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Indoor Air Bacteria in Apartment Homes Before and After Occupancy

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ABSTRACT

A study of indoor air bacteria was carried out in 18 apartments with either a natural or mechanical exhaust or with mechanical exhaust and supply ventilation. Air samples were taken before the apartments were occupied and during three years after the occupation with six-stage impactors on tryptone-glucose-yeast agar. The bacteria levels increased significantly, from GM 170 to 520 cfu/m³ during the first year of occupation and to 1,150 cfu/m³ after two years. After three years, the levels remained at 1,070 cfu/m³. The levels increased irrespective of the ventilation system. The main group of indoor air bacteria were gram positive cocci (60%); gram positive rods and gram negative rods were also frequent.

INTRODUCTION

Airborne bacteria are found everywhere in indoor and outdoor air. Outdoors, bacteria become aerosolized from soil, water, and vegetation. Indoors, the main source of bacteria is humans. Bacteria become airborne by the desquamation of human skin and by sneezing and coughing, which are the main sources of airborne infectious agents.

The role and importance of bacteria as contaminants of indoor air are not well known. There are suggestions about their association with certain diseases, such as humidifier fever (Kohler et al. 1976), or known connections, such as legionellosis (Keleti and Shapiro 1987), but the evidence is mainly epidemiological and from occupational exposure situations.

From the indoor air quality point of view, it is important to know the normal behavior of pollutants to be able to detect harmful levels or otherwise to characterize an unusual exposure situation. Furthermore, the possible value of airborne bacteria as an indicator of indoor air quality should be evaluated. Therefore, information is needed about the normal sources, the range of the typical concentrations, and the main factors that affect their levels. Such information on airborne bacteria has been practically nonexistent.

In this study, the normal indoor air bacteria were monitored in a residential environment in order to provide basic information about their sources, levels, and behavior. To observe the importance of occupancy, the study was carried out in new apartment homes before and during the first three years of occupancy.

MATERIAL AND METHODS

The homes studied were new concrete element townhouses located in Kuopio, eastern Finland, where the climate is subarctic. The houses, six apartments in each, were identical except for the ventilation system, which was either natural ventilation, mechanical exhaust ventilation, or mechanical exhaust and supply ventilation.

Airborne bacteria samples were taken in the fall, when the houses were completed but not yet occupied; in the winter, when the apartments had been occupied for four months; in the spring, after eight months of occupancy; and in the fall during three consecutive years. Samples were taken in the daytime during the weekdays when some of the occupants were staying at home, e.g., mothers with young children, and some were not present, either at work or school. The samples were taken twice a day in the bedroom or in the living room at a height of 1.5 m. Two outdoor air samples were taken daily, first in the morning and then in the afternoon, in the yard of the sampled house.

The bacteria samples were taken with six-stage impactors with a sampling flow rate of 28 L/min on tryptone-glucose-yeast agar with 0.5 mg/mL cycloheximide as a fungicide. The sampling times were 10 to 20 minutes indoors and 20 to 30 minutes outdoors. The Petri plates were incubated at room temperature for three to five days and the colony counts were corrected according to Andersen (1958). The concentrations of bacteria are reported in units of cfu/m³ (colony-forming units per cubic meter of air).

Eight six-stage samples were chosen for further characterization of bacterial colonies. All the colonies, about 1,500 in all, were isolated from these samples. All strains were gram stained, and oxidase and catalase tests were made. Gram positive rods were tested for sporulation, and the motility, growth at different temperatures, and ability to hemolyze blood and utilize casein were screened. Appropriate types of API kits were used to confirm the identification.

RESULTS

The concentrations of bacteria in indoor air varied from 170 cfu/m³ to 12,000 cfu/m³. The distributions of the counts were close to lognormal and, therefore, the levels are expressed as geometric means (GM) in Table 1. The geometric mean of the bacteria levels in newly completed, unoccupied apartments was

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TABLE 1
Levels of Airborne Bacteria
(Geometric Mean, GM; Geometric Standard Deviation, GSD)
in New Townhouses before Occupancy
and During the First Three Years of Occupancy

Group of Samples		Bacteria Levels cfu/m^3 GM	GSD
Fall	Before occupancy	170	0.47
Winter	After occupancy	140	1.45
Spring		680	0.91
Fall	After 1 yr of occupancy	520	0.90
Fall	After 2 yrs of occupancy	1,200	0.80
Fall	After 3 yrs of occupancy	1,100	1.12
Outdoors		110	1.38

170 cfu/m^3 and increased statistically significantly ($p < 0.0005$) during the first year of occupancy to GM 520 cfu/m^3, as seen in Figure 1. After two years of occupancy, the levels had risen further to GM 1,150 cfu/m^3, which again was significantly ($p < 0.0005$) higher than a year before. This increase occurred in all three townhouses with six apartments each, regardless of ventilation system. After three years, the bacteria levels had stabilized to GM of 1,070 cfu/m^3. During all these sampling periods, the outdoor bacteria levels were of the same order of magnitude, GM 110 to 150 cfu/m^3 (Figure 1).

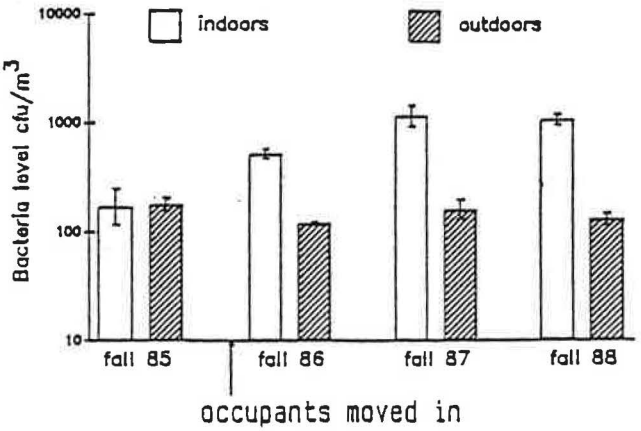

Figure 1 *Bacteria levels in new townhouse apartments before occupancy and after one, two, and three years of occupancy*

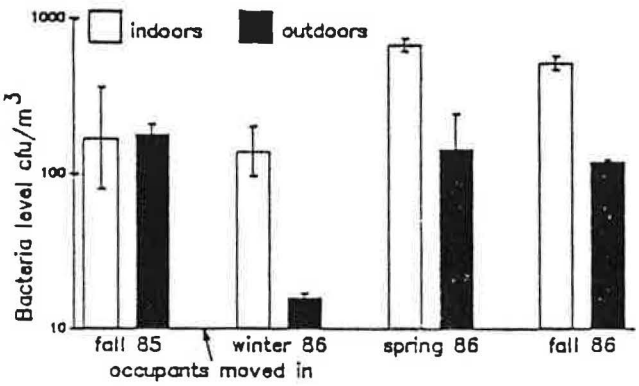

Figure 2 *Bacteria levels in new townhouse apartments before and during the first year of occupancy*

The bacteria levels during the first year of occupancy are presented in Figure 2. The geometric means of the bacteria levels were 140 cfu/m^3 in the in the winter, 680 cfu/m^3 in the spring, and 520 cfu/m^3 in the fall.

Of the bacterial strains identified, 60% were gram positive cocci, 23% gram positive rods, and 14% gram negative rods. In outdoor air, the percentages were 3%, 19%, and 78%, respectively. The most common genera in indoor air were *Micrococcus* and *Staphylococcus*, while that of the outdoor air was *Pseudomonas*.

DISCUSSION

The variation of the levels of airborne bacteria was wide—three orders of magnitude—even if the sampled rooms were normal residential environments with no other evident sources than the occupants and their everyday activities. Hence, bacteria levels in residential indoor air do not necessarily indicate either the absence or the presence of any unusual source of bioaerosols. The levels in this study were remarkably higher than those reported recently by Macher et al. (1991), who reported median concentrations of 98 cfu/m^3 in a new apartment. The differences between the absolute levels may partly be due to different sampling procedures (single-stage sampling simultaneously for bacteria and fungi vs. six-stage sampling on bacteria medium only in our study) and partly due to the fact that the apartment studied by Macher et al. was only occupied by one person who was absent daily. In our study, at least two persons were living in each apartment.

The results show that occupancy of an apartment brings along a population of airborne bacteria. Apparently it takes two years before the bacterial accumulation from the occupants and their activities becomes stabilized. Although it is known that humans are an important source of airborne bacteria (Lidwell 1948), this accumulation of bacteria in indoor air in up to two years of occupation is a new finding. The reasons for this accumulation are not obvious. The number of persons living in the apartments did not increase during the study period. There was no marked decrease in ventilation rates either, which would have explained the accumulation of bacteria.

During the first year of occupancy, the bacteria levels were monitored in different seasons (Figure 2). The total number of bacteria was almost the same in the unoccupied apartments and after four months of occupation. However, there was a significant difference in the bacterial flora. In the unoccupied apartments, the bacteria were mostly those of the outdoor air, while in the winter samples, the indoor air bacteria were of human origin and, in parallel, outdoor levels were very low due to the snow cover. In the results of this winter sampling, the indoor levels are clearly higher than those outdoors, which shows the importance of the intramural sources to the indoor air bacteria levels. This can also be seen in the spring and fall samples of the first year of occupation. Even if the outdoor levels were higher after the snow cover had melted, the indoor levels were clearly higher than those outdoors.

The dominating group of indoor air bacteria were the closely related genera *Staphylococcus* and *Micrococcus*. They are typical bacteria of the human skin, which evidently is the main bacterial source in residential environments. The indoor air bacterial flora differed from that outdoors, where *Pseudomonas* was the dominating genus.

CONCLUSIONS

The conclusions of this study are:

1. The bacteria levels in indoor air in homes have a wide range, 10^2 to 10^4 cfu/m^3. The absolute numbers of bioaerosol con-

centrations are, however, strongly dependent on the sampling and analytical method used.

2. Outdoor levels of bacteria are low, $\leq 10^2$ cfu/m^3, in the winter of a subarctic climate when the ground is frozen and covered with snow. From spring to fall, the levels are more variable, $< 10\text{–}10^3$ cfu/m^3.
3. In new homes, levels of airborne bacteria increase due to the occupants and their activities. Bacteria are accumulated for as long as two years after occupancy, after which they stabilize to the final level.
4. The *Staphylococcus/Micrococcus* group includes the dominating bacterial genera in indoor air but is a minor group in outdoor air.
5. Data bases are needed about the normal bacteria levels in indoor air in order to determine an unusual exposure situation.

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