MICROBIAL INVESTIGATIONS AND ALLERGEN MEASUREMENTS IN GROUND-COUPLED EARTH-TO-AIR HEAT EXCHANGERS

B. Flückiger, C. Monn

Institute for Hygiene and Applied Physiology, Environmental Hygiene Section, ETH Zurich

ABSTRACT

Different ground-coupled earth-to-air heat exchangers have been constructed in many residential and occupational buildings in Switzerland to precool or preheat the incoming air. Many technical and energetic facts favour such systems. The objective of this study was to determine if microbial growth occurs within these tubes and if adverse health effects must be considered. The results show large reductions in viable bacteria and spore concentrations along the tubes and very low concentrations in the supply air compared to the outdoor air. Fungal allergens however, could still be detected in the supply air even if no or only very small amounts of spores were determined with the viable sampling techniques. Based on the results from this study the operation of ground-coupled earth-to-air heat exchangers is acceptable. Regular controls and cleaning of the facilities should be undertaken.

INTRODUCTION

Many buildings with modern energy concepts are equipped with mechanical ventilation. In Switzerland ground-coupled air systems have been constructed in combination with heat recovery units in order to precondition the incoming air. In buildings of variable size and purpose (one-family houses, dwellings, commercial buildings) the incoming air is drawn through a piping system which is buried underneath the building or along the construction pit. The piping systems with their collecting and distributing ducts vary in size, design, pipe material (plastic or concrete) and in the filter quality used in the heat recovery units. Since the relative humidity (rh) is very high and the temperatures are moderate within the pipes, concern has arisen regarding the hygienic aspects of ground-coupled air systems. Studies of conventional ventilation systems have demonstrated that microbial contamination has in many cases caused discomfort or adverse health effects [1]. The crucial factor for microbial proliferation within ventilation systems seems to be the water availability [2,3,4]. Since condensation occurs and standing water was noticed in a number of pipe-systems microbial growth must be considered, especially since the accumulated dust inside the pipes presents an adequate substrate.

The aim of this study was to determine if microbial growth does occur in existing ground-coupled air systems and if the supply air might become contaminated with a concomitant risk for a health hazard. A cross-sectional investigation of viable spores and bacteria in different kinds of ground-coupled air systems as well as a one-year study in three selected buildings was carried out. In addition, the allergen concentrations of the important outdoor moulds *Alternaria* and *Cladosporium* were determined repeatedly in four of the air systems. The allergen measurements were performed since the first samplings showed a large decrease in the airborne spore concentrations along the buried pipes [5]. The measurements should help to investigate the fate of the sedimented microorganisms. The results will allow a better estimation of the exposure to fungal allergens which might be present in the supply air.

METHODS

Investigations were carried out in twelve ground-coupled earth-to-air heat exchangers to determine the concentrations and the genera of microorganisms in outdoor air (Figure 1, a), in the air at the end of the earth tubes (e) and in the supply air (f). The buildings were selected to represent the spectrum in design, pipe material, size and age of all the ground-coupled air systems built in Switzerland. Included were therefore four one-family houses and eight large buildings with cement or plastic pipes and various purposes (dwellings, office buildings, school house, restaurant, food markets). The air systems were between one and thirteen years old.

Three buildings (one-family house, office building, school house) were examined quarterly to cover seasonal changes. For a better estimation of the exposure of allergic patients to the allergens of the moulds *Alternaria* and *Cladosporium*, allergen concentrations were determined in addition to the viable spore concentrations in four earth-to-air heat exchangers during spring, summer and autumn (at the sites a, e, f). In three buildings additional sampling was once performed at sites b and d to look at the influence of the long tubes and the curves and angles of the air stream on the concentrations of airborne microorganisms.

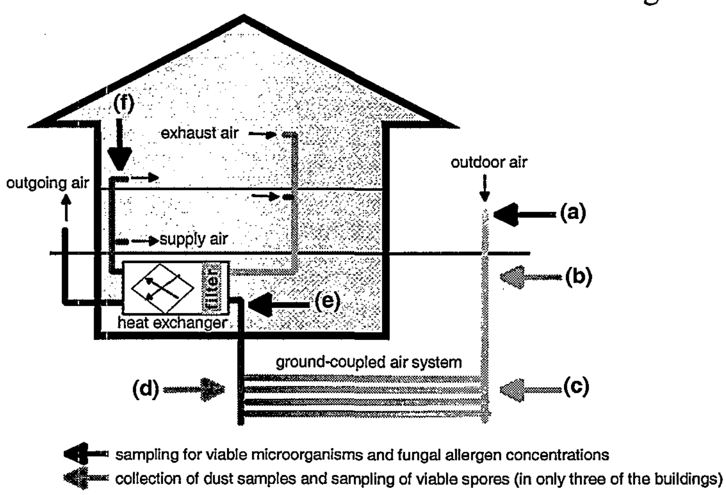

Figure 1. Scheme of a ground-coupled air system. The sites, where samples for viable spores and bacteria, fungal allergens, and dust were collected, are indicated.

A Slit-Sampler (FH2, Loreco Reckert, Germany) with petri dishes filled with Malt Extract Agar (MEA) for the sampling of viable fungi and Tryptic Soy Agar for viable bacteria was operated. In addition, Multistage Liquid Impingers [6] filled with phosphate buffered saline (containing 0,05% Tween 20) were used for size-selective sampling of viable spores and spore fractions containing fungal allergens. The viable spore concentrations collected in the liquid were determined by plating out 1ml samples from each of the three stages of the impingers onto MEA. Together with the MEA plates from the Slit-Sampler, they were incubated at room temperature for five days, colonies were counted and identified microscopically to genus level. Bacteria were grown at 30°C and colonies were grouped according to morphology. The gram positive were microscopically grouped into rods, cocci and actinomycetes. All the results were expressed as colony forming units per cubic meter of air (CFU/m^3).

For the quantification of the airborne fungal allergens, a direct competitive ELISA (Enzyme Linked Immunosorbent Assay) [7] for *Cladosporium herbarum* and *Alternaria tenuis* with sera from allergic patients was used. Microtiter plates were coated with *Alternaria* or *Cladosporium* extracts (Allergopharma Joachim Ganzer KG). The samples from the impingers or dilutions of the extracts for the standard curve were mixed with the patient serum, added to the plates and incubated. The remaining IgE-antibodies to *Cladosporium* or *Alternaria*, which had not reacted with the sample and were therefore free to be captured by the coated antigens, were detected with enzyme labeled antibodies. The results were calculated to Biological Units (BU) per m^3 of sampled air.

Dust samples from both ends of the earth tubes (c, d) were collected with a vacuum cleaner equipped with an ALK-attachment (Allergological Laboratory, Denmark) to collect the dust on an glass fibre filter. The dust samples were suspended in phosphate buffered saline and analysed for viable spores, protein concentration (Lowry Protein Assay) and allergen content (ELISA). The results were given as CFU, mg protein, or BU/g dust.

RESULTS

Viable spores and bacteria

In general, the concentrations of fungal spores and bacteria in the air of the underground pipes were lower than in the outdoor air (Figure 2). Larger reductions in the concentration of the airborne microorganisms were found in the tubes of large buildings compared to one-family houses. Very low concentrations of viable bacteria and fungal spores were observed in the supply air.

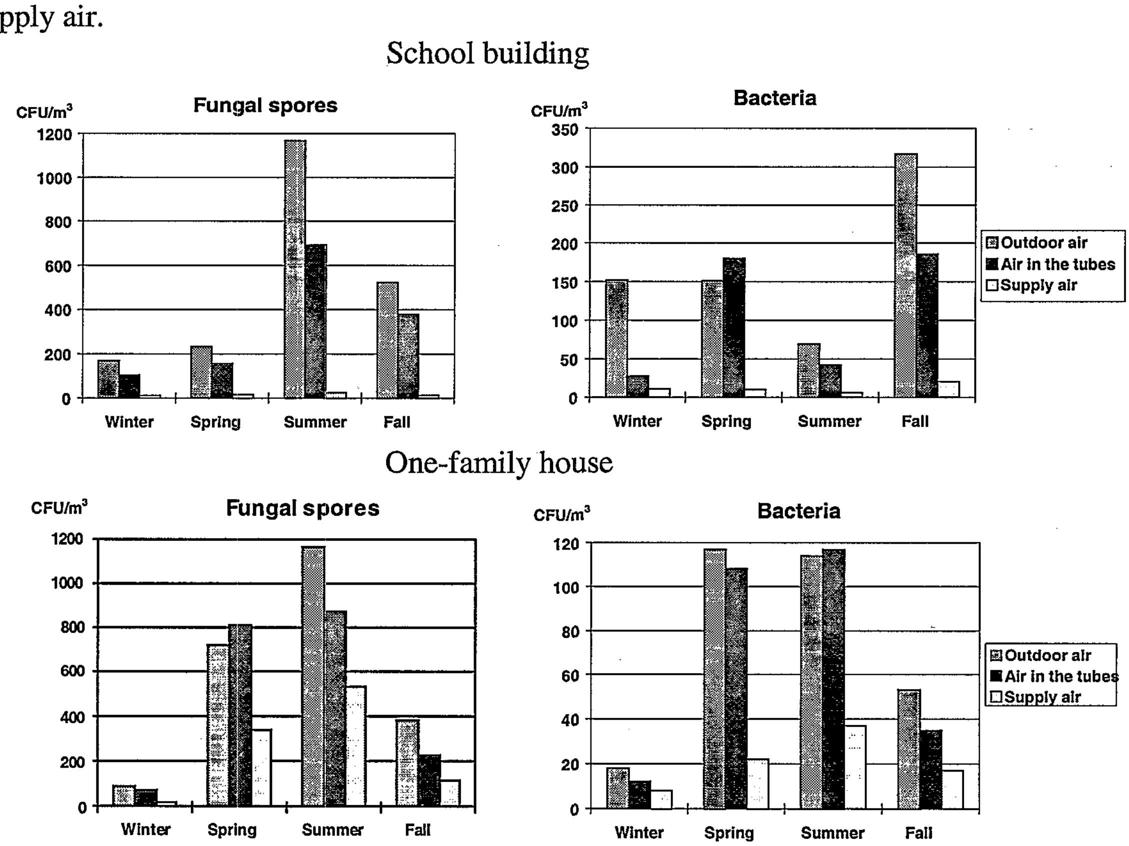

Figure 2. Fungal spores and bacteria in the outdoor air, in the air of the tubes and in the supply air of a school building and a one-family house.

The most abundant fungal genus in the outdoor air year-round was *Cladosporium* with 60-90% (in summer almost 100%) of the total viable spores. Other fungal spores found frequently were *Penicillium, Aspergillus, Botrytis, Alternaria, Fusarium, Mucor* and many more. The lower spore concentrations in the supply air were mainly due to a decrease in *Cladosporium* spore concentration. Occasionally, an increase of the concentration of one single fungal genus (*Penicillium* or *Aspergillus*) compared to the outdoor air was noted in the air of the earth tubes, but never after the filter units.

The results of the additional sampling points show that the concentration of viable spores almost gradually decreases along the pipes of the ground-coupled air systems (Figure 3). In the school house a slight and statistically not significant increase in viable spore concentration was noticed just behind the air intake. Office building A is equipped with a coarse filter at the air intake and already lower concentrations are recorded behind the air intake compared to the outdoor air. The general decrease along the way of the air stream may be explained by sedimentation and impaction of the spores on the bottom of the tubes and on the walls. Dust sampling at both ends of the buried pipes revealed higher concentrations of sedimented spores at the end of the pipes than at the beginning. *Cladosporium* was the most abundant genus (beginning of the pipes: 500-50'000 CFU/g dust; end of pipes: 3'500-370'000 CFU/g dust). The lowest concentrations of viable spores in the dust were found in office building A with the coarse filter at the air intake.

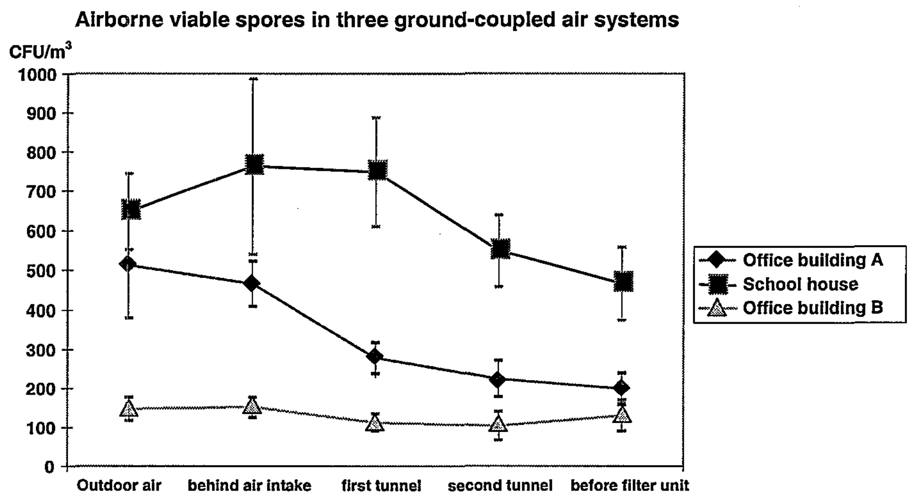

Figure 3. Decrease of airborne viable spores along the ground-coupled air systems of two office buildings and one school house during the sampling in winter 1998. The mean concentrations at each point and the standard deviations of the different samples (n=10) are indicated.

Allergen concentrations

To determine the airborne allergen concentrations Multistage Liquid Impingers were used. The liquid samples in the three stages of the impingers were analysed for viable spores to evaluate the sampling efficiency of the impingers by comparing the concentrations with the Slit-Sampler results. The correlation of the two sampling techniques was strongly significant for all the viable fungal spores ($r_s=0.89$, $p<0.001$) and the *Cladosporium* ($r_s=0.93$, $p<0.001$) and *Alternaria* ($r_s=0.77$, $p<0.001$) concentrations.

The *Cladosporium* allergen concentrations detected with the ELISA in all the samples show a weak but significant correlation with the viable *Cladosporium* spores collected with the impinger and the Slit-Sampler (both $r_s > 0.33$, $p < 0.05$). No significant correlation between the allergen concentrations and the viable spore counts of *Alternaria* was observed.

The strongest correlation between allergen concentrations and viable spore concentrations was observed outdoors. In the supply air, where no viable *Alternaria* spores were found and the concentrations of *Cladosporium* spores were very low, no significant correlation was found between the concentrations of viable spores and allergens. The ratio of the allergen concentrations and the viable spore concentrations in the supply air were generally much higher than outdoors but also more variable (Figure 4).

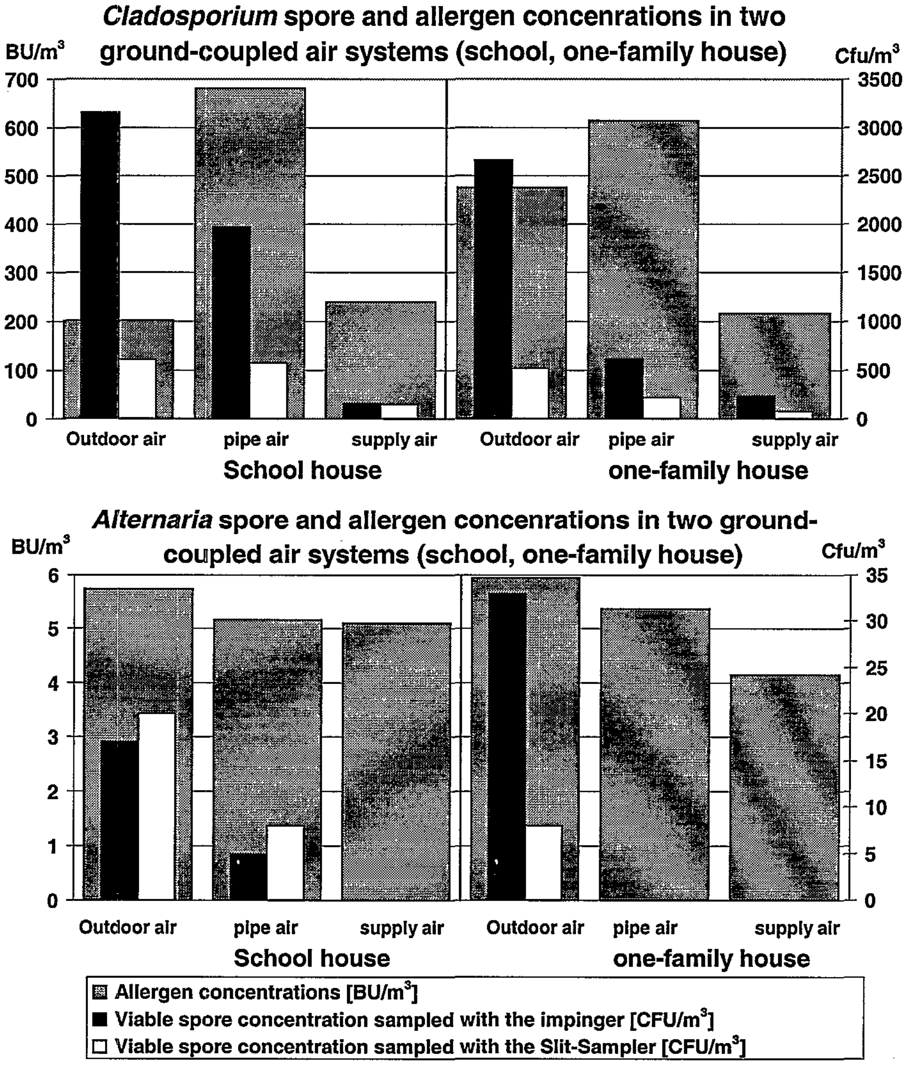

Figure 4. Concentrations of viable spores and allergens of *Cladosporium* (top) and *Alternaria* (bottom) in the outdoor air, in the pipe air and in the supply air of a school building and a one family house in late summer 1998.

DISCUSSION

This study was performed because of concerns of potential microbial growth in the buried pipes of ground-coupled air systems. The results however demonstrate, that no harmful growth occurs and that the airborne concentrations of viable spores and bacteria, with few exceptions, even decreases after passage through the pipe-system. On the other hand, the measurements of the allergen concentrations of the oudoor moulds *Cladosporium* and *Alternaria* showed that even if no or only small airborne concentrations of viable spores are found at the end of the pipes (or in the supply air after the filters), the allergens are still present. The concentrations of the allergens are generally lower in the supply air than in the outdoor air, but they may still contribute to an allergic reaction.

No differences were found between the pipe-systems of different materials or age. However, the size of the ground-coupled air system and the total airflow seem to have an influence on the decrease in the concentration of viable microorganisms. Big differences were thus observed between one-family houses and larger buildings.

CONCLUSIONS

Based on these investigations the operation of ground-coupled earth-to-air heat exchangers is acceptable as long as regular controls are undertaken and if appropriate cleaning facilities are available.

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