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The indoor environmental quality in a Dutch day care centres:

the effects of ventilation on the conditions within the baby cots

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Abstract

The indoor quality of an occupied space is very important for the well-being of its occupants, especially in the case of young children. The poor condition of the indoor environment in almost 80% of the Dutch classrooms has led to the drafting of a program of demands for fresh schools. This program of demands is currently only available for the accommodation of primary schools whilst a healthy indoor environment for younger children (age 0-4) is far more important. The lungs of a young child are still growing and adverse conditions could affect this development. Babies and young children spend a lot of their time in day care centers, while little is known about the effects of different indoor environmental factors present in these day care centers. The results of the studies were compared with the results of an earlier Dutch study in a day care centre. The results proved that the indoor air quality situation in day care centres is not completely acceptable and clear. More attention is needed to improve the current situation.

Keywords – Day care centers, Indoor Air Quality, baby, young children

1. Introduction

In the Netherlands, the indoor environment in primary schools has attracted increasing attention in recent years. Poor IAQ can result in: headaches, fatigue, drowsiness, mucosal irritations and an aggravation of allergies and respiratory symptoms and thereby they also affect the cognitive performance of the children attending primary school [1]

Around 300.000 Dutch children in the age of 0 to 4 attend daycare centers [2], this is about 30% of all children in this age category [3]. All these children spend a large amount of time at daycare centers whilst the parents are at work. These infants have an increased need for oxygen according to their size, therefore they breath more rapidly and inhale relatively more pollutants [4], also their lung defenses against pollution are

not fully developed yet [5]. Therefore infants are more vulnerable to pollution than the children attending primary school. This means that it is important to provide good IAQ in daycare centers. Nevertheless, the IAQ in daycare centers has been neglected for a long time. Besides that, infants spend relatively large amounts of time sleeping during their stay at a daycare center, and during their sleep these infants are even more vulnerable to indoor air pollutants. The sleeping infants are strongly influenced by their sleeping microenvironment, in other words the IAQ in the vicinity of a sleeping infant or inside the baby is vital for growing infants. But there have been very few studies on the IAQ in the vicinity of sleeping infants.

Some research was conducted in Sweden [6], Canada [7], Finland [8], United States [9], Latvia [10] and France [11] regarding the state of the IAQ at daycare centers, see table 1. In the Netherlands an extensive research is conducted by Versteeg [12] concluded that the IAQ at Dutch daycare centers is not optimal. However, the measurements were not performed in the vicinity of the sleeping infant. In a research conducted by de Waard [13] the IAQ was measured in the vicinity of the infant, the results showed that CO₂ concentration close to the infants is sometimes unacceptable higher than in the general rooms.

Table 1 CO₂ concentrations at daycare centers in previous research

Researcher	Country	Minimum CO ₂ ¹	Mean CO ₂ ¹	Maximum CO ₂ ¹	Population ²
Berglund, 1982	Sweden	-	880	-	1
Daneault et al., 1992	Canada	816	1505	2442	91
Ruotsalainen et al., 1993	Finland	400	810	2500	30
Ferng & Lee, 2002	US	669	1142	2500	26
Versteeg, 2009	Netherlands	639	1452	3629	60
Stankevica & Lesinskis, 2011	Latvia	421	731	1356	4
Roda et al., 2011	France	479	817	2177	28
de Waard, 2014	Netherlands	508	1185	3940	1

¹ CO₂ concentration [ppm]

² Number of daycare centers [n]

2. Methodology

During the field study the CO₂ concentration will be continuously measured in combination with the hygrothermal performance, by measuring the temperature and relative humidity. This field study is conducted with high accuracy equipment: CO₂ is measured with a SBA-5 CO₂ analyzer while the temperature and relative humidity are measured with Humitter 50U/50Y(X) transmitter. This equipment is installed in the bedroom of two different daycare centers in order to measure the inside baby cot and to measure the CO₂ concentration of general condition and hygrothermal performance of the bedroom. The measurement is conducted continuously for five workdays in both daycare centers.

CO₂, indicated using parts per million [ppm], is a colorless and practically inodorous stable chemical compound heavier than air and CO₂ thus flows downwards. CO₂ itself is considered non-toxic, but high exposure can cause: headache, fatigue and it increases the risk of sudden infant death syndrome [10]. SIDS occurs more often at daycare centers than at home. Despite of the incomprehension of the exact reason why SIDS occurs there are some statistical proven reasons, related to daycare centers, why SIDS occurs here more often. Stress is most likely the major reason why SIDS can occur. Their stay at daycare center can be rather stressful for an infant: the infant is without his parents, presence of new caretakers, new smells, new sounds, different baby cot and different routine. Besides that IAQ often does not succeed/achieve/meet legislation. The relation between room ventilation and SIDS risk has received scant attention. Inadequate ventilation might facilitate pooling of CO₂ around a sleeping infant's mouth and nose and might increase the likelihood of rebreathing [14,15]. Increased movement of air in the room of a sleeping infant may potentially decrease the accumulation of CO₂ around the infant's nose and mouth and reduce the risk of rebreathing and eventually SIDS. As mentioned CO₂ is heavier than air, theoretically this will lead to a CO₂ gradient inside the room with higher concentrations close to the floor. However, also some other parameters influence the gradient (e.g. air flows due to ventilation). Research conducted by Schäfer et al. shows that for a mixed ventilation, which is applied in most Dutch buildings, that there is hardly any CO₂ gradient (Fig. 1 [16]).

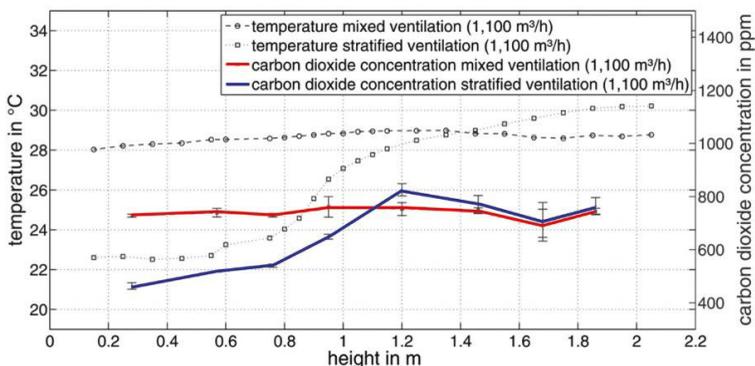


Fig. 1 Temperature and carbon dioxide profiles for mixed and stratified ventilation of 1100 m³h [16]

Therefore this gradient does not need to be taken into account when designing the measurement set-up. Carbon dioxide is selected as an indicator for the IAQ in this research, though, it is not a comprehensive IAQ indicator because it cannot indicate non-occupant related pollutants. In this research, IAQ is assessed in the vicinity of a sleeping infant. The infant spends

relatively large amounts of time sleeping during their stay at daycare center and the metabolism rate of the infant is quite high whilst sleeping. It is the inhaled air that causes the health risk. By measuring the IAQ of the microenvironment around the infant is determined as it is exposed to the infant. The air in the vicinity can have different CO₂ concentration than the air in the room, due to obstructions caused by the baby cots, which can generate low air velocities, whilst gaseous diffusion is too slow to remove the polluted air [14].

3. Measurements

The equipment used during the measurement is displayed in Table 2.

Table 2 The equipment used for the measurement

Measurement	Device	Measuring point	Interval	Inaccuracy
CO ₂	SBA-5 CO ₂ Analyzer	Baby Cot, General Condition, Outside	10 sec	±20 ppm
Temperature	<u>Humitter</u> 50U/50Y(X)	Baby Cot, General Condition	60 sec	±0,7°C
Relative Humidity	<u>Humitter</u> 50U/50Y(X)	Baby Cot, General Condition	60 sec	±3%
Data Logging	Squirrel 2020 <u>serie</u>	X	60 sec	±0,075%

The measurement took place in the spring of 2015 (Table 3). These measurements had both a duration of five days to prevent coincidences and to achieve representable data. Daycare center 1 was occupied for three days and daycare center 2 was occupied for four days.

Table 3 Measurement dates in daycare centers

Daycare center	Start date	End date
1. A	01-06-2015	05-06-2015
2. B	08-06-2015	12-06-2015

4. Case studies

Daycare Center 1

The first daycare center is located in a residential area in Eindhoven at a distance of 100 m from an important arterial thoroughfare. The recently renovated, daycare center is part of a comprehensive school including a: primary school, pre- school and a daycare center. It is equipped with CO₂

based demand-controlled balanced ventilation (DCV). The inlets are placed in the playing areas and outlets are placed in bed- and bathrooms, the CO₂ sensors are located in the bedrooms, see Fig. 2.

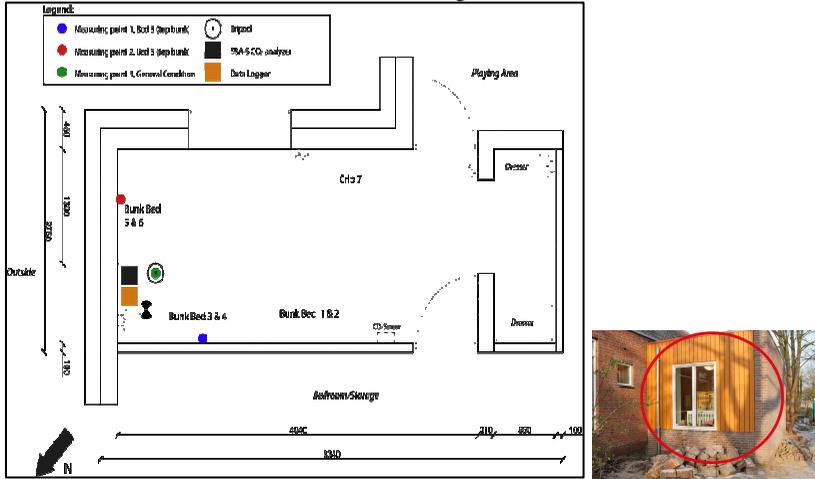


Fig. 2 Floorplan of bedroom in daycare center 1 and from outside, the red circle shows the bedroom

Daycare Center 2

The second Daycare center is located in one of the residential areas of Eindhoven, the access road to the entire neighborhood, is within a 100m. This building is applied with a natural ventilation system. Natural ventilation is the most basic ventilation strategy. The ventilation is driven by wind pressure, therefore will provide irregular ventilation. Nevertheless most older Dutch buildings, including most daycare centers, are natural ventilated. This system is often used in the past, but nowadays the system is barely used anymore. The CO₂ sensors are located in the bedrooms, see Fig. 3.

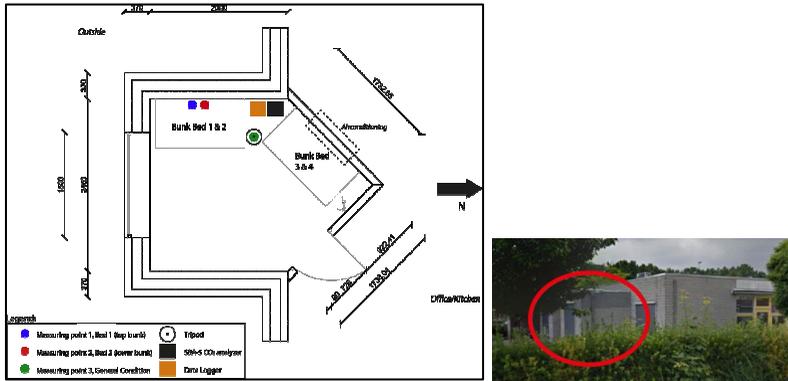


Fig. 3 Floorplan of bedroom in daycare center 2 and from outside, the red circle shows the bedroom

5. Results

Here only a selection of all measurements will be presentend, focussing on the outcomes for different bed in the sleeping quarters.

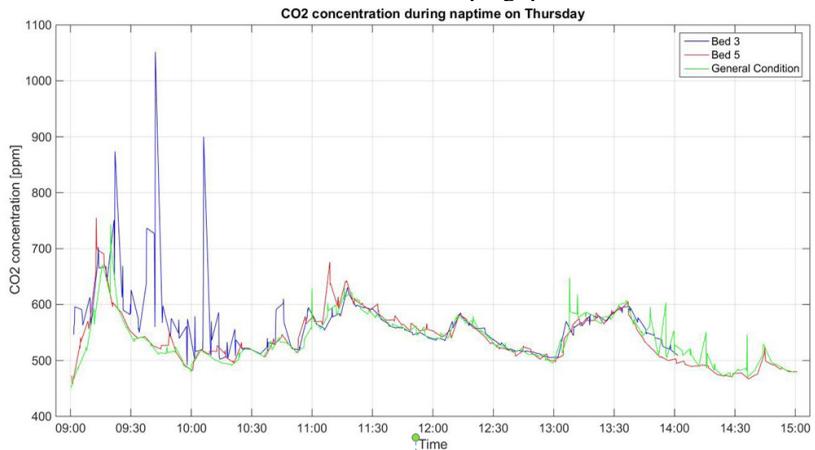


Fig. 4 CO₂ concentration when occupied during naptime on Thursday at DCC 1 (04-06-2015)

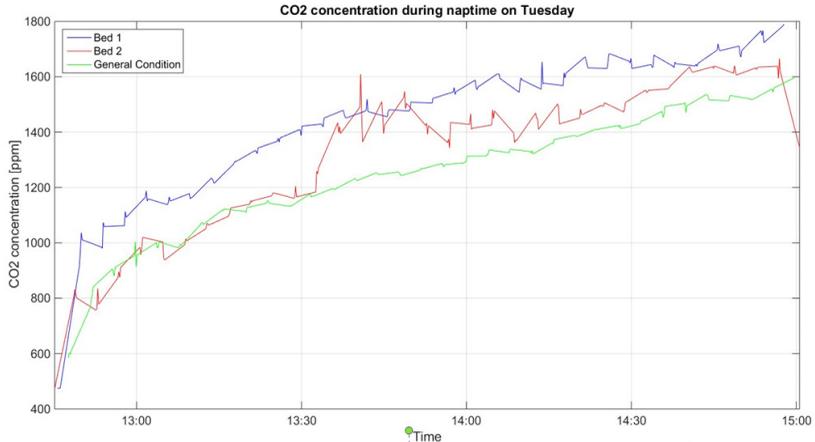


Fig. 5 CO₂ concentration when occupied during naptime on Tuesday at DCC 2 (09-06-2015)

In Fig. 6 the results of daycare center 1 and daycare center 2 are put into one boxplot, in order to achieve a good overview of the differences between the daycare centers.

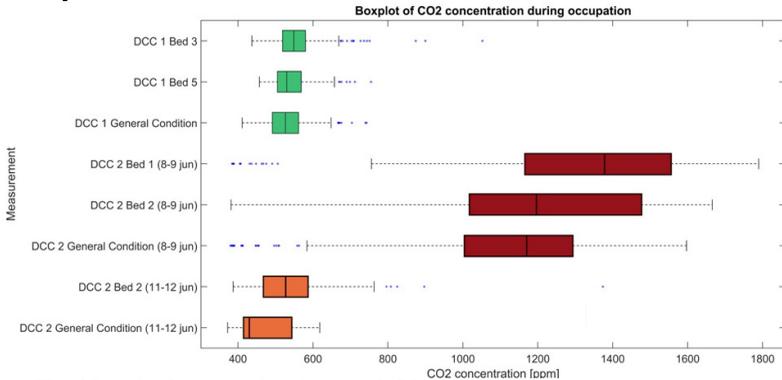


Fig. 6 Boxplot for comparison between DCC 1 and DCC 2

Daycare center 2 resembled daycare center 1 relatively well during the days that the auxiliary devices are used, when this electric fan is not used there is absolute no resemblance. At daycare center 1 the General Condition and the beds almost have the same CO₂ concentration, while for daycare center 2 the differences between the beds and General Condition were somewhat larger. The air circulation of daycare center 1 was much better and more efficient due to the DCV ventilation. Even when the room is fully occupied the IAQ of daycare center 1 is still much better than the IAQ in daycare center 2 which is occupied by less infants. Only during the last two

days of the measuring period the CO₂ concentration of daycare center 2 resembled daycare center 1. The reason lies in the application of additional devices, electric fan and air-conditioning, to enhance air circulation and reduce the indoor temperature. In most conditions these devices are not turned on, therefore the IAQ is much lower than the IAQ of daycare center 1.

6. Comparison with previous research

De Waard did a research to the IAQ in a hybrid ventilated daycare center, by measuring the CO₂ concentration in the microenvironment of sleeping infants, the comparing results are illustrated in Fig. 7.

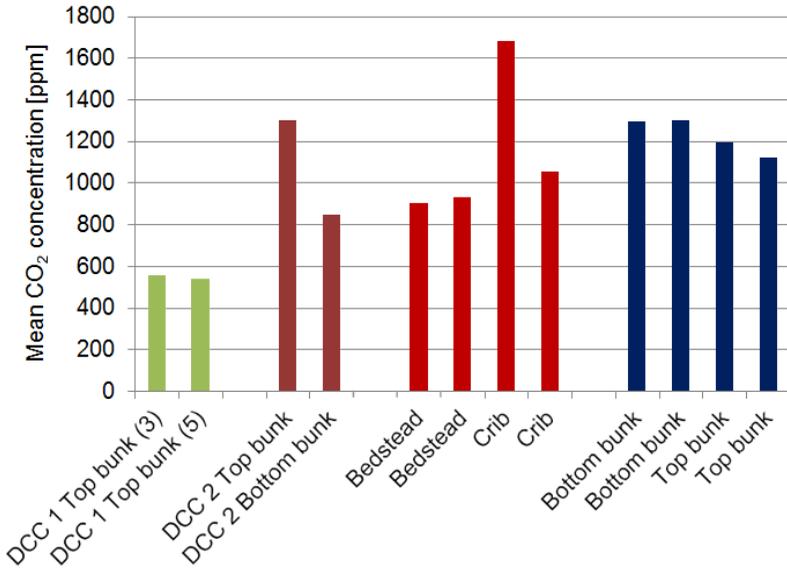


Fig. 7 Comparison with research conducted by de Waard [13]

The IAQ inside the beds of daycare center 1 was clearly better than in the beds measured by de Waard [13], this was expectable because the DCV system of daycare center 1 performs normally better than a hybrid ventilation system as applied in the measured daycare center of De Waard. The CO₂ concentrations of daycare center 2 match the result of de Waard much better, normally natural ventilated systems as applied in daycare center 2 perform worse than hybrid ventilated systems. Nevertheless the results of daycare center 2 are a little better, this is partly caused by the enhanced air circulating, by the electric fan and air-conditioning, to cool down the bedroom of daycare center 2. In all likelihood, without the high temperatures

and the associated behavior, daycare center 2 would not have performed better than in de Waard's research [13].

7. Discussion and conclusions

Previous research showed that IAQ in Dutch daycare centers often is inadequate, the same counts for Dutch primary schools, therefore the Fresh School program is developed, in which daycare centers are neglected, while in general infants are more susceptible for a low IAQ. The goal of this research was to investigate the CO₂ concentrations of bedrooms in Dutch daycare centers, with an emphasis on the microenvironments inside the baby cots, it was expected that the CO₂ would be higher inside the cot because it may act as a confined space. CO₂ is used as an indicator for the IAQ, because CO₂ is able to indicate the pollutants coming from the human body, in addition CO₂ is relatively easy to measure and often used in legislation. CO₂ itself is not particularly harmful for infants, however it plays a role in sudden infant death syndrome.

Measurements were conducted in the bedrooms of two daycare centers located in Eindhoven. During this measurement CO₂ as well as the temperature and relative humidity were monitored. The applied equipment are chosen for their high accuracy that results in some practical limitations, for instance, all measuring points had to be relatively close to each other. Two measuring points are applied inside the microenvironment of the sleeping infant inside the baby cot, and one measuring point is applied to measure the general condition of the bedroom. In both daycare centers the measurements have a duration of one workweek. The measurement data is only analyzed during occupation.

Daycare center 1 is applied with a CO₂ based demand-controlled ventilation system (DCV), this was retrievable from the measuring results. Daycare center 2 is applied with a natural ventilation system. The measurements showed that the DCV system provides a much better IAQ than natural ventilation system. According to the Public Health Services in daycare center 1, the mean CO₂ concentration around beds is approximately 550 ppm, and is classified as 'Good' and the general condition is classified as 'Very Good'. In daycare center 2, with a mean CO₂ concentration of approximately 900 ppm, all measuring results are classified with 'Very Poor'.

Compared to previous researches done in the Netherlands, both daycare centers performed better than the average daycare center in the Netherlands, however, the IAQ of daycare center 2 is still substandard. High CO₂ concentrations inside the microenvironment of the baby cot were not caused by the confined space of the baby cot. In daycare center 1 there were no significant differences between the CO₂ concentrations of the beds compared to the general condition. While in daycare center 2 there were significant

differences, however these differences were rather small. The measured CO₂ concentrations inside the microenvironment of the bed are caused by the ventilation rate of the entire bedroom. Therefore the performance of daycare center 1 is much better than daycare center 2 because the installed CO₂ based DCV system guarantees a sufficient ventilation rate while the natural ventilated ventilation system is uncontrollable.

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