INDOOR AIR AND ENERGY ECONOMY IN SCHOOL BUILDINGS

Johanna Jalas, Kalle Karjalainen and Pirjo Kimari

Oulu Polytechnic

ABSTRACT

The purpose of this study was to investigate solutions for renovation processes in the ventilation of fifteen school buildings. The quality of indoor air as well as the operation of ventilation were studied. Both measurements and questionnaires to teachers were used before and after the renovation work.

The quality of the indoor air measured in the school buildings was essentially improved as the renovation work proceeded. As the contents of carbon dioxide in the school buildings ranged between 1,200 – 2,400 ppm before the renovation work, they were below 1,250 in the maximum in all the school buildings with only one exception after that. After the renovation the maximum carbon dioxide contents in the school buildings furnished with natural ventilation were decreased 850 ppm in the average. The air temperatures were higher than recommended both before (23°C in the average) and after (22°C in the average) the renovation. The heating network was not balanced in all the school buildings before the measurements were made after the renovation work. In the estimates given by teachers working in these school buildings the quality of the air was experienced to have improved from school grade 6.5 to that of 7.9 (scale 4…10).

KEYWORDS: SBS, schools, energy conservation, perceived air quality, ventilation

INTRODUCTION

There are approximately 6,000 school buildings in Finland, in which more than 700,000 people spend several hours of their time every day. Most of these buildings do not meet the requirements of healthy and comfortable indoor climate[1]. In order to guarantee a healthy indoor climate, the ventilation systems in these defective cases should be balanced, or partly or totally replaced. There are many reasons for difficulties in improving the ventilation of schools. Their owners and users often have insufficient information about indoor climate problems and about their solution possibilities. The costs caused by replacement and renovation of ventilation equipment also frighten them. In addition, there is a tendency to avoid powerful ventilation equipment because of its higher operation costs.

The objective in the research project Indoor Air and Energy Economy in School Buildings was to create concrete models and instructions for air technical solutions concerning indoor air problems in school buildings. The impact of construction technique on indoor air was taken into consideration within limits, but it was not concentrated on in this project.

The effect of ventilation renovation on the quality of indoor air and on energy economy, costs caused by the renovation, and problems in the renovation process were investigated in 14 research objects. The ventilation in the schools were renovated in all the objects either as centralized or decentralized mechanical supply and exhaust ventilation. Heat recovery was involved in all the solutions.

METHODS

The study objects for the project Indoor Air and Energy Economy in School Buildings were school buildings in which municipal authorities had decided to carry out renovations. The purpose was to select schools with different age, extension, properties and ventilation systems. Two of the objects represented large school centers with several buildings. The study covered seven small village school type lower levels of comprehensive schools. Two of the objects were medium-sized city school buildings. In two large school buildings the ventilation renovation was carried out only in some of the classrooms. Before the renovation work there was mechanical supply and exhaust ventilation in three buildings, mechanical exhaust ventilation in one building and natural ventilation in the rest of the buildings. Two objects in which cleaning and balancing were made had mechanical supply and exhaust ventilation.

The air temperature, relative humidity and content of carbon dioxide in the classrooms were measured by means of continuous measurements during one lesson. The measurements were performed in the classrooms with ordinary human loads.

The teachers of the schools were delivered questionnaires on their health and on the indoor climate conditions in job environments.

RESULTS

The measured quality of indoor air in schools was improved essentially due to the ventilation renovation. Before the renovation work in eleven out of fifteen schools the maximum carbon dioxide contents exceeded the limit 1,500 ppm set by the guide (Indoor climate instruction) [2] of the Finnish Ministry of Social Affairs and Health. After the ventilation renovation the contents were below the limit 1,500 ppm in all the objects. The carbon dioxide contents in schools previously equipped with natural ventilation decreased 850 ppm in the average. The carbon dioxide contents in the study objects provided with mechanical supply and exhaust ventilation prior to the renovation hardly dropped at all. The reason for ventilation renovation in these objects was not the improvement of indoor air quality but replacement of the old equipment in connection with the overall renovation work. After the renovation the measured maximum carbon dioxide contents were with one exception in all the objects below 1,250 ppm, which is the limit of class S2 (Classification of indoor climate, construction work and surface materials) [3]. Air flows were dimensioned according to the class S3, but one class higher air qualities were generally reached in ordinary circumstances. Figure 1 shows the comparison between the maximum carbon dioxide contents in the school buildings before and after the renovation. The ventilation systems prior to the renovation are also stated in the figure.

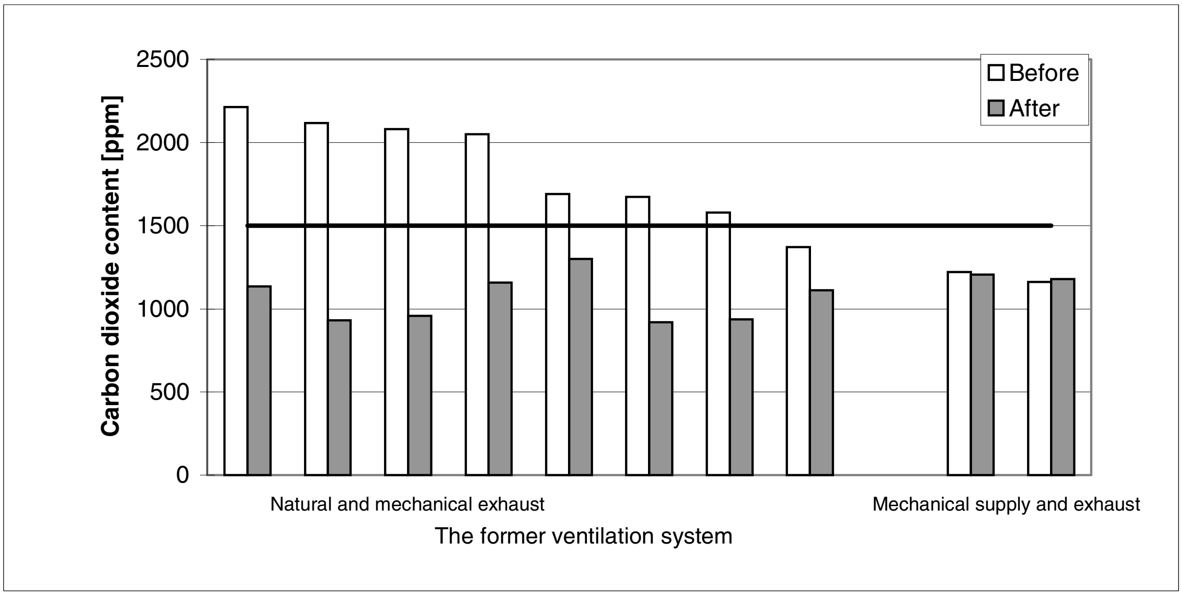

Figure 1. The maximum carbon dioxide contents in the test schools before and after the ventilation renovation. The thick line represent the guideline value in Finnish building code [4].

The air temperatures were higher than recommended both before and after the renovation work [5]. The average temperature was 23°C before and 22°C after the renovation. The temperature variation in both cases was 5°C in the average. The result on one hand shows that the ventilation in the objects was not dimensioned in accordance with the heat loads. On the other hand, the result was also affected by the fact that the heating networks of the objects had not been adjusted and balanced before the measurements. The air temperature averages, minimum temperatures and maximum temperatures of the measured classrooms before and after the renovation work are presented in table 1 [5]. The effect of ventilation renovation on both experienced and measured thermal conditions was distinctly slighter than its effect on purity.

Table 1. The air temperatures [°C] of the schools before and after the renovation work.

	Average	Average of minimum values	Average of maximum values
Before renovation	23	20	25
After renovation	22	19	24

The perceived indoor air quality improved due to the improvement of ventilation as grades given by the teachers 1.4 in the average. The teachers estimated the quality of indoor air on scale 4 … 10. The teachers' estimates on indoor air quality before and after the renovation are shown in table 2 [5].

Table 2. The perceived indoor air quality before and after the renovation.

Experienced indoor air quality	Before	After
Average grade	6.5	7.9
Minimum average out of the averages per school	5.3	6
Maximum average out of the averages per school	7.3	8.7

The results concerning the answers to the questions on symptoms possibly caused by the indoor climate and on their frequencies are presented in figure 2 [5].

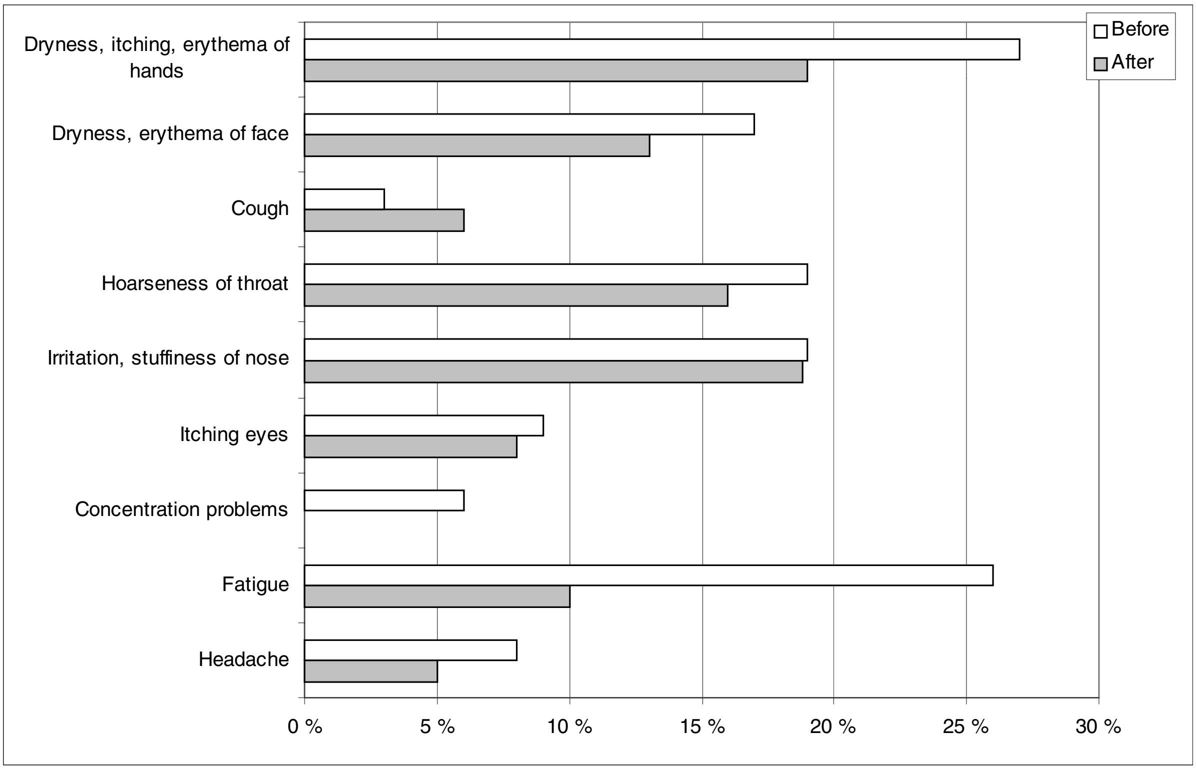

Figure 2. Weekly occurrences of symptoms before and after the renovation.

In regard to occurrence frequencies of indoor climate problems the most common weekly problems still after the renovation were stuffy air and inadequate ventilation. However, the shares of those suffering from indoor climate problems were considerably diminished. The share of those suffering from too high temperatures was also decreased, which corresponds the measuring results.

The percentage of those experiencing draught was also diminished. The conditions improved due to the ventilation renovation as for all the questioned indoor air problems except the noise. Table 3 summarizes the percentages of teachers who experienced weekly indoor air problems in the winter before and after the renovation [5].

Table 3. Percentages of teachers who experienced weekly indoor air problems in the winter before and after the renovation.

Indoor air problem	Before	After
Draught	28 %	13 %
Inadequate ventilation	57 %	14 %
Too high room temperature	11 %	6 %
Too low room temperature	11 %	5 %
Varying room temperature	15 %	9 %
Stuffy air	61 %	19 %
Unpleasant smell	22 %	11 %
Dry air	28 %	9 %
Dusty air	21 %	3 %
Dust on surfaces	21 %	9 %
Ventilation noise	6 %	14 %
Humidity problems	1 %	2 %

A lot of expectations were addressed to the ventilation improvement in the study objects. Before the renovation 82 % of the teachers suggested ventilation renovation as a means to improve indoor air quality. Furthermore, the ventilation was considered to be totally unfunctional by 29 % of the teachers and fully functional by only 1 % before the renovation. After the renovation the respective percentages were 2 % and 33 %. Table 4 presents the comparison between the shares of those having been satisfied and unsatisfied with the ventilation in the winter before and after the renovation. Airing was regularly used by 27 % of the teachers after the renovation and by 69 % of them before it.

Table 4. The comparison between the shares of those having been satisfied and unsatisfied with the ventilation.

	After	Before		
		Natural	Mechanical exhaust	Mechanical supply and exhaust
Fully satisfied	33 %	0 %	0 %	2 %
Fully unsatisfied	2 %	32 %	41 %	25 %

DISCUSSION

Considering Finnish outdoor climate, in order to guarantee good indoor air quality in schools and to reach high energy economy, school buildings have to be equipped with mechanical supply and exhaust ventilation which also includes heat recovery from the exhaust air.

ACKNOWLEDGEMENTS

The study project was funded by Technology Development Centre, Finland (Teknologian kehittämiskeskus), and business members of Finnish Air Technical Association (Suomen Ilmateknillinen Toimialayhdistys). The management group of the research project comprised of representatives from the above mentioned parties and from National Board of Education (Opetushallitus), Ministry of Environment (Ympäristöministeriö), Ministry of Social Affairs and Health (Sosiaali- ja terveysministeriö), The Association of Finnish Local and Regional Authorities (Suomen Kuntaliitto), The Finnish Association of Architects (Suomen arkkitehtiliiitto), Helsinki Public Works Department (Helsingin kaupungin rakennusvirasto) and Finnish Development Centre for Building Services Ltd (Suomen Talotekniikan Kehityskeskus).

REFERENCES

1. Kurnitski, J. & Palonen, J. & Engberg, S. & Ruotsalainen, R. 1996. Koulujen sisäilmasto – rehtorikysely ja sisäilmastomittaukset. Espoo: Teknillinen korkeakoulu, konetekniikan osasto, LVI-tekniikan laboratorio, Sarja B 43. 60 s. ISBN 951-22-3061-5
2. Sisäilmaohje. 1997. Asuntojen ja muiden oleskelutilojen fysikaaliset, kemialliset ja mikrobiologiset tekijät. Helsinki: Sosiaali- ja terveysministeriö. 72 s. (Sosiaali- ja terveysministeriön oppaita 1997:1.) ISBN 952-00-0261-8
3. Sisäilmayhdistys. 1995. Sisäilmaston, rakennustöiden ja pintamateriaalien luokitus. Helsinki: Sisäilmayhdistys. 32 s. (Sisäilmayhdistyksen julkaisu 5.) ISBN 951-97186-2-1
4. Ympäristöministeriö.1987. Suomen rakentamismääräyskokoelma. D2. Rakennusten sisäilmasto ja ilmanvaihto. Määräykset ja ohjeet 1987. 20 s. ISBN 951-860-624-2
5. Karjalainen, K. & Kimari, P. 1999. Koulujen sisäilma ja energiatalous. Helsinki: TAKE, Serie IAQ F, Report 12