# INDOOR CLIMATE AND MOISTURE PROBLEMS IN FINNISH SCHOOLS

J. Kurnitski[1], S. Enberg[1]

[1]Helsinki University of Technology, HVAC-Laboratory

## ABSTRACT

The purpose of the study was to assess actual ventilation, indoor air quality and also the quality of repairing process in the Finnish schools. The measurements that included ventilation rate, $CO_2$ and particle concentrations, and temperature and humidity in the classrooms were carried out in 20 schools. Repairing of schools were studied on the basis of 32 schools. The typical needs for repairing HVAC-systems and building structures and also typical repairing measures and faults were reported. The most common problem was the classrooms' old-fashioned or even missing ventilation devices. The type of ventilation system had a significant influence on the quality of indoor air and on the occurrence of problems. The air change rates were higher and, $CO_2$ concentrations and occurrence of draught were remarkably lower in mechanical supply and exhaust ventilation compared to natural ventilation and mechanical exhaust ventilation systems. In general the problems, connected to the ventilation system, were more common than water damage and mold problems. The average concentration of particles was measured in the winter 0,14 mg/m$^3$ and in the autumn 0,07 mg/m$^3$. It is remarkable that the concentration of respirable particles was higher in the autumn when the total concentration of particles was lower than in the winter.

## INTRODUCTION

In Finland there are about 5,000 schools where there study and work altogether about 750,000 pupils of comprehensive and secondary pupils and teachers. During last years it has been noticed that there are more and more problems with indoor climate.

The objectives of the ventilation and indoor climate measurements were to assess the typical levels of classroom's ventilation rates, $CO_2$ and particle concentrations, temperature and humidity in the cases of different ventilation systems.

The purpose of the study of renovating and repairing was to gather information about repairing field of schools, by aid of which the repairs and financial support for repairs can be guided in a way that leads to appropriate direction of repairing measures. The typical needs for repairing HVAC-systems and building structures and also typical repairing measures and the faults were studied.

## METHODS

Ten schools were chosen for the measurements and the total number of the classrooms measured were 56. There were 2 schools with natural ventilation system from the fifties, 3 schools with mechanical exhaust ventilation from the sixties and 5 schools with mechanical supply and exhaust ventilation (2 from the seventies, 2 from the eighties and one from the nineties). The measurements were carried out during a cold period of winter in February 1996, when the outdoor temperature was between -20...-10°C.

In each school the next measurements from six classrooms were done:

- $CO_2$ concentration during one class (45 minutes)
- indoor air temperature during one class
- relative humidity during one class
- extract airflows
- particle concentrations from indoor air, supply air and outdoor air (ranges' 0,3-0,5; 0,5-1,0; 1,0-5,0 and 5-10 μm)
- visible water damages and surface moisture content

The particle samples were taken with a particle counter during a couple of minutes and are therefore considered as instantaneous measurements. In the autumn of 1996, measurements were carried out in further ten schools. The particle concentrations were in each school measured in one classroom for one school day. This time the measurements were done both with a particle counter and with a standardized filter method. This was to confirm the way to calculate the total particle concentration, in the unit mg/m³, out of particle concentrations measured with a particle counter. The parameters in formula 1 below were chosen so that the two methods gave the same results.

The particle counter counts and divides the particles into six fractions and returns the concentration of particles in couples/m³. The total concentration of particles was calculated on the assumption that the particles were spheres with density of 830 kg/m³. The concentration of particles increase greatly with smaller particle size. Therefore a characteristic diameter for each fraction was defined (Table 1).

Table 1. Characteristic diameters for particles.

| Fraction | Size [μm] | Characteristic diameter [μm] |
|---|---|---|
| 1 | 0,3 - 0,5 | 0,366 |
| 2 | 0,5 - 1,0 | 0,670 |
| 3 | 1,0 -5,0 | 2,33 |
| 4 | 5,0 - 10 | 6,70 |
| 5 | 10 - 25 | 15,0 |
| 6 | > 25 | 25,0 |

During the day, the concentration of particles fluctuate because of changes in weather conditions and activities in the classrooms. One typical result of the measurements in one classroom is shown in Figure 1. The fluctuating is taken into consideration by counting an average concentration for each fraction.

Based on the characteristic diameters and the assumptions above, the total concentration of particles was calculated with Formula 1,

$$m_{Tot} = \sum_{i=1}^{6} (Vi * n * \rho) \quad (1)$$

where $m_{Tot}$ is the total concentration of particles, $n$ the average concentration in the fraction, $\rho$ the density and $V_i$ the volume of a sphere with the characteristic diameter for the fraction i.

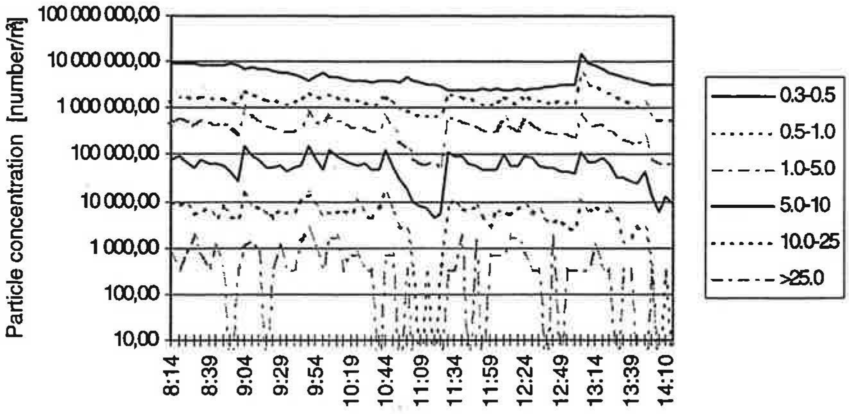


Figure 1. Concentration of particles in the fractions during one school day.

The repairs of HVAC-systems and water damages were studied in 32 schools on the basis of design documents, interviews of the local authorities and the staff of schools, surveys and small scale measurements.

## RESULTS

The average classroom size was 60 $m^2$ and average value of pupils was 23. Some mean values representing the general situation are shown in Table 2. Min. and max. values are the lowest and highest mean values, measured during one class. Mean values are calculated as averages of all measured mean values (during one class).

Table 2. Minimum, average and maximum values of mean values of $CO_2$ concentration, temperature and humidity during one class and mean values of exhaust airflows.

| | $CO_2$ concentration [ppm] | Temperature [°C] | Humidity [%] | Ventilation rates* [l/s,person] | [l/s $m^2$] |
|---|---|---|---|---|---|
| Average | 1061 | 21,4 | 21,9 | 3.5 | 1.2 |
| Minimum | 607 | 17,2 | 10,8 | | |
| Maximum | 2113 | 25,4 | 30,6 | | |

* Finnish guideline values are 6 l/s,person or 3 l/s $m^2$

Different ventilation systems are compared in Figure 2. Mean values of exhaust airflows and $CO_2$ concentrations are shown.

Results of the two particle concentration measuring methods correlate strongly. With a density of 830 kg/$m^3$ and the characteristic diameters in Table 1, the correlation coefficient between the results of the two methods was 0,95. The results from the measurements in the autumn are shown in Figure 3. School buildings equipped with mechanical supply and exhaust ventilation had an average total particle concentration 0,059 mg/$m^3$ measured with the particle counter and 0,061 mg/$m^3$ measured with the filter method. The schools number 7 and 10 were equipped with mechanical exhaust ventilation and the school number 8 with natural ventilation. The average total particle concentration for all the schools was 0,07 mg/$m^3$.

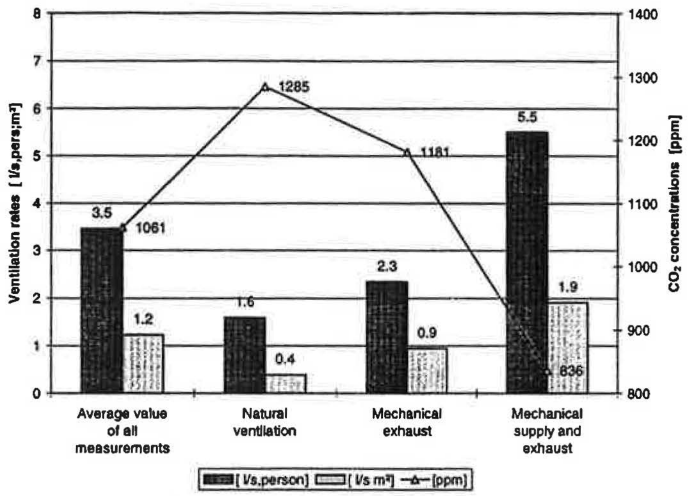


Figure 2. Mean values of exhaust airflows and $CO_2$ concentrations in different ventilation systems

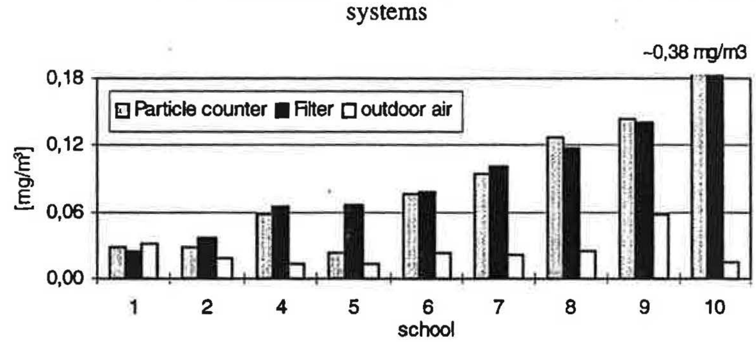


Figure 3. Total particle concentrations in ten school buildings in autumn.

The order between the schools did not depend on the method used. The order did not change much if only the particles in the range of 0.3 - 5.0 μm are taken into account (Figure 4). These particles form a part between 9 and 15% of the total particle concentration. It seems the concentration of respirable particles rises when the total particle concentration rises.

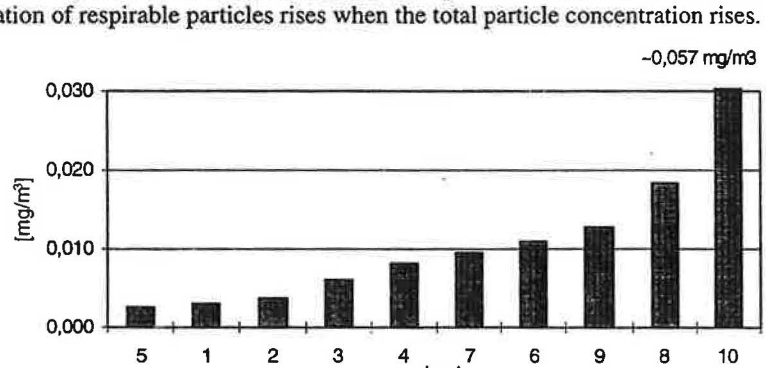


Figure 4. Particle concentration PM-5 (particles less than 5,0 μm dia.). Ten schools, autumn.

Because of the good correlation between the results of the different methods, the results from the measurements in the winter 1996 were calculated with the same assumptions as above. The total particle concentration was in average 0,178 mg/m$^3$ in schools with natural ventilation, 0,160 mg/m$^3$ in schools equipped with mechanical exhaust ventilation and 0,121 mg/m$^3$ in schools with mechanical supply and exhaust ventilation. The average concentration of particles for all schools was 0,07 mg/m$^3$. Only in one school was the total particle concentration close to the Finnish recommendation 0,060 mg/m$^3$ /3/.

Even though the total particle concentration was lower in the autumn, the concentration of respirable particles was higher than in the winter (Figure 5). The weather conditions during the measurements in the winter were especially cold and dry and in the autumn quite moist.

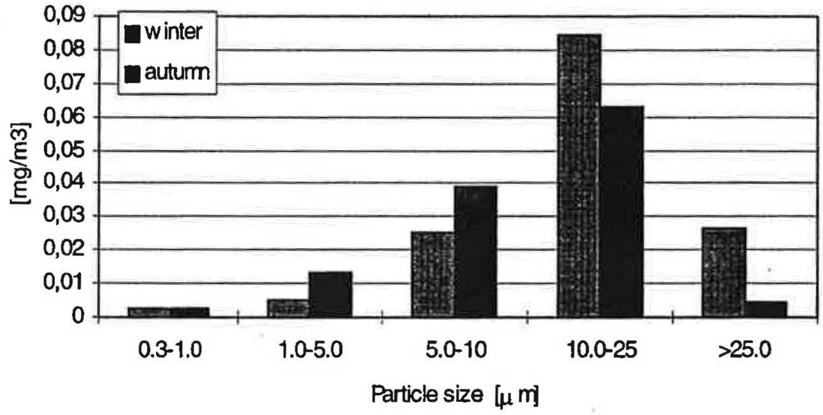


Figure 5. Average particle concentration for each fraction in the winter and in the autumn.

Study of the 32 repaired schools showed that the most important reasons for repairing measures were:

- extensions and reorganisations, and renovating the old buildings in 63% of schools, in connection with the water damages and HVAC-systems often been also repaired
- water damages and mold problems in 25% of schools
- repair of HVAC-systems in 6% of schools
- odour problems in 6% of schools

Some stage of water damages were reported in 30 schools (out of 32), but only in 5 schools this was the most important reason of repairing. The water damages were located in floor structures (in 17 schools), in roof structures (in 12 schools) and in facades (in 7 schools). The mold problems were detected in 10 schools and this was the most important reason of repairing in 3 schools. Common places for mold growth were floor and roof structures.

## DISCUSSION

On the basis of this research, the indoor air quality problems seem to be common in schools. The type of ventilation system had a significant influence on the quality of indoor air and the occurrence of problems. The solutions of natural ventilation and mechanical exhaust ventilation that were used in practice, suited poorly to the school buildings. In both systems the intake air caused draught. Furthermore, insufficient ventilation rates were a problem in natural ventilation systems. Mechanical supply and exhaust ventilation showed remarkably better performance by higher ventilation rates and lower $CO_2$ concentrations. Also, the occurrence of draught was approximately fifty percent lower. However, the occurrence of different indoor air quality problems in mechanical supply and exhaust ventilation indicates faults in control and maintenance, and in some cases low design quality.

The measured particle concentrations were compared with the Finnish recommendation of 0,060 mg/m$^3$ (total particle concentration). It is easy to show that the guideline must be more specific. In the winter the total particle concentration was 0,14 mg/m$^3$ and it is twice as much as the recommendation. In the autumn, the total concentration was roughly as big as the recommendation (0,07 mg/m$^3$), but the concentration of respirable particles was higher than in the winter. Thus, do we have a problem in the winter or autumn? At least the comparing with recommendation does not tell much.

The biggest problem in the repairing field were the classrooms' old-fashioned or even missing ventilation devices. The low level of indoor air quality in the classrooms was usually not a sufficient reason to start repairing measures, despite teachers and students complaining about draught and poor indoor air quality. The ventilation systems were commonly renovated with reorganisation of classrooms or with building new rooms. The only exception was the ventilation system in workshops that were usually replaced by the demand of safety and fire authorities. In practice this has caused a situation where the ventilation system serving ordinary classrooms has not been repaired.

When repairing mold and water damages the documentation of repairing measures was insufficient. In many cases the documentation was entirely missing. This can cause problems in the future because the measures and solutions used are unknown.

## ACKNOWLEDGEMENTS

The Research has been financed by the Finnish Ministry of Education and by Association of Finnish Manufacturers of Airhandling Equipment (SITY).

## REFERENCES

1. Kurnitski J, Palonen J, Enberg S, Ruotsalainen R. Indoor climate in schools - questionnaire for the principals and measurements (in Finnish). Espoo 1996. Helsinki University of Technology, HVAC-laboratory. Report B43. 60 s. ISBN 951-22-3061-5

2. Kurnitski J, Vilkki R, Jokiranta K, Kettunen A-V, Hejazi-Hashemi S. Indoor Climate and Water Damages in Schools. Espoo 1996. Helsinki University of Technology, HVAC- and Structural Engineering laboratories. Report B46. 70 s. ISBN 951-22-3397-5

3. Classification of Indoor Climate, Construction and Finishing Materials. Helsinki 1995. Finnish Society of Indoor Air Quality and Climate, FiSIAQ. 32 s. ISBN 951-97186-3-X