INDOOR AIR QUALITY AND THERMAL COMFORT EVALUATION IN LATVIAN DAYCARE CENTERS WITH CARBON DIOXIDE, TEMPERATURE AND HUMIDITY AS INDICATORS

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ABSTRACT

Latvian children under the age of 7 can spend up to 60 hours per week in daycare centers and therefore it is very important to establish a healthy and comfortable daycare environment that children will find pleasant and stimulating to stay in. This study investigates the indoor air quality and thermal comfort within six daycare centers (old, renovated and new-built) in moderate climate zone of Latvia. The measurements of carbon dioxide, air temperature and relative humidity were carried out, and the data regarding daycare center characteristics and maintenance activities were collected via combination of field visits, record analysis and interviews. It was found that the carbon dioxide concentrations exceeded 1000 ppm in 75% of the daycare centers studied, with the highest (1356 ppm) measured in a renovated facility with the natural ventilation system. Thus, installation of a more efficient ventilation system (mechanical) is recommended to provide acceptable indoor air quality, since opening of windows itself cannot provide the optimal conditions indoors. In all facilities the temperature was kept above 20°C and the average relative humidity was 40 ± 5%, creating comfortable thermal environment for children.

Key words: daycare center, indoor air quality, thermal comfort

INTRODUCTION

About 75% of all children under the age of 7 living in the capital of Latvia Riga spend about 30-60 hours per week in daycare centers. However, research studies indicate that daycare facilities due to the improper indoor air quality (IAQ) may actually be hazardous to children's health. (Hagerhed-Engman et al., 2006; Haby et al., 2000) have reported increased risks of asthma and allergies for children spending their time in daycare environments compared to the care obtained at home. Therefore, for the last few decades an increased attention has been directed towards creation of appropriate indoor environment in daycare centers.

Carbon dioxide (CO_2) is one of the most commonly used indicators of IAQ in spaces, where people are the main pollution source, and it also serves as the determiner for adequate ventilation. CO_2 itself is normally not harmful, however its excessive exposure is found to cause headaches, fatigue, increases the risk of sick leave (Erdmann, 2002; Milton et al., 2000), and even risks for sudden infant death (Corbyn, 1993). The maximum recommended CO_2 concentration in a space is 800 ppm (parts per million) above the outdoor according to the European standard (EN 13779, 2005). The upper limit for the CO_2 concentration in the ASHRAE standard 62.1 (ASHRAE, 2004) should not exceed 2500 ppm, while 1000 ppm is the recommended value. The majority of indoor climate studies in daycare environments were conducted in Nordic countries. The mean CO_2 levels reported in Scandinavian countries were as follows: 810 ppm in Finnish daycare centers (Ruotsalainen and Jaakkola, 1993), about 1400 ppm in Denmark (Pejtersen, 1991), and as low as 640 ppm in Sweden (Cars et al. 1992). (Borodinecs and Budjko, 2009) investigated IAQ in two Latvian daycare centers and reported the maximum CO_2 concentration as high as 1700 and 1450 ppm in rooms with PVC and wooden frame windows respectively.

While CO_2 describes IAQ, temperature and relative humidity are usually used to determine the thermal comfort level in indoor environments. According to the Latvian building norms No. 596 (MK, 2002) the minimum acceptable air temperature in daycare centers is at least 20.0°C or 18.0°C for children younger and older than 3 years respectively. The ASHRAE standard 62.1 (ASHRAE, 2004) recommends keeping the temperature in the range of 23-26°C and relative humidity between 30 and 60%.

The majority of Latvian daycare centers were constructed in accordance to the old Soviet building codes which stated that ventilation should be achieved by natural means, i.e., fresh air supplied through the window construction and exhausted through the vents (stack effect). It was presumed that such solution would result in sufficient air exchange. Lately the majority of daycare centers in Riga were reconstructed: the external walls insulated and wooden frame windows were changed to PVC (polyvinyl chloride) ones. However, these actions alone possess great risk of IAQ problems,

since the buildings became more airtight leading to insufficient air exchange indoors.
Since very limited data are available regarding the indoor air quality in Latvian daycare centers, and being concerned about IAQ children are exposed to in the present construction buildings, the author of this study evaluated the current IAQ and the thermal comfort status in six daycare centers in Riga Region.

MATERIALS AND METHODS

Daycare center selection

Six daycare centers (4%) from a total of 153 were randomly selected from the Education, Youth and Sports Department database of the Riga Council. The facilities differ in the type of construction, i.e., whether the building is old, renovated or new-built (two buildings per each category). All daycare centers were inspected and details of their characteristics were noted, including the type of heating and ventilation system, occupant density, building materials etc. In addition, the daycare center personnel were inquired about the frequency of window opening, cleaning routines and day regime at the facilities.

Field measurements

The CO_2 concentration, temperature and relative humidity are convenient and reliable indicators of the indoor air quality and comfort level. The measurements of these parameters were carried out simultaneously during the period of one week in October 2010 at all daycare facilities, with the exception of CO_2 concentration that was measured only in renovated and new-built daycare centers. Indoor sampling locations were determined prior the measurements through a walkthrough assessment. Since the placement of the measuring devices close to the breathing zone of children, i.e., at the height of 0.5-0.7 m, was restricted, the indoor samplings were performed at the height of 1.5-1.8 m close to the internal perimeter wall. All measurements were conducted continuously from 7 am on Monday to 5 pm on Friday at 5 min intervals. The indoor air temperature and humidity data were collected by the HOBO U12 Family data loggers with the following parameters: temperature -20°C to 70°C (±0.35°C) and relative humidity 10% to 90% with the accuracy (±2.5%). The HOBO loggers were interfaced with the CO_2 monitors Telaire 7001 measuring in the range of 0 to 10000 ppm (±50 ppm). In addition to the HOBO loggers, Testo 175-H2 measuring devices were used, having the following parameters: measurement range -20°C to 70°C with resolution 0.1°C, and relative humidity 0 to 100% with resolution of 0.1%.
Since only two measurement sets of HOBO and Telaire were available it was decided to measure simultaneously in one renovated and new built daycare center couple for the first three days and during the last two days at the second couple of renovated and new-built facilities.
The daycare centers in this paper are designated by their type, i.e., new-built, renovated or old, and corresponding number. Three daycare centers (New 2, Renovated 1, Old 2) have a single room for nap and playing; in other daycare centers nap activity and playing are carried out in separate spaces. In the latter case sampling was performed in the playing room, where children consequently spend more time.

Data analysis

The measured IAQ and thermal environment parameters among three categories of daycare centers were compared. The means and ± standard deviation (SD) of CO_2, room temperature and relative humidity levels were calculated. Results and Discussion.

Daycare center characteristics

The basic data of the daycare centers and the selected spaces investigated are given in Table 1.

Table 1

Daycare center details

Daycare center	Area [m^2]	Ventilation system [-]	Heating system [-]	Floor area per person [m^2/pers]*
Old 1	742	Natural	Radiators	3.2
Old 2	1078	Natural	Radiators	3.2
Ren. 1	2152	Mechanical	Radiators	3.3
Ren. 2	2112	Natural	Radiators	3.3
New 1	3472	Mechanical	Underfloor	5.7
New 2	2024	Mechanical	Underfloor	3.8

* In the measured space

The number of children in one group ranged from 15 to 22 children. The age of children in the rooms investigated varied from 3-6 years. The typical daytime regime in the daycare centers was as follows: from 7 am to 10:30 am indoor activities in the playing room, 10:30 to 12 am promenade, 12:30 to 15:00 nap-time, and the rest of the time is spent indoors.
All daycare facilities have double glazed windows in PVC frames. The maintenance personnel in all daycare centers still relies on natural ventilation for achieving acceptable indoor air quality, and opens the windows every time the children are outside.

Carbon dioxide

In this study the average indoor CO_2 concentration during the daytime for all daycare facilities was 730 ± 170 ppm (Table 2).
In the majority of the daycare centers (75%) CO_2

levels exceeded the ASHRAE recommended value of 1000 ppm. However, this increase was not substantial and the maximum values measured were halved ASHRAE's tolerance maximum of 2500 ppm.

Table 2

Summary statistics of measured carbon dioxide concentration expressed in parts per million (ppm)

Daycare c.	Mean (95% CI)	Median	Min	Max
New 1	707 (603-811)	732	450	1123
New 2	609 (470-748)	601	421	945
Ren. 1	743 (604-882)	775	462	1140
Ren. 2	864 (651-1077)	843	500	1356
Overall	731 (561-901)	734	421	1356

It was also observed that in multipurpose rooms (for general activities and nap), the nap-time average CO_2 level was about 60 ppm higher compared to the non-nap time average CO_2 level. This can be explained by the fact, that children were placed in a closed space without adequate air exchange. Even though in the present study the CO_2 concentration was not measured in sleeping-only rooms, the study conducted in the US daycare centers (Ferng and Lee, 2002) showed 24.3% CO_2 increment from non-nap time to nap-time in this type of rooms. Thus, it can be expected that Latvian daycare centers might follow the similar tendency, but this should be confirmed by further experiments in sleeping-only rooms. The highest CO_2 concentration was obtained in the Renovated 2 daycare center, which has a natural ventilation system as opposed to the other three daycare centers with a mechanical system installed. Even though opening of windows does lower the CO_2 concentration, it is still not enough to achieve the optimal level since low outdoor air temperature limits the airing period.

Thus, better indoor air quality is achieved in mechanically ventilated spaces with constant supply of fresh air.

Temperature

The outdoor air parameters for October 26, which was a typical mid-week, cold day, are presented in Figure 1.

The outdoor air temperature varied from 2.0°C to 8.8°C and the relative humidity was in a range of 44% to 100%.

The variation of the daytime room temperature across the daycare centers on the 26th October is shown in Figure 2.

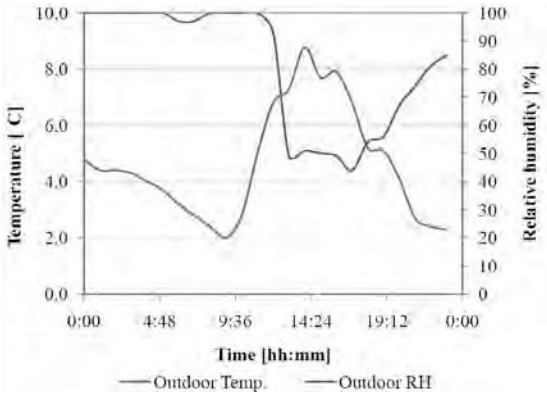

Figure 1. Atmospheric conditions on 26th October.

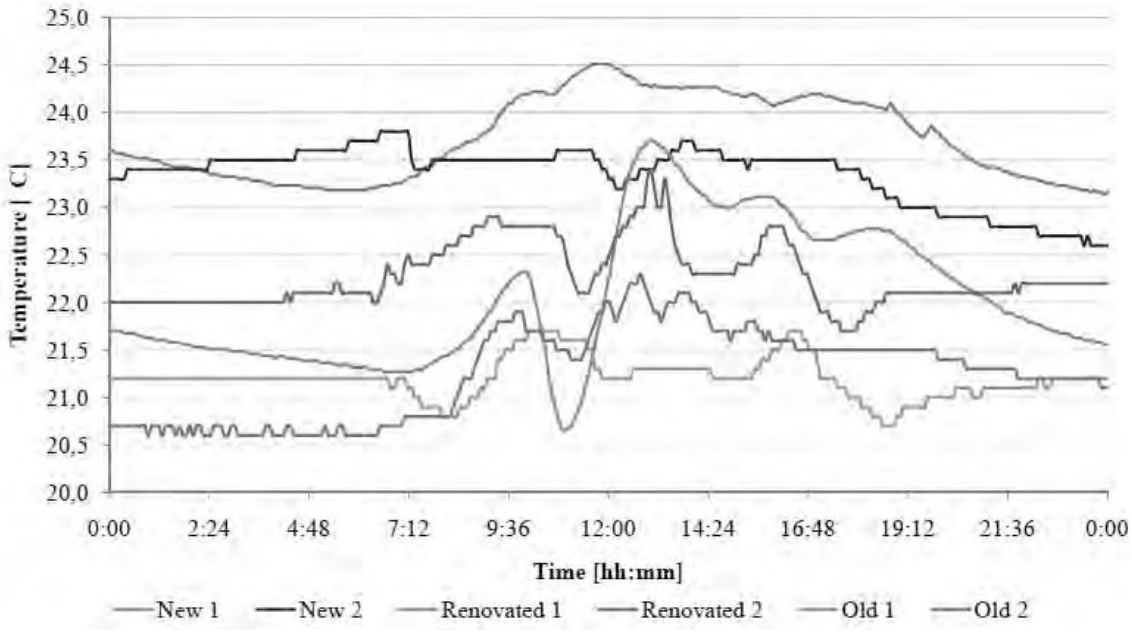

Figure 2. Temperature variation in six daycare centers on 26th October.

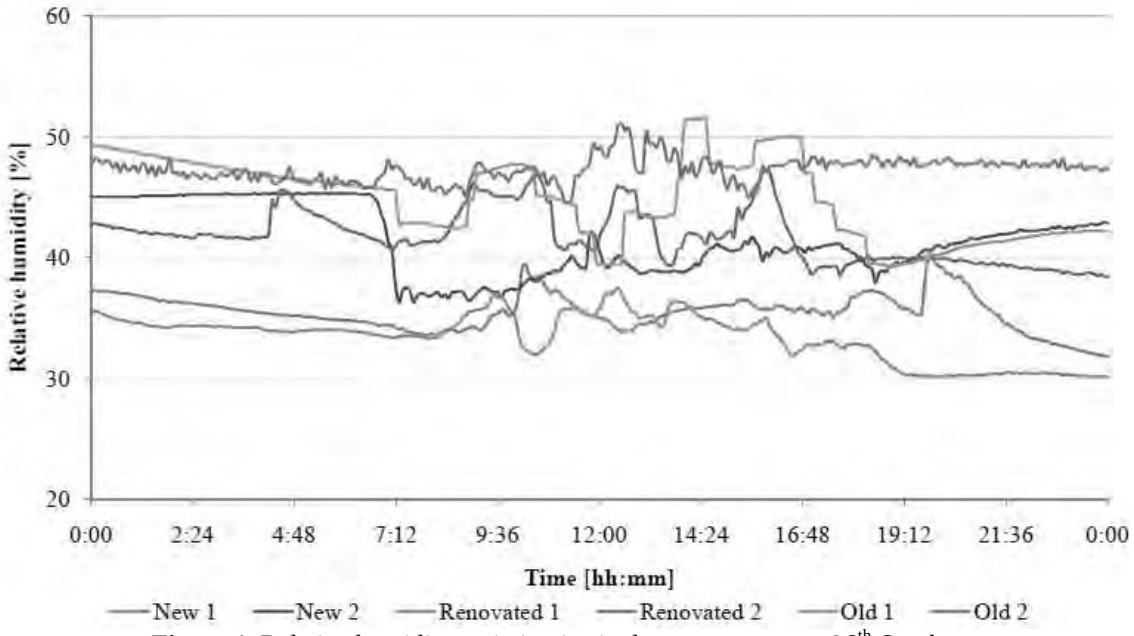

Figure 1. Relative humidity variation in six daycare centers on 26th October

The average room temperature in all six daycare centers during the daytime was 22.5 ± 1.1°C. In all facilities the temperature was kept above 18°C, which is the minimum acceptable stipulated by the Latvian building norms No. 596 (MK, 2002) for children older the age of three. 67% of the daycare facilities were outside the ASHRAE recommended comfort range of 23-26°C, having temperatures lower than 23°C. The temperatures were highest in the new-built daycare centers, that both have the underfloor heating system and mechanical ventilation system that explains also not very large temperature fluctuations, i.e., 24.1 ± 0.3°C and 23.5 ± 0.1°C for the New 1 and New 2 daycare center, respectively. The greatest temperature fluctuations occurred in the renovated facilities, especially in the Renovated 1 (σ = 0.8°C), where the temperature ranged from 20.7°C to 23.7°C. The temperature drops are a result of extensive airing by opening the windows and consequent creation of draft. However, the indoor temperature does not drop rapidly due to the relatively short time of windows being opened.. In all of the facilities there is a potential for saving energy by using the night-time temperature setback of up to 3°C.

Relative humidity

The variation in the relative humidity across the six daycare centers is shown in Figure 3. The average relative humidity of the six daycare centers was 40 ± 5% and did not vary to a great extent during the day. All of the facilities had the relative humidity in a range of 30 to 60% that is recommended by the ASHRAE standard 62.1 (ASHRAE, 2004). The relative humidity slightly decreased every time the windows were opened. The largest decrement was observed in the first half of the working day. This also corresponds to the rapid outdoor humidity decrease by almost 50% after 12 pm (Figure 1).
The relatively low humidity levels in the spaces also correspond to no visible signs of any moisture damage or mold growth on the indoor surfaces that were examined during the building visits.

CONCLUSIONS

This study provides assessment of the indoor air quality and thermal comfort in Latvian daycare centers with carbon dioxide, temperature and relative humidity as indicators. The CO_2 concentrations exceeded 1000 ppm in 75% of the daycare centers studied, with the highest (1356 ppm) measured in the Renovated 2 daycare facility with the natural ventilation system. Thus, the installation of more efficient ventilation system (mechanical) is recommended for improving the indoor air quality, since opening of the windows cannot provide the optimal conditions indoors. In all facilities the temperature was kept above 20°C and the average relative humidity was 40 ± 5%, creating comfortable thermal environment for children. The greatest temperature fluctuations were observed in the renovated daycare centers and this is another indicator that the daycare center personnel still rely entirely on natural ventilation for proper indoor air quality. Therefore, Riga Municipality must take actions to educate the personnel, and carry out regular inspection and maintenance of the ventilation system to ensure its proper operation. In all of the facilities there is a potential for saving energy by using the night-time temperature setback of up to 3°C.

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