Quality of indoor air and functionality of ventilation in day care centres

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ABSTRACT
The aim of the study was to develop solutions to the problems and deficiencies encountered in ventilation systems of day care centres, and which were manifested as poor IAQ or excessive energy consumption in the buildings at the maintenance stage of their ventilation systems. During the afternoon rest hour the IAQ was monitored and other measurements of ventilation capacity were made. The directors and maintenance personnel of the day care centres were interviewed and a questionnaire was presented to the staff. Based on the results of the first stage of the research, even new systems did not work as intended because of inadequate planning and construction of ventilation or inadequate use or maintenance of the ventilation systems. Based on the results of the second stage of the research, both measured and experienced IAQ is good when the clearly defined goals are verified by calculations and measurements during the process.

INDEX TERMS
Air quality; Carbon dioxide; Ventilation; Questionnaire; Guideline value

INTRODUCTION

There are approximately 1870 municipal day care centres in Finland, in which more than 141 000 children spend several hours of their time every day. Several studies in the 1990s repeatedly ended up on reports on numerous problems in IAQ of Finnish schools and day care centres.

The aim of the study, Quality of Indoor Air and Functionality of Ventilation in Day Care Centres, was to develop solutions to the problems and deficiencies encountered in the ventilation systems of day care centres, which were manifested as poor IAQ or excessive energy consumption in the buildings at the maintenance stage of their ventilation systems. This paper summarizes the results of the 3 year project.

At present, there are no minimum recommendations for the sizes of playrooms or for the minimum floor area for a child. The number of children per department varies, depending on the ages of children. There are approximately 12 children aged under 3 years and 21 children aged 3–6 years in a group in general.

According to the guide, *Indoor Climate Instruction of the Finnish Ministry of Social Affairs and Health*, the maximum permissible amount of carbon dioxide is 1500 ppm. According to the National Building Code of Finland (1987) the minimum guideline value of airflow in playrooms and resting rooms is 5 l s^{-1} per person. If the number of children per department is not known, the airflows can be designed by using the guideline value 2 l s^{-1} m^{-2}. According to the National Building Code of Finland (1987) when the outdoor temperature is, at the most, 15°C higher than the calculated outdoor temperature of the locality, airflow to each room can be temporarily decreased at the most by 50% to decrease the calculated power of a heating apparatus.

METHODS

At the first stage of the project mostly day care centres (15) constructed in the 1990s with the mechanical exchange of supply and exhaust air were chosen for study. Four day care centres built in the 1960s to the 1980s, were also included. During the afternoon rest hour, carbon dioxide content, temperature and relative humidity were monitored and other measurements of ventilation capacity were made in 32 resting rooms altogether. During the same period of time, the directors and maintenance personnel of the day care centres were interviewed. The personnel of the day care centres were delivered questionnaires on the indoor climate conditions in their job environments.

On the basis of the observations and results from the first part of the research project design, implementation and client instructions for the ventilation of the day care centre were compiled. At the second stage of the research the compiled instructions were utilized and tested in new day care centres (2) being built, as well as in an old day care centre being renovated. During the first year the functionality, usability and serviceability of ventilation as well as the effect of ventilation on the IAQ were determined.

RESULTS

The First Stage of the Research

The carbon dioxide content is too high if the ventilation is inadequate relative to the number of people present (Table 1). In six resting rooms out of 32, the carbon dioxide content exceeded the official recommendation of 1500 ppm when monitored during a rest break. One of the resting rooms was in an old day care centre facility with only a mechanical exhaust system. In 12 resting rooms altogether, the carbon dioxide content of the indoor air remained under 1000 ppm during the 2 h measurements, indicating that the quality of the indoor air in the rooms was good in terms of the carbon dioxide content. Two of the resting rooms were in an old day care facility with the mechanical exchange of both the supply and exhaust air.

Table 1 The number of rooms divided by the maximum carbon dioxide content

The maximum of carbon dioxide	Built in the 1990s (n = 25)	Built in the 1960s to the 1980s (n = 7)	Altogether (n = 32)
<1000 ppm	10	2	12
1000–1250 ppm	6	2	8
1250–1500 ppm	4	2	6
>1500 ppm	5	1	6

In 15 resting rooms, the quantity of the supply air measured during the rest hour differed from the design value by more than 20%. In seven rooms out of 15, the supply airflow was notably higher than the design value, while in eight rooms it was lower than the design value. In 12 resting rooms, the exhaust airflow measured during the rest hour differed from the design value by more than 20%. In all cases, the measured exhaust airflow was lower than the design value.

The low airflows were because of dusty air terminal devices, incorrect speed of rotation of air handling units and incorrect adjustment of airflows. In 21 resting rooms the flow rate of exhaust air measured was under the guideline value, 5 l s^{-1} per person. The airflows in resting rooms and playrooms were designed mainly by using the guideline value 2 l s^{-1} m^{-2}instead of the number of children as a design criterion.

The personnel of the day care centres were delivered a questionnaire about the quality of indoor air and indoor environment. At the first stage of the research 209 persons altogether answered the questionnaire. According to the questionnaire, the staff of new day care centres mostly complained about stuffy air, thermal conditions, dry air, draught and inadequate ventilation in the winter. Table 2 summarizes the number of day care centres in which more than 40% of the personnel complained about indoor air problems.

Table 2 The number of day care centres in which more than 40% of personnel experienced different indoor air problems

Indoor air problem	Number of day care centres (n = 15)
Stuffy air	9
Cold floor	9
Dry air	9
Varying room temperature	8
Draught	8
Too high room temperature	6
Too low room temperature	6
Inadequate ventilation in winter	5
Ventilation noise	5
Unpleasant smell	5
Inadequate ventilation in summer	3
Poor lighting	2
Dust on surfaces	1
Too humid air	1
Other noise	1

In Finland, it is common to reduce airflow rates by 50% in the winter time in cold weather to lower the heat output of heating equipment. In each facility studied, the ventilation capacity was cut down by 50% in very cold weather to save energy.

The Second Stage of the Research

At the second stage of the study two new day care centres and the renovation of the ventilation system of one old day care centre were chosen for the study (they were pointed out by the partners in co-operation). The results and experiences from the first stage of the study were utilized in the decision-making process, by the building owners, during the time of design and construction. During the first year, the functionality, usability and serviceability of ventilation as well as the effect of ventilation on the IAQ were determined.

The airflows were designed by using the minimum guideline value per floor area (2 l s^{-1} m^{-2}) in one building and the minimum guide value per person (5 l s^{-1} per person) in another building. In another building the airflows were designed by using 4 l s^{-1} m^{-2}.

Measurements were made in eight resting rooms. In all resting rooms, the carbon dioxide content of the indoor air remained under 1200 ppm during the 2 hour measurements. In six rooms altogether, the carbon content of the indoor air remained under 1000 ppm indicating that the quality of the indoor air in the resting rooms was good in terms of the carbon dioxide content.

Figure 1 shows the relation between the maximum of the carbon dioxide content and the supply airflow per person in each room measured. Figure 2 shows the relation between the maximum of the carbon dioxide content and the exhaust airflow per person in each room measured.

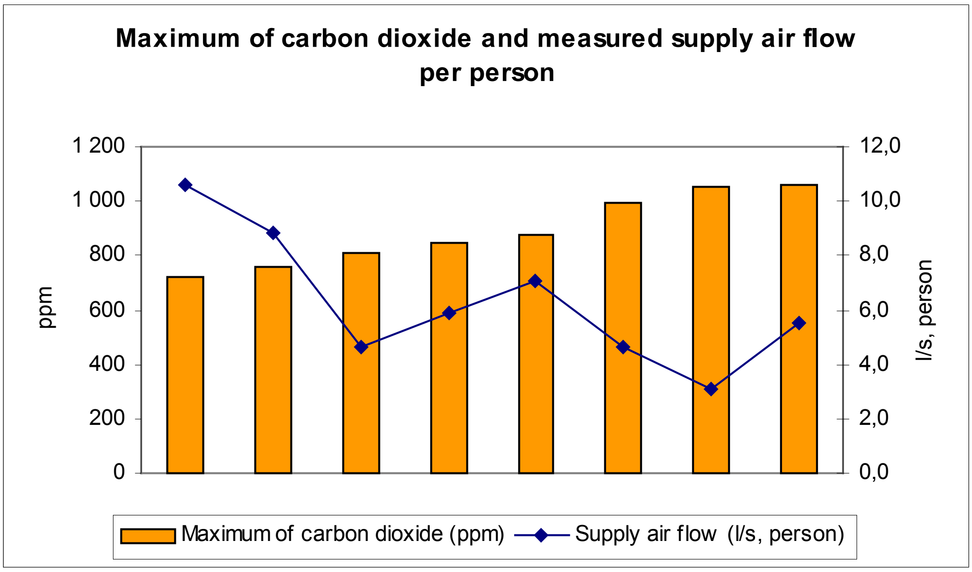

Figure 1 The maximum of carbon dioxide content and measured supply airflow per person in rooms studied.

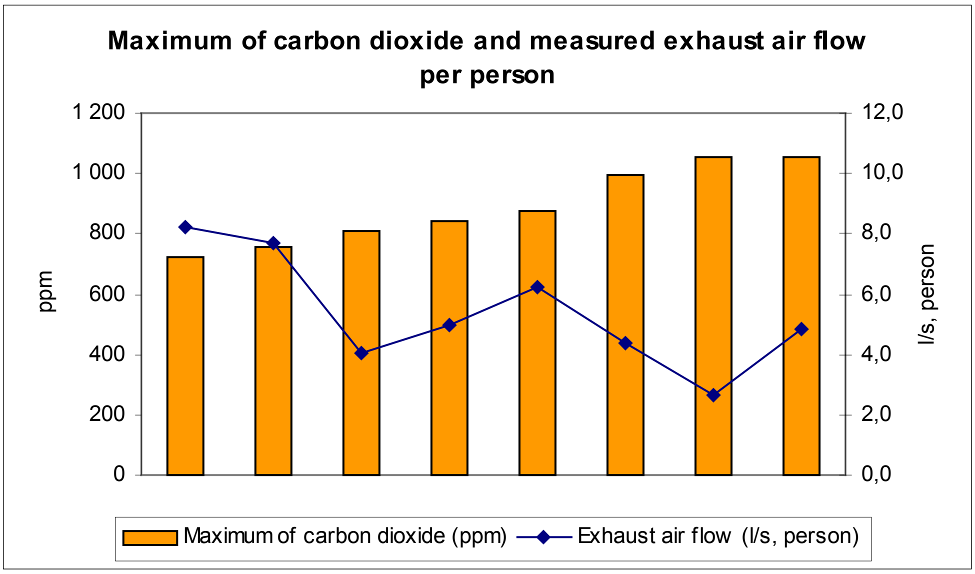

Figure 2 The maximum of carbon dioxide content and measured exhaust airflow per person in rooms studied.

DISCUSSION

Based on the results of the first stage of the research, even new systems do not work as intended because of inadequate planning and construction of ventilation or inadequate use or maintenance of the ventilation system. Based on the results of the second stage of the research, the quality of indoor air, both measured and experienced, is good when the clearly defined goals are verified by calculations and measurements during the process.

Based on the results, the quality of indoor air is poor in the children's rooms, if the supply and exhaust airflows are only half of the recommended minimum value (currently 2 l s^{-1} m^{-2} or 5 l s^{-1} per person). The calculated floor-area-based airflow should always be checked by comparing it to the person-based airflow.

The quality of the indoor air is not necessarily improved by merely increasing airflows. An architect's stipulations for positioning air distributions can change the way air is distributed and thereby cause cool incoming air to settle in the living zone. Also, the effect of the way heat is distributed, as well as the effect of positioning windows, lamps and furnishings should be determined to prevent complaints about such things as draught or uncomfortable temperature conditions. The architect should also consider the space required by building technology systems.

A typical problem is also the fact that the number of children exceeds the one originally planned. In very few cases did the personnel know exactly the intended maximum number of occupants. Thus, the decision-makers and local authorities, and also the personnel in the day-care centre, should know the maximum number of occupants per room—which is one of the main design criteria for ventilation.

CONCLUSION AND IMPLICATIONS

The goals for the indoor climate of day care centres must be set early in the implementation process of day care centre ventilation so that life cycle calculations can be done. In the implementation process, additional resources should be reserved for examining alternative solutions, providing guidelines for the client plan and supervising the implementation on the site.

When a new building is adopted into use, it should be ensured that the ventilation functions adequately in all the situations that can be anticipated to occur. At the maintenance stage, the functionality of the ventilation system should be checked regularly by measuring the quality and the temperature of the indoor air and the airflows in each room. The ventilation system should also be cleaned regularly.

On the basis of the observations and the results from the research project, designs, implementation and client instructions for the day care centre ventilation were compiled. The guidebook was posted to all cities and local authorities in Finland.

At the beginning of October 2003 the new version of the National Building Code of Finland (Indoor climate and ventilation in buildings) will be adopted. Based on the results of this study and other studies, the new guideline values for airflow in playrooms and resting rooms are 2.5 $l\ s^{-1}\ m^{-2}$ and 6 $l\ s^{-1}$ per person. The maximum carbon dioxide content is set as 1200 ppm.

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