

Indoor Air Quality and Thermal Comfort in Latvian Daycare Centres

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Abstract: This study investigates the indoor air quality and thermal comfort within six Latvian daycare centres (old, renovated and new-built). Measurements of carbon dioxide, air temperature and relative humidity have been carried out and the daycare centre characteristics data have been collected. Carbon dioxide concentrations exceeded 1000 ppm in 75% of the daycare centres studied, with the highest concentration (1356 ppm) measured in a renovated facility. In all facilities the temperature is kept above 20°C and the average relative humidity is $40 \pm 5\%$, thus creating a comfortable thermal environment for children.

Key words: Daycare centre, indoor air quality, thermal comfort

I. INTRODUCTION

About 75% of all children under the age of seven living in the Latvian capital – Riga spend about 30-60 hours a week in daycare centres. However, research studies indicate that daycare facilities, due to the improper indoor air quality (IAQ), may actually be hazardous to children's health. [1; 2] report on the increased risks of asthma and allergies for the children who spend their time in the daycare centre environments, compared to the care obtained at home. Therefore, during the last few decades an increased attention has been directed towards creation of the appropriate indoor environments at daycare centres.

Carbon dioxide (CO₂) is one of the most commonly used indicators of IAQ in areas, where people are the main source of pollution and it also serves as the determiner for adequate ventilation. CO₂ itself is not harmful normally, however its excessive exposure is found to cause headaches, fatigue, the increased risk of sick leave [3; 4] and even risks of sudden infant death [5]. According to European standard [6] the maximum CO₂ concentration in a space should not exceed 800 ppm (parts per million). The upper limit for the CO₂ concentration according to the ASHRAE standard [7] should not exceed 2500 ppm, while 1000 ppm is the recommended value.

Most of the indoor climate studies in daycare environments have been conducted in Nordic countries. Mean CO₂ levels reported in Scandinavian countries are as follows: 810 ppm in Finnish daycare centres [8], about 1400 ppm in Denmark [9], and as low as 640 ppm in Sweden [10]. [11] has investigated IAQ in two Latvian daycare centres and reports the maximum CO₂ concentration as high as 1700 and 1450 ppm in rooms with PVC and wooden frame windows respectively.

While CO₂ describes IAQ, the temperature and relative humidity are usually used to determine the thermal comfort

level in indoor environments. According to the Latvian building norms [12], the minimum acceptable air temperature in daycare centres must be 20.0°C or 18.0°C for children below and above the age of three respectively. The ASHRAE standard [7] recommends keeping the temperature within the range of 23-26°C and the relative humidity between 30 and 60%.

The majority of Latvian daycare centres were built in accordance with the old Soviet building codes which stated that ventilation should be achieved by natural means, i.e. fresh air supplied through window structures and exhausted through the vents (the stack effect). It was presumed that such solution would result in the sufficient air exchange. Lately the majority of daycare centres in Riga have been reconstructed: external walls have been insulated and wooden frame windows have been replaced by the PVC ones. However, these actions alone possess a big risk of IAQ problems, since buildings became more airtight which leads to insufficient air exchange indoors.

Since very limited data regarding the indoor air quality in Latvian daycare centres are available, the author of this study, being concerned about IAQ children are exposed to in the present construction buildings, has evaluated the current IAQ and the thermal comfort status in six daycare centres in the Riga Region.

II. MATERIALS AND METHODS

A. Daycare Centre Selection

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

B. Field Measurements

CO₂ concentration, temperature and relative humidity are convenient and reliable indicators of the indoor air quality and comfort level. 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 the CO₂ concentration that was measured only in renovated and newly-built daycare centres. Indoor sampling locations were

determined prior to the measurements through the walkthrough assessment. Since placement of measuring devices close to the breathing zone of children, i.e. at the height of 0.5-0.7 m, is restricted, indoor samplings have been taken 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 the humidity data have been collected by HOBO U12 Family data loggers with the following parameters: temperature -20°C to 70°C ($\pm 0.35^\circ\text{C}$) and relative humidity 10% to 90% with the accuracy $\pm 2.5\%$. The HOBO loggers are interfaced with CO₂ monitors Telaire 7001 measuring in the range of 0 to 10000 ppm (± 50 ppm). In addition to HOBO loggers, Testo 175-H2 measuring devices with the following parameters have been used: the measurement range -20°C to 70°C with the resolution 0.1°C, and the relative humidity 0 to 100% with the resolution of 0.1%.

CO₂ concentration was measured only in renovated and newly-built daycare centers.

Daycare centres in this paper are designated by their type, i.e. newly-built, renovated or old, and the corresponding number. Three daycare centres (New 2, Renovated 1, Old 2) have a single room for nap and playing; in other daycare centres nap activity and playing are carried out in separate areas. In the latter case, sampling was performed in the playing room, where children, consequently, were spending more time.

C. Data Analysis

The measured IAQ and thermal environment parameters among three categories of daycare centres have been compared. The means and \pm standard deviation (SD) of CO₂, the room temperature and the relative humidity levels have been calculated.

III. RESULTS AND DISCUSSION

A. Daycare Centre Characteristics

The basic data about the daycare centres and the selected investigated areas are given in Table 1.

The number of children in one group ranges from 15 to 22. The age of children in the investigated rooms varies within 3-6 years. The typical daytime regime in the daycare centres is as follows: from 7 am to 10:30 am – indoor activities in a playing room, 10:30 to 12 am – promenade, 12:30 to 15:00 – nap-time, and the rest of the time is spent indoors.

Daycare centre	Age of children [years]	Windows [-]	Ventilation system [-]	Heating system [-]
Old 1	6	PVC	Natural	Radiators
Old 2	3-5	PVC	Natural	Radiators
Ren. 1	4	PVC	Mechanical	Radiators
Ren. 2	4-5	PVC	Natural	Radiators
New 1	3	PVC	Mechanical	Underfloor
New 2	4-5	PVC	Mechanical	Underfloor

TABLE 1
DAYCARE CENTRE DETAILS

The maintenance personnel in all daycare centres still relies on natural ventilation for achieving the acceptable indoor air quality and opens windows every time the children are outside.

B. Carbon Dioxide

In this study, the average indoor CO₂ concentration during daytime for all daycare facilities is 730 ± 170 ppm (Table 2).

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

In most of the daycare centres (75%), CO₂ levels exceeded the ASHRAE recommended value of 1000 ppm. It has also been observed that in multipurpose rooms (for general activities and nap), the nap-time average CO₂ level is about 60 ppm higher, compared to the non-nap time average CO₂ level. This can be explained by the fact that children are placed in a closed area without the adequate air exchange. Even though in the present study CO₂ concentration was not measured in sleeping-only rooms, the study conducted in US daycare centres [13] showed 24.3% CO₂ increment from non-nap time to nap-time in this type of rooms. Thus, it can be expected that Latvian daycare centres might follow a similar tendency, but this should be confirmed by further experiments in sleeping-only rooms.

The highest CO₂ concentration was obtained in Renovated 2 daycare centre, which has a natural ventilation system, as opposed to the other three daycare centres with the mechanical ventilation system installed. Even though opening of windows does lower the CO₂ concentration, still it is not enough to achieve the optimum level, since low outdoor air temperature limits the airing period. Thus, better indoor air quality is achieved in mechanically ventilated spaces with a constant supply of fresh air.

C. Temperature

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

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

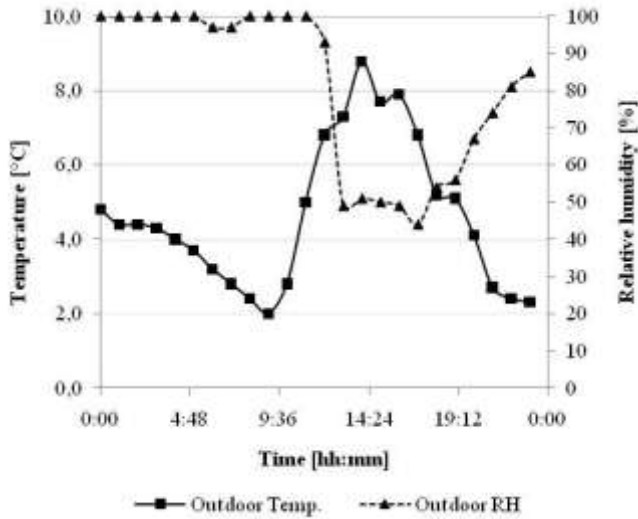


Fig. 1. Atmospheric conditions on 26 October

The variation of daytime room temperature across the daycare centres on 26 October is shown in Fig. 2.

The average room temperature in all six daycare centres during the daytime was $22.5 \pm 1.1^\circ\text{C}$. In all facilities, the temperature was kept above 20°C , which is the minimum acceptable level stipulated by Latvian building norms [12] for children under the age of three. 67% of the daycare facilities were outside the ASHRAE recommended comfort range of $23\text{--}26^\circ\text{C}$, having the temperatures below 23°C .

Temperatures are the highest in the new-built daycare centres which both have an underfloor heating system and a mechanical ventilation system – this also explains the not very large temperature fluctuations, i.e. $24.1 \pm 0.3^\circ\text{C}$ and $23.5 \pm 0.1^\circ\text{C}$ for New 1 and New 2 daycare centres respectively. The largest temperature fluctuations occurred in the renovated facilities, especially in Renovated 1 ($\sigma = 0.8^\circ\text{C}$), where the temperature ranged from 20.7°C to 23.7°C . The temperature drops are the result of extensive airing by opening windows and, consequently, creation of draft. However, the indoor temperature does not drop rapidly due to the relatively short time of windows being opened.

In the entire facilities, there is a potential for saving energy by using the night-time temperature setback of up to 3°C .

D. Relative Humidity

The variation in relative humidity across six daycare centres is shown in Fig. 3.

The average relative humidity of six daycare centres was $40 \pm 5\%$ and did not vary to a great extent during the day. All of the facilities had relative humidity within the range of 30 to 60%, as recommended by ASHRAE standard [7]. The relative humidity slightly decreased every time 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 (Fig. 1).

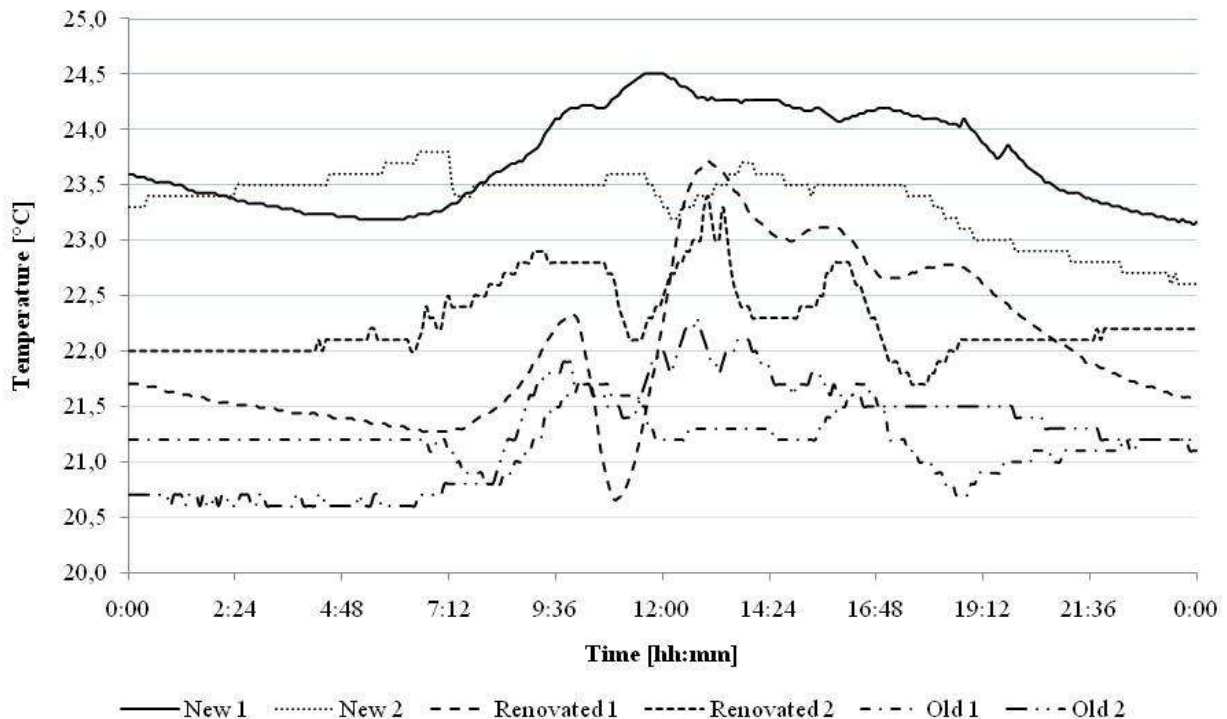


Fig. 2. Temperature variation in six daycare centers on 26 October

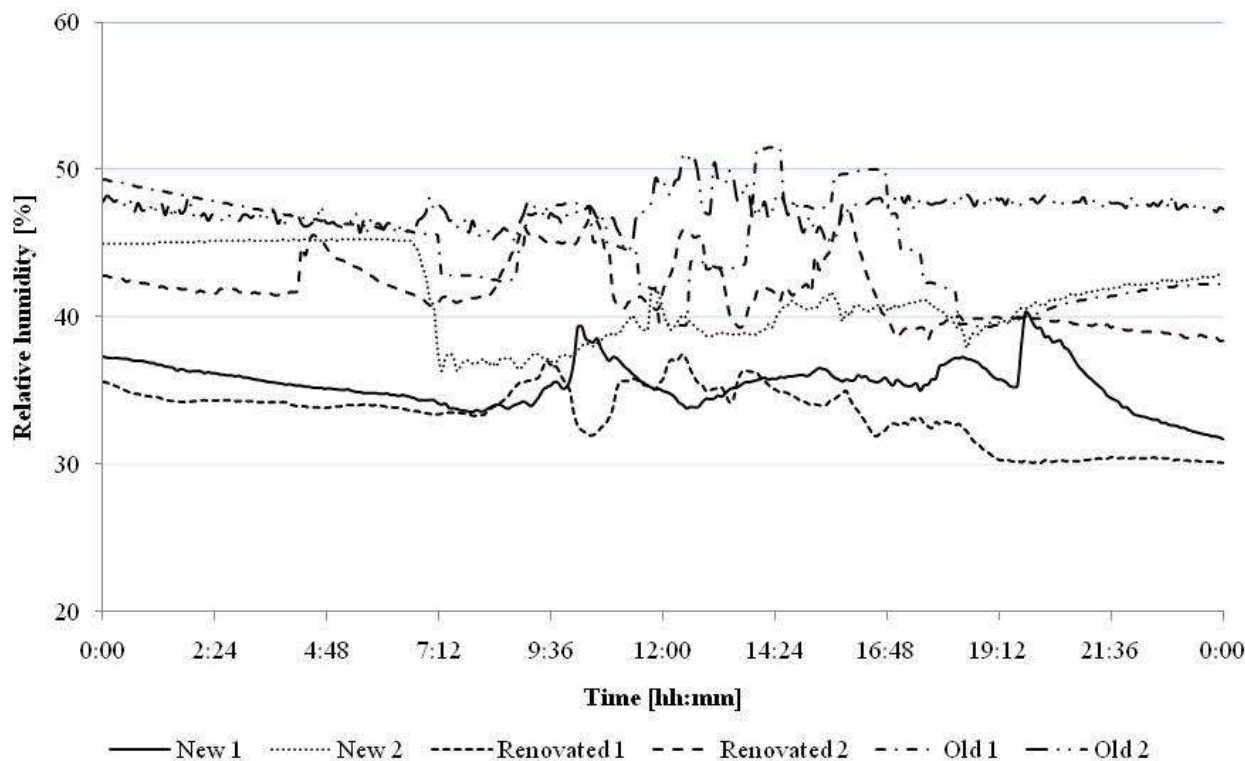


Fig. 3. Relative humidity variation on 26 October

IV. CONCLUSIONS

This study provides assessment of the indoor air quality and the thermal comfort in Latvian daycare centres with carbon dioxide, temperature and relative humidity as indicators.

The CO₂ concentrations exceeded 1000 ppm in 75% of the studied daycare centres, with the highest level (1356 ppm) measured in Renovated 2 daycare facility with the natural ventilation system. Thus, installation of a more efficient ventilation system (mechanical) is recommended for improving the indoor air quality, since opening of 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%, thus creating a comfortable thermal environment for children. The largest temperature fluctuations were observed in renovated daycare centres and this is another indicator that daycare centre personnel still rely entirely on natural ventilation for the proper indoor air quality. Therefore, the Riga municipality must take actions to educate the personnel and carry out regular inspections 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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Gaļina Stankeviča, Arturs Lešinskis. Iekštelpu gaisa kvalitāte un termālais komforta Latvijas bērnu dārzos

Pēdējo piecu gadu laikā lielākajā daļā Latvijas bērnu dārzu tika veikti energoefektivitāti uzlabojoši pasākumi, kuru starpā bija arī ēkas fasāžu siltināšana un veco koka karkasa logu nomaiņa pret PVC tipa logiem. Tomēr šo pasākumu ieviešana var negatīvi ietekmēt telpas mikroklimatu, jo ēkas līdz ar to kļūst gaisa necauraidīgākas, un tas savukārt var novest pie nepietiekamas iekštelpu gaisa apmaiņas, ja neveic ventilācijas sistēmas uzlabošanu. Tā kā Latvijas bērnu dārzos bērni pavada līdz pat 60 stundām nedēļā, ir ļoti svarīgi radīt veselīgu un komfortablu iekštelpu vidi, kurā bērniem būtu patīkami uzturēties. Pētījums tika vērst uz iekštelpu gaisa kvalitātes un termālā komforta analīzi Latvijai raksturīgā mērenā klimata zonas bērnu dārzos (vecos, renovētos un jaunbūvēs). Darba ietvaros tika veikti oglekļa dioksīda, gaisa temperatūras un relatīvā mitruma mērījumi, kā arī ievākta informācija par izvēlēto bērnu dārzu konstrukcijām, siltuma enerģijas patēriņu, uzstādītajām inženiersistēmām un apkopes pasākumiem. Pētījuma rezultātā konstatēts, ka oglekļa dioksīda koncentrācija pārsniedza rekomendējamo 1000 ppm vērtību 75% bērnu dārzos, no kuriem augstākā koncentrācija (1356 ppm) tika izmērīta renovētajā bērnu dārzā ar dabisko ventilācijas sistēmu. Līdz ar to logu atvēršana nespēj radīt un uzturēt optimālu gaisa mikroklimatu telpās, un tāpēc ir ieteicams uzstādīt efektīvāku ventilācijas sistēmu (mehānisko), lai nodrošinātu pieņemamu iekštelpu gaisa kvalitāti. Gaisa temperatūra visos bērnu dārzos pārsniedza 20°C un relatīvais mitrums bija vidēji 40 ± 5%, tādējādi uzturot komfortablu termālo vidi. Visos bērnu dārzos ir iespējams ietaupīt elektroenerģiju, samazinot telpu temperatūru par 3°C nakts laikā.

Галина Станкевича, Артурс Лешинскис. Качество воздуха и термальный комфорт в латвийских детских садах

В течение последних пяти лет в большей части детских садов Латвии были проведены меры по повышению их энергоэффективности. В том числе дополнительная теплоизоляция фасада зданий, а также замена старых, деревянных оконных рам на стеклопакеты из ПВХ-профиля. Вышеупомянутые меры могут негативно повлиять на микроклимат помещения, так как здания стали более герметичными, что в свою очередь ведет к недостаточному обмену воздуха в помещении. В детских садах Латвии дети могут находиться до 60 часов в неделю, поэтому очень важно создать здоровые и комфортные условия для детей. Это исследование направлено на анализ качества воздуха и теплового комфорта в детских садах (старых, реконструированных и новостройках) Латвии, находящийся в полосе умеренного климата. В рамках работы были произведены измерения внутренней температуры воздуха и его относительной влажности, а также концентрации углекислого газа в воздухе. Кроме того была собрана информация в отобранных детских садах, об их конструкциях, установленных инженерных системах, и их техническом обслуживании. Результаты исследования показали, что концентрация углекислого газа превышает 1000 ppm в 75% детских садов. Наибольшая концентрация (1356 ppm), наблюдалась в реконструированном объекте с естественной системой вентиляции. Таким образом, установка более эффективной системы вентиляции (механической) желательна для поддержания приемлемого качества внутреннего воздуха, так как открытие окон само по себе не может обеспечить оптимальные условия в помещениях. Во всех объектах температура поддерживалась выше 20°C, средняя относительная влажность воздуха составляла 40 ± 5%, создавая комфортные тепловые условия для детей. Существует возможность экономии энергии во всех детских садах за счёт понижения температуры на 3°C в ночное время.