The CO₂ conditions within the baby cots of day care centres

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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. Although nowadays little children spend a lot of their time in day care centres, relatively little is known about the effects of different indoor environmental factors present in these day care centres. Therefore this research investigated the indoor air quality of the sleeping accommodation of two Dutch day care centre as well as the conditions with the baby cots. Besides an extensive literature research actual measurements were performed in two day care cent to find out the indoor air conditions within baby cots. The results of the detailed studies were compared with the results of earlier Dutch studies in day care centres. Although, our latest findings were not as bad as results from our earlier case studies, still more attention is needed to get a better understanding of the current situation in which babies sleep.

1 Introduction

Young children, and their immune system, are continuously under development. Adverse conditions could influence this development [1], or might even increase the risk of sudden infant death [2,3]. Children are more vulnerable to airborne pollution due to the fact that their airways are narrower than adults, they have markedly increased needs for oxygen relative to their seize, they breathe more rapidly and inhale more pollutants per pound of body weight [4]. Babies and little children spend a lot of their time in day-care centers while parents are at work. The infants normally stay at a child day-care centre until their fourth birthday. Strangely enough little is known about the indoor environmental conditions in these day-care centers [5, 6, 7, 8, 9, 10, 11, 12]. This while a healthy environment is very important for the development of infants and especially their lungs as such they are the most vulnerable group of our population. Table 1 provides an overview of some studies, in most cases between 20 up to 75% of all measured daycare centers had CO₂ concentrations well above the recommended level by the Dutch government of 1000 ppm in class rooms and 800 ppm in sleeping rooms.

In most studies the overall CO₂ level is measured in the class rooms and in some also in the bedroom. Therefore it was decided to examine especially the ventilation of the daycare bedrooms in detail. The objective of this research is to determine CO₂ concentration in the breathing zone of a sleeping infant of baby cots used in child day care centres and see if they meet the demands in the Dutch building code of 2012. Field studies have been done among the different types of baby cots in different daycare centers to measure the CO₂ concentrations inside these baby cots [13,14] of which an overview was made [17]

Table 1. Overview of CO₂ concentrations in daycare centers from different studies

Year	Location	Number	Average CO ₂ [ppm]	Reference
2005	Netherlands	51-62	920 (bedrooms) 1297 (class room)	[5]
2009	Netherlands	60	1452	[7]
2011	Latvian	4	731	[8]
2011	Paris	28	933	[9]
2012	Montreal	21	1333	[17]
2014	Portugal	52	1563	[10]
2016	Italy	1	1100	[11]
2016	Europe	4	1128	[12]

In this paper the results of further investigations in two more modern daycare centers are presented. The results of the measured CO₂ concentrations inside baby cots of day-care centers made it clear why it is important to focus also on the ventilation effectiveness inside baby cots and not only on the ventilation rates in general. These effects can lead to CO₂ concentrations which can be on average around 25% (with in some situations even up to nearly 60% higher) than the average concentrations in the sleeping rooms of the day-care centers from the extensive research by Versteeg in 2009 [7].

2 Methods

As stated in section one, the goal of this research is to determine what the CO₂ concentration are near a sleeping infant and to see if they meet the current demand of the Dutch building code 2012. To determine this measurements were performed in different type of baby cots in two day care centres. The purpose of these

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measurements was to obtain enough CO₂ data to compare the conditions within a specific baby cot and to determine if the differences between these baby cots are significant and accountable for possibly higher CO₂ concentrations. In our earlier research [13,14], different types of baby cots were monitored inside the day care centre, see Figure 1. The first type, a crib is used for children in the age of 2 -4 and which tend not to get out of bed while sleeping. The second type, the bedstead, is used by both new bourns as children in the age of 2 -4. The last type was the bunk bed used, top and bottom, with children in the age of 10 weeks up to 2 years.

Figure 1. Different types of baby cots

2.1 Measurement setup

In the research of de Waard [13], the breathing zone was determined to be $\pm 0.3\text{m}$. This is therefore the distance that was aimed to apply in the 'practical conditions'. The general setup can be seen in Figure 2.

Figure 2. General measurement setup

1. Two CO₂ sensors
2. Cable bundler
3. Two pressure sensors
4. Central box
5. Mains supply

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

Table 2. Measurement equipment

Measurement	Device	Interval	Inaccuracy
CO ₂	SBA-% CO ₂ Analyser	1 sec	± 20 ppm
Data logging	Squirrel 2020 series	1 sec	$\pm 0,075\%$

To ensure to safety of the infant inside (and outside) the crib, none of the equipment was placed inside the crib. Also all the wires where made unreachable from inside the crib.

2.2. Measurements

The measurement results are gathered from the 18th of June until the 21st of June. All the measurement took place in the Netherlands, in 'den Haag'. In total two location were measured over a period of two days, [1] respectively [2] in table 5, each at a different room, these locations can be seen in Table 3. Both locations where recently renovated and where mechanically ventilated, meeting the ventilation demands of the Dutch building code 2012.

Table 3. Measured locations

Date	Location	Room
18-06-2018	A	1
19-06-2018	A	2
20-06-2018	B	3
21-06-2018	B	4

All date generated during the measurements were stored on a logger. Afterwards the logger can be read out and the data can be used for analysis. During the measurement a logbook was kept to store all the actions that might have an effect on the registered data. For an example of this logbook see Table 4.

Table 4. Example logbook location A room 2

Time	Action
9.17	Measurement started
9.58 – 10.07	Test baby is placed in the crib (and 4 others)
10.55-10.58	Baby is taken out of the crib (and 4 others)
11.00	Measurement setup is checked
12.00	One baby is placed in other crib
13.15	Another baby is placed in the crib (stacked crib)
15.01	2 babies are taken out of their crib
15.05	Test baby and four other baby are placed in their bed
15.07	Measurement setup is checked
16.14	Test baby and all the other babies are taken out of the crib
16.21	Fine particle measurement installed
16.32	Measurement setup turned off

3. Results

Figure 3. Measurement setup and results location A, room 1

Figure 4. Measurement setup and results location A, room 2

Figure 5. Measurement setup and results location B, room 3

Figure 6. Measurement setup and results location B, room 4

3.2. CO₂ levels

The CO₂ concentration during nap-time (the infant is inside the crib) is summed up in Table 5. Each percentage resembles the amount of time during nap-time that the CO₂ concentrations are within the listed classes. The listed classes are based on the test values for ventilation in schools and child daycares [15]. The classes can be described as:

- A: Very good
- B: Good
- C: Acceptable
- D: Insufficient
- E: Very poor

Table 5. CO₂ concentrations during nap-time (GGD)

Legenda: A.R1[1], means Location A room 1 measurement session 1

Class	A	B	C	D	E
CO ₂ [ppm]	< 650	650-800	800-1000	1000-1400	> 1400
A.R1 [1]	97.6%	0.9%	0.7%	0.6%	0.2%
A.R1 [2]	99.4%	0.5%	0.1%	0.0%	0.0%
A.R2 [1] Nap 1	7%	91%	2%	0%	0%
A.R2 [2] Nap 1	47%	46%	7%	0%	0%
A.R2 [1] Nap 2	95%	4%	0%	0%	0%
A.R2 [2] Nap 2	67%	8%	6%	13%	5%
B.R3 [1] - Nap 1	0%	7%	88%	4%	1%
B.R3 [2] Nap 1	0%	87%	12%	1%	0%
B.R3 [1] - Nap 2	70%	28%	1%	1%	0%
B.R3 [2] Nap 2	93%	5%	1%	1%	0%
B.R4 [1]	0%	44%	44%	12%	0%
B.R4 [2]	0%	62%	28%	11%	0%

The results from Table 5 were added up in Figure 7 and Figure 8. In figure 7 and 8, the left column represents the measurement position inside the crib attached to the bars, the right column represent the measurement position at the wall.

COMBINED CO₂ CONCENTRATIONS - NAP TIME

Figure 7. CO₂ concentrations during nap-time, all measurements

However it is advised to take actions if this occurs too much.

During the measurements in location B room 3, the ventilation unit malfunctioned in the first nap-period. When these values are excluded, see Figure 8, the CO₂ concentrations meet the conditions for class A and B for 85% (bars) and 85% (wall) of the time. It also can be seen that the class A increases from 52% and 47% to 64% and 58%. The undesired class C is also significantly lower.

COMBINED CO₂ CONCENTRATIONS - NAP TIME

Figure 8. CO₂ concentrations during nap-time, Nap 1 B R3 excluded

The class D and E conditions also occur in both figures, however this is a small percentage. During the test period at the TU/e it was noticed that if someone is close to the sensors, and breaths directly into the air intake, the

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values spike tremendously. As explained before, during the experiment the children were put to bed, but where not asleep directly. In some cases it was noticed that the children would stand directly to one of the sensors, especially the sensor attached to the bars.

In Table 4 it can be seen class D and E are most reached during Nap 2 in location A room 2, these values are displayed in Figure 7. During the end of the sleeping period the values of above 1000 ppm are mostly reached.

Figure 9. CO₂ (PPM) vs. movement – Location A, room 2

4. Discussion and Conclusions

It should be noted that the results given here are only applicable to the measurement period used in this research: Summer. Measurements at another time of the year, for instance during the winter, can lead to other results and possibly to other conclusions because then the natural supply of fresh air will be limited by the cold outside temperature and danger of draft. The detailed measurements of CO₂ concentrations within the breathing zones of the babies, incidentally showed difference in results caused by the location and the type of baby cot.

The measurement setup had to be installed in a practical condition, the desirable measurement distance to the head of an infant is 0.3m, at the researched location this was significantly higher, around 0.4m (also depending on the position of the baby). This to ensure the safety of the infants, no measurement equipment could be placed inside the cribs. The ventilation amounts that were applied during nap-time, led to indoor air quality conditions that met the guidelines of the Dutch Building Code and even the more strict guidelines of local health authorities GGD. The final classification for each investigated room is calculated according the guidelines by the GGD (2006) [15], therefore a percentile of 98% is taken into account. The results are displayed in Table 6. ‘B 3. – Nap 1’ can be neglected due to the malfunctioning of the air handling unit. However, this clearly shows the positive effect of the applied mechanical ventilation system.

Table 6. Final classification (GGD) for each baby cot.in the different rooms on the 2 locations A and B.

Location, (sensor 1 and 2)	CO ₂ [ppm]	Class
A.1.	514.7	A
A.2.-Nap 1	674.1	B
A.2.-Nap 2	681.4	B
B.3.-Nap 1	800.7	C
B.3.-Nap 2	590.1	A
B.4.	821.6	C

This article presents the results of CO₂ concentrations inside different baby cots of 2 day-care centers and shows that the daycare facilities performed according to the GGD classification. However there were increased CO₂ levels by occupied cribs compared to empty cribs as well as there was negative effects of specific location of the cribs in the corner of rooms. Therefore, it is important to do more research on the ventilation effectiveness inside of the baby cots and not only on the ventilation rates in the room in general. The effects can lead to CO₂ concentrations which can be on average around 25% (with in some situations even up to nearly 60% higher) than the average concentrations in the sleeping rooms of the day-care centers. This clearly shows the importance of these factors and why it is not sufficient to just measure an overall CO₂-concentration as an indicator of the Indoor Air Quality within day-care centers.

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