

## COMPARISON OF AIRBORNE MICROBIAL LEVELS IN SCHOOL KITCHEN FACILITIES AND OTHER SCHOOL AREAS

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### ABSTRACT

Airborne microbial conditions of the kitchens, dining halls, and main study areas were compared in six moisture damaged index schools and two non-damaged reference schools. The average total viable fungal concentrations were lower in the reference than in the index schools in all three types of spaces investigated; however, the difference was statistically significant only for the main study areas. The levels were also always rather low. The same fungal genera and groups, *Penicillium*, yeasts, *Cladosporium*, and *Aspergillus* were dominant in all space types. The amount of different fungal genera detected in a certain type of space was found to have a linear relationship with the amount of samples taken. The bacterial concentrations increased in the order: kitchens, dining halls, and other spaces. This was mainly due to differences in cleaning, occupant density, and ventilation efficiency.

### INDEX TERMS

Mold, Bacteria, Schools, Moisture damage, Indoor air quality.

### INTRODUCTION

An extensive study on moisture and microbial problems has been carried out in Finnish schools (Haverinen *et al.* 1999, Meklin *et al.* 2000). As a part of it, a substudy was conducted in the school kitchens and dining halls. Especially the kitchens were considered to be vulnerable for fungal growth due to large amounts of water used for cleaning. In addition, potatoes, carrots, and other edible roots, which belong to the indoor sources of fungal spores, are frequently handled in the kitchens. It was, however, detected that the airborne and surface concentrations of fungal spores remained low in the kitchens. Bacterial counts were higher than the fungal levels, but those were not especially high either (Kalliokoski *et al.* 2000). In this paper, the airborne microbial flora of school kitchens, dining halls, and the main study areas are compared.

### METHODS

The study included eight schools, six of which were classified as moisture-damaged ones (index schools) and two were non-damaged reference schools. All the schools were made of concrete or brick. As shown in Table 1, the level of damage was clearly more serious in the index schools than in the reference schools. The differences in the damage densities (amount of damage areas/m<sup>2</sup>) were also statistically significant both in the kitchens and other areas. Damage areas included damage classes 2 and 3 (on the five classes grading; Nevalainen *et al.* 1998, Lignell *et al.* 2000). More serious damage (classes 4-5) was not detected.

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**Table 1.** The amounts of moisture damage and their ratios to the floor areas in the school kitchens and in the other school areas (including both dining halls and the main study areas).

School	Kitchens		Other areas	
	Amounts of damage	Amounts of damage / floor area	Amounts of damage	Amounts of damage / floor area
1	15	0.083	105	0.010
2	4	0.043	61	0.019
3	3	0.055	64	0.011
4	4	0.030	96	0.019
5	3	0.065	56	0.017
6	11	0.134	130	0.042
7	2	0.019	28	0.009
8	3	0.011	31	0.003

Microbial sampling was done by using Andersen six-stage impactor. Fungal samples were taken on 2% malt extract agar (MEA) and on dichloran glycerol agar (DG 18). Tryptone glucose yeast agar (TGY) was used for bacteria. After incubation, the microbial colonies were counted and fungi identified by genus using a microscope. The method has been described elsewhere (Meklin *et al.* 2002). Air sampling was carried out in two or three consecutive winters. The amount of samples was 2-12 in the kitchens, 4-14 in the dining halls, and 14-108 in the other areas.

## RESULTS

The results of the total viable fungal concentrations in the air of various space types are presented in Table 2. The counts obtained with MEA and DG 18 were similar, therefore, only the MEA results are presented.

**Table 2.** Total airborne concentrations of viable fungi [cfu/m<sup>3</sup>].

School	Kitchens	Dining halls	Other areas
1	118	54	32
2	61	36	74
3	27	19	67
4	8	11	28
5	11	6	27
6	25	89	102
7	53	21	10
8	2	1	31

The mean concentrations were low and rather similar in various types of spaces. In the index schools, the mean levels were 42 cfu/m<sup>3</sup> in the kitchens, 36 cfu/m<sup>3</sup> in the dining halls, and 55 cfu/m<sup>3</sup> in the other areas. The corresponding values were 27, 11 and 21 cfu/m<sup>3</sup> in the reference schools. The difference is statistically significant only for the other areas. On the other hand, there was no significant correlation between the concentrations observed in different spaces.

The airborne concentrations of viable bacteria are listed in Table 3. The differences both between different types of spaces and index and references schools were larger for bacteria than for fungi. The mean bacterial concentrations in the air of the index schools were 351

cfu/m<sup>3</sup> in the kitchens, 677 cfu/m<sup>3</sup> in the dining halls, and 1074 cfu/m<sup>3</sup> in the other areas. The corresponding concentrations were 119, 236, and 617 cfu/m<sup>3</sup> in the reference schools.

**Table 3.** Total concentrations of airborne viable bacteria [cfu/m<sup>3</sup>]

School	Kitchens	Dining halls	Other areas
1	643	454	1382
2	921	506	639
3	181	107	1495
4	26	229	1287
5	54	20	545
6	282	2745	1098
7	176	411	795
8	61	60	438

The amounts of different fungal genera and groups detected in different schools are presented in Table 4. The mean numbers were 5, 5.9, and 13.6 in the kitchens, dining halls, and other areas, respectively.

**Table 4.** The amounts of different fungal genera and groups detected. The amount of samples is given in the parenthesis.

School	Kitchens	Dining halls	Other areas
1	4 (4)	5 (6)	11 (24)
2	8 (2)	7 (4)	8 (14)
3	5 (6)	8 (14)	24 (100)
4	4 (6)	6 (8)	18 (108)
5	3 (2)	5 (4)	7 (22)
6	4 (2)	7 (4)	13 (50)
7	11 (12)	8 (12)	17 (108)
8	1 (8)	1 (8)	11 (56)

The four most common genera and groups were *Penicillium*, yeasts, *Cladosporium*, and *Aspergillus* in this order in all three types of areas. The fifth most frequent genus was *Aureobasidium* in the kitchens and main study areas and *Eurotium* in the dining halls.

Only yeasts were detected in the air of the kitchen and dining hall of the reference school 8, whereas 12 different fungal genera and groups were observed in the air samples of the other reference school 7 including three moisture indicator fungi (Samson *et al.* 1994, Flannigan and Morey 1996). The fungal flora was more versatile in the other areas of the reference schools containing 17 genera in the school 7 and 10 genera in the school 8. Among them, 4 moisture indicative genera were detected in the school 7 and 3 genera in the school 8. In addition, *Aspergillus* species that are regarded as moisture damage indicators (*A. versicolor* and *A. fumigatus*) were observed.

The amount of different fungal genera was 3-8 in the kitchens and dining halls of the index schools. More genera, 7-24, were again detected in the other areas. The amount of moisture damage indicator genera was low (0-1) in the index kitchens. In addition, *A. versicolor* was observed in one of the index kitchens. The indicators were also rather rare in the dining halls (1-3 genera/kitchen and *A. versicolor* and/or *A. fumigatus* present in two kitchens) and again most common in the other areas (1-6 genera and indicator *Aspergillus* species present in all six index kitchens).

## DISCUSSION

In spite of large damage areas, the total concentrations of viable fungi were significantly higher only in the main study areas of the moisture-damaged schools than in the reference schools. This difference was also observed in the schools with concrete/brick construction in the larger data base of the whole school study (Meklin *et al.* 2002). In this study, all schools were made of concrete or brick. The sources were located mainly in the kitchens and in the main study areas. The fungal concentrations in the dining halls, which were generally also situated between the two source areas, laid usually between the levels in the kitchens and main study areas. Although the highest total counts of viable fungi were detected in the most damaged kitchens and main study areas the airborne concentrations did not correlate well with the amount of the damage areas or with its ratio to the floor area. The latter was, however, found to be a practical and graphic measure of damage degree, which also clearly separated the reference schools from the index schools. It was originally assumed that the highest microbial counts would be found in the kitchens due to large quantities of water used in them. This appeared not to be true. Obviously, the frequent washing also helped to maintain good general hygiene and was probably an important reason for the low levels of airborne microbes. In addition, the occupant density was lower and the ventilation more efficient in the kitchens than elsewhere in the schools.

*Penicillium*, yeasts, *Cladosporium*, and *Aspergillus* were clearly the most common fungal genera and groups in all three space types. This same order also appeared in a larger Finnish study of occurrence of fungi in indoor air and moist building materials (in six day-care centers and 12 residences; Hyvärinen *et al.* 2001) and also in whole school study (Meklin *et al.* 2002). Other genera, *Oidiodendron*, *Aureobasidium*, *Acremonium*, and *Stachybotrys*, found frequently in both studies, were also common in the main study areas of the schools investigated in this study. In another recent Finnish study, which included two residences, the same order was again observed in the reference building, whereas the order was slightly different, *Penicillium*, *Aspergillus*, yeasts, *Cladosporium*, in the index building (Hyvärinen *et al.* 2001).

The presence of a large amount of different fungi, and especially certain fungal genera and species are commonly regarded as indicators of a moisture problem (Samson *et al.* 1994, Flannigan and Morey 1996). In this study, there was a strong influence of the amount of the samples on the number of fungal genera in the main study areas. When 100-108 samples were taken, the average amount of different fungal genera was 19.7, with 50-56 samples the average number was 12.0, and with 14-25 samples only 8.7. Similar phenomenon was also obvious for the kitchen and dining room samples. Because there was a large variation in the amount of samples not only between the schools but also between the three space types, the results cannot be directly compared.

The fungi regarded as indicators of moisture problems were not commonly detected in the kitchens. However, this may well be due to the small amount of samples taken. The indicator fungi were detected in every school (also in the reference schools) in the main study areas where the amount of samples was much larger than in the kitchens.

It has been reported already earlier (Kalliokoski *et al.* 2000) that bacterial growth seemed to constitute a larger problem than fungi in the school kitchens. It was an interesting finding that the bacterial levels were also rather systematically higher elsewhere in the index schools than in the reference schools. This is also somewhat surprising because people are usually a major bacterial source indoors and there were always large amounts of students present.

## CONCLUSION AND IMPLICATIONS

The most important finding was that the versatility of fungal flora seems to be strongly influenced by the amount of samples taken. The relationship was almost linear and showed no clear tendency to level off even at the largest sample sizes ( $n \leq 100$ ). Thus, it is important to sample all the spaces equally to guarantee their comparability. Less samples have often been taken in the reference rooms than in the index rooms. This disproportion may have even influenced on the validity of some of the previous conclusions. Another interesting result was the difference observed in the airborne bacterial levels between moisture-damaged and reference schools in all kind of spaces. Because no bacterial classifications were made, it is impossible to conclude if this was related to the moisture damage or merely an indicator of insufficient ventilation.

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