbial aerosols: Human health aspects. *Public Health* **98**, 229-244, 1983.
7. Gammage, R. B. and Kaye, S. V. : Indoor and human health. Chelsea, MI : Lewis Publishers, 1985.
8. Food and Drug Administration. Bacteriological Analytical Manual. Gaithersburg, MD: AOAC International, 1995.
9. Murray, P. R. and Baro, E. J. : Manual of Clinical Microbiology. Washington DC: American Society for Microbiology, 1996.
10. Jung, S. H. : A Study on airborne microorganisms in hospitals. Seoul, Korea: Seoul National University, 1997.
11. Chung, Y. H., Hong, J. B. and Chang, Y. H. : A study on the microbial air pollution of urban living and indoor environment. *Kor. J. Env. Hlth. Soc.* **27**, 1-9, 2001.
12. Jaffal, A. A., Nsanze, H., Banat, I. M., El Mogheth, A. A., Bener, A. and Ameen, A. S. : Hospital airborne microbial pollution in a desert country. *Environ. Int.* **23**, 167-172, 1997.
13. Kodama, A. M. and McGee, R. I. : Airborne microbial contaminants in indoor environments naturally ventilated air-conditioned homes. *Arch. Environ. Health* **41**, 306-311, 1986.
14. Walter, E. A. and Bowden, R. A. : Infection in the bone marrow transplant recipient. Infect. *Dis. North Am.* **9**, 823-847, 1995.
15. Rutala, W. A., Katz, E. B., Sheretz, R. J. and Sarubbi, F. A. Jr. : Environmental study of a methicillin-resistant *Staphylococcus aureus* epidemic in a burn unit. *J. Clin. Microbiol.* **18**, 683-688, 1983.
16. Kumari, D. N. P., Keer, V., Hawkey, P. M., Parnell, P., Joseph, N., Richardson, J. and Cookson, B. : Comparison and application of ribosome spacer DNA amplicon polymorphisms and pulsed-field gel-electrophoresis for differentiation of methicillin-resistant *Staphylococcus aureus* strains. *J. Clin. Microbiol.* **35**, 881-885, 1997.
17. Farrington, M., Ling, J., Ling, T. and French, G. L. : Outbreaks of infection with methicillin-resistant *Staphylococcus aureus* on neonatal and burns units of a new hospital. *Epidemiol. Infect.* **105**, 215-228, 1990.