THE FIRST DUTCH PASSIVE HOUSE AND PLUS ENERGY SCHOOLS: SOME DUTCH IAQ EXPERIENCES IN SCHOOLS

Wim Zeiler, Mark de Waard and Gert Boxem

TU Eindhoven
Den Dolech 2
Eindhoven, Netherlands
w.zeiler@bwk.tue.nl

ABSTRACT

Ventilation is especially important to get a good Indoor Air Quality in schools. This is important as the young children have very vulnerable still developing longs which are very sensitive to all kind of pollutions. During the last decade different types of sustainable schools were built. The first schools were like very well insulated schools up to the Passive House standard. The next step in this development are schools which generate more energy hat they need themselves: Plus Energy schools. In 2011 a first school of this type was built in the Netherlands. The evaluation of the indoor quality and comfort conditions of this school and two recently finished Passiv House schools was done by measurements as well as questionnaires. The results will be combined with those of two earlier studies on energy efficient schools (in total 8 schools) and compared with those of a recent other study in which 12 more traditionally designed and recently built Dutch schools were examined. This enabled us to compare the new sustainable school designs with the more traditional school types. It proved that the design outcome on IAQ and perceived comfort of the latest sustainable schools were on average better than the earlier designed sustainable schools however they not better than the recent traditional designed schools. So we conclude that extra care should be taken by designers to healthy indoor environment aspects especially when designing energy efficient schools.

KEYWORDS

School ventilation, sustainable schools,Indoor Air Quality

1 INTRODUCTION

The energy use of school buildings became a critical factor in the design during the last decennia as the sustainability demands are getting tighter. However although energy is very important we should not forget the indoor air quality, necessary attention level and health of the vulnerable children as they spent a large part of their time in school. Therefore it is very important that the Indoor Air Quality of a school is good. Although the indoor environment is very important for the health and concentration of children often Indoor Air Quality in schools is still problematic in many countries (Clements-Croome et al 2008, Hellwig 2010, Bakó-Biró et al 2011, Hani et al 2011, Mercier et al. 2011, Salleh et al 2011, Al-Rashidi et al 2012, Montazami et al 2012, Mydlarz et al 2012, Wargocki and Wyon 2012, Satish et al 2012).
Indoor Air Quality in schools is primarily evaluated by CO_2-concentrations. ASHRAE Standard 62-1999 recommends an indoor CO_2-concentration of less than 700 ppm above the outdoor concentration, which means around 1200 ppm, to satisfy comfort criteria with respect

to human bio effluents. Dutch schools have to meet the Dutch Building Code, which recommends a level of 1000 ppm CO_2-concentration with a maximum of 1200 ppm. The latest Dutch design guide, ISSO publication no. 89 (ISSO 2008) should lead the path to better IAQ in schools, see Table 1.

Table 1. Different classes for IAQ regarding CO2-content

Class	A (Very good)	B (Good)	C (Acceptable)	D (Insufficient)
CO_2 content (ppm)	95%of total school hours < 800	95% of total school hours 800 - 1000	95% of total school hours 1000 - 1200	95% of total school hours > 1200

However if we look at the results of earlier Dutch studies on school ventilation (Zeiler and Boxem 2007), it shows that there is no adequate Indoor Air Quality on quite a number of schools.

2 METHODOLOGY

To investigate the results of the sustainable schools during a week measurements were done concerning indoor air quality and comfort. To characterize the indoor air quality and thermal comfort in the three different schools, measurements are being executed using a measurement pole which measured 5 different parameters: Indoor temperature, Radiant temperature. Relative humidity, Indoor air velocity and CO_2 concentration. The different sensors were placed a tripod put in a classroom.

Table 2: Used measurement equipment

Type of measurement	**Equipment**	**Brand**	**TU/e ID**	**Range**
Temperature	Sensor	EE80	2335	0° - 40°C
Radiant temperature	Black sphere PT100	-	612	-100° - 300°C
Relative humidity	Sensor	EE80	2335	0 - 100%
Air velocity	Omni speedometer	Sensor HT428	708	0.05 - 5 m/s
CO_2 -concentration	Sensor	EE80	2335	0 - 5000 ppm
Log data	Data logger 2F8	Grant 2020 series	1816	n.v.t.
Process data	Laptop	Dell Latitude C840	1629	n.v.t.

In all schools also questionnaires were given to the teachers to get an impression of the satisfaction of the users, with regard to thermal comfort and perceived indoor air quality. The questionnaire used was based on the validated list which has been developed in the Health Optimization Protocol for Energy-efficient Buildings research (HOPE 2001).

2.1 School A

Number of students	285
Number of staff	24
Classrooms	11
Gross floor area	1475m²
Date completion	2012
Ventilation	Mechanical supply and exhaust
Heating/cooling	Heating by ventilation system

School A is the first passive school in the Netherlands. The construction of the school was finished in July 2011. It was build according to the passive house principle which meant extreme air tightness, triple glazing and highly insulation with a Rc = 10 m²K/W. The

conditioning is done by individual room ventilation systems with heat exchangers. The air distribution is by textile ducts, see Fig.1 .

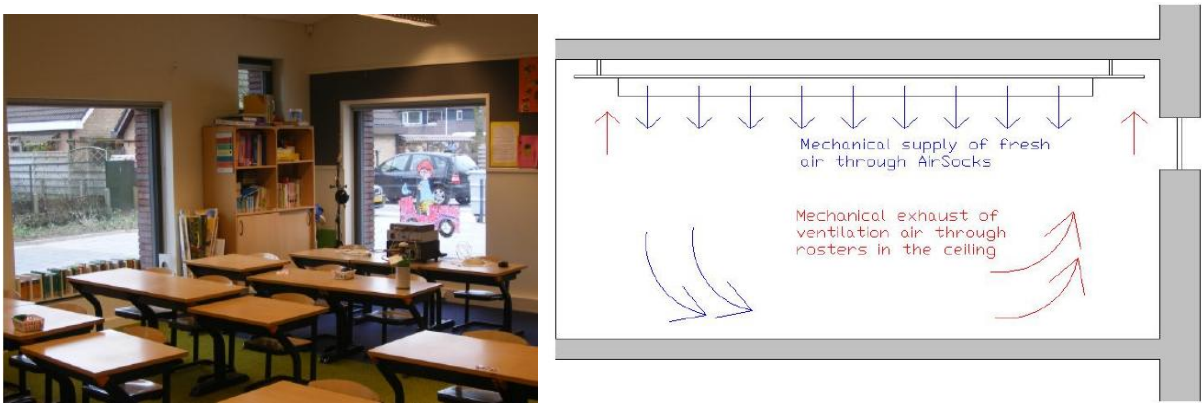

Figure 1. School A first passive house school with air distribution through textile ducts

2.2 School B

Number of students	210
Number of staff	40
Classrooms	20
Date completion	2011
Ventilation	Mechanical supply and exhaust
Heating/cooling	Heating by the ventilation system

In 2009 the Dutch government initiated the so called UKP NESK program to stimulate innovation for energy neutral buildings. UKP means unique chances projects and NESK means 'Towards energy neutral schools and offices' (Naar Energieneutrale Scholen en Kantoren). School B is the first school within the UKP NESK program that was finished, see Fig. 2. The energy concept of the school is based on applying the Passive house-concept, with an average insulation with a Rc-value of 10 m^2W/K and triple glazing. The school has a ground source heat pump, low temperature floor heating system and balanced mechanical ventilation with 85% heat recovery. IAQ is control on a maximum CO_2-level of 800 ppm.

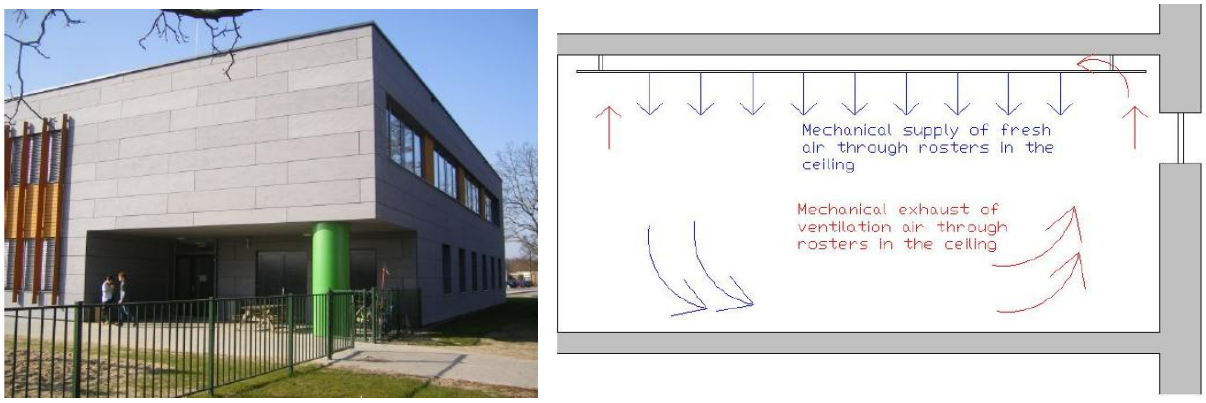

Figure 2. School B UKP NESK school with mechanical air supply through grills in ceiling

2.3 School C

Number of students	**472**
Number of staff	**73**
Classrooms	**42**

Gross floor area	**7800m²**
Date completion	**2010**
Ventilation	**Mechanical supply and exhaust**
Heating/cooling	**Floor heating/cooling**

This is the first CO2-neutral and energy plus school in the Netherlands. The indoor climate is regulated with a floor heating / cooling system with a ground source heat pump. The school has an Energy Roof, a combination of PV and thermal collectors integrated into its roof cover, which generates over a whole year more energy than the school needs for its own use. A balanced ventilation system is used to provide sufficient fresh air in the classrooms and this can be used for additional cooling during the summer, see Fig.3.

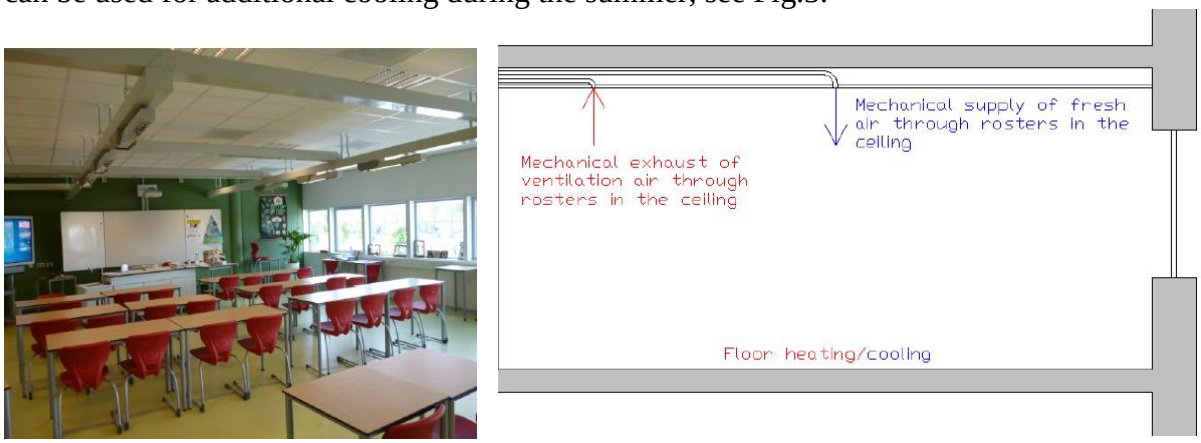

Figure 3. School C Energy plus school with mechanical air supply through grills in ceiling

3 RESULTS

3.1 Measurements

As visible in Fig.4 the three schools have a similar development in IAQ as well. During school hours the CO_2 concentration rises to a level between 800 and 1200 ppm. School C is in this case an exception. In this school the CO_2 concentration rises to a level far beyond 1200 ppm (maximum allowable concentration) and reaches concentrations around 2000 ppm. The concentrations in school C are unacceptable for buildings with an educational function.

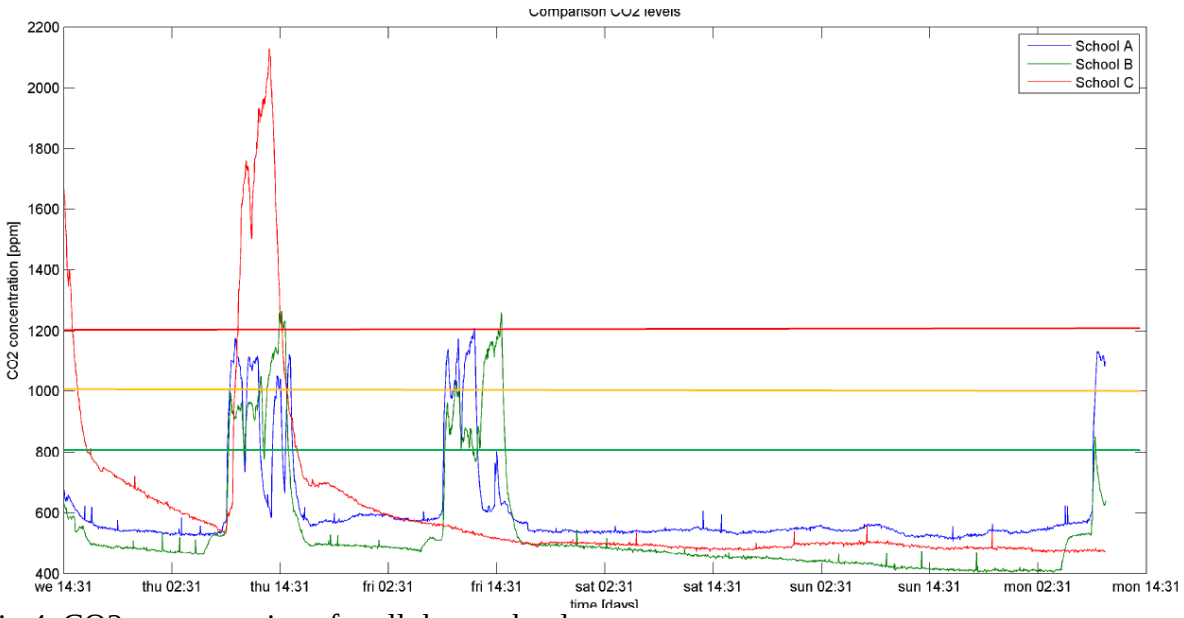

Fig 4. CO2-concentrations for all three schools

From the overview in table 3 it shows that none of the schools reach ventilation quality level A. School A en B (just!) reach level C and school C doesnot reach even that level.

Tabel 3 . Overview of the percentage of time that the conditions are in each IAQ quality level

Class	A (Very good)	B (Good)	C (Acceptable)	D (Insufficient)
CO_2 content [ppm]	percentage of school hours < 800	percentage of school hours 800 - 1000	percentage of school hours 1000 - 1200	percentage of school hours > 1200
School A	32%	22%	46%	< 1%
School B	15%	47%	32%	6%
School C	28%	12%	10%	49%

3.2 Questionnaires

The survey in school A was held among the personnel of the school (24 people). 9 members of the personnel filled in the survey which leads to a response of 37.5%. The results of this questionnaire are depicted in the figures below.

Figure 5 shows a box plot for each reviewed topic with the corresponding median, minimum and maximum value for winter and summer

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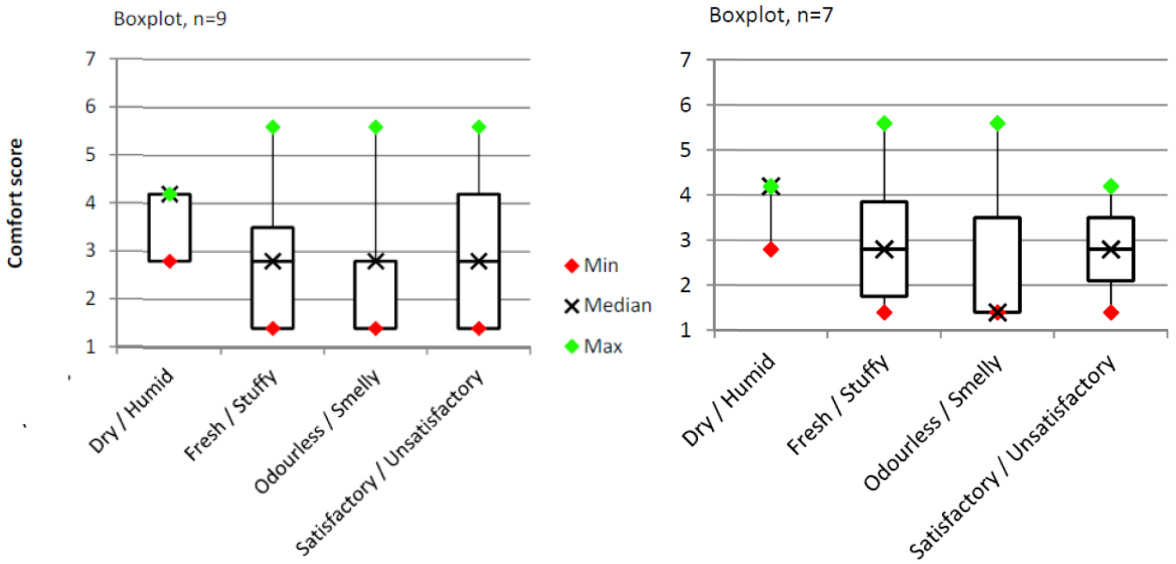

Figure 5: Results survey school A winter and summer

The survey in school B was held among the personnel of the school (40 people). Only 4 members of the personnel filled in the survey which leads to a response of 10%. The results of this questionnaire are depicted in the figure 6.

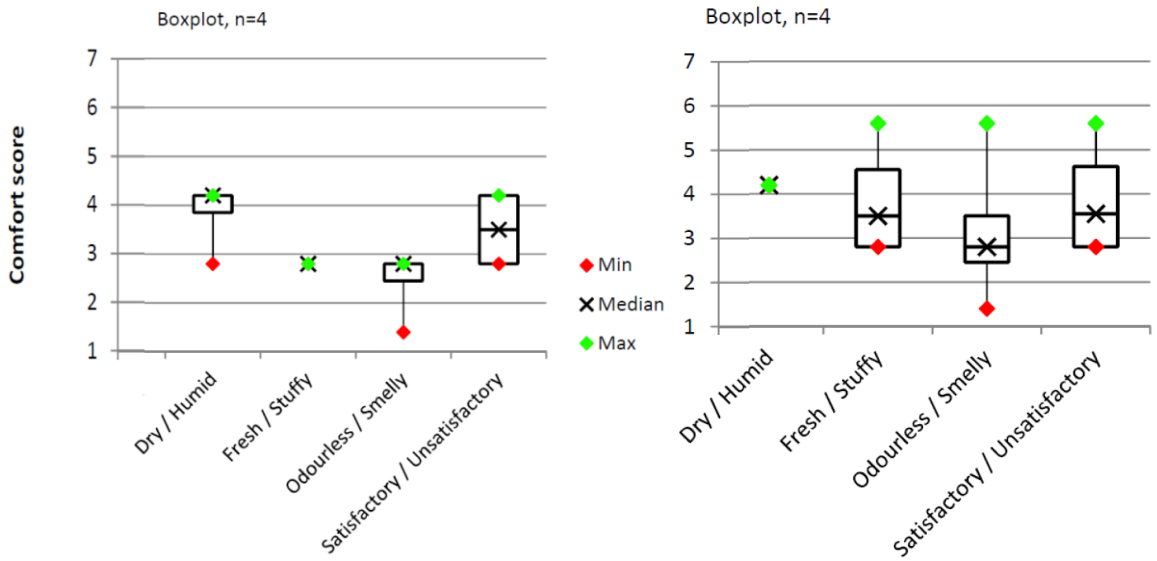

Figure 6: Results survey school B winter and summer

The survey in school C was held among the personnel of the school (73 people).18 members of the personnel filled in the survey which leads to a response of 25%. The results are given in Fig. 7.

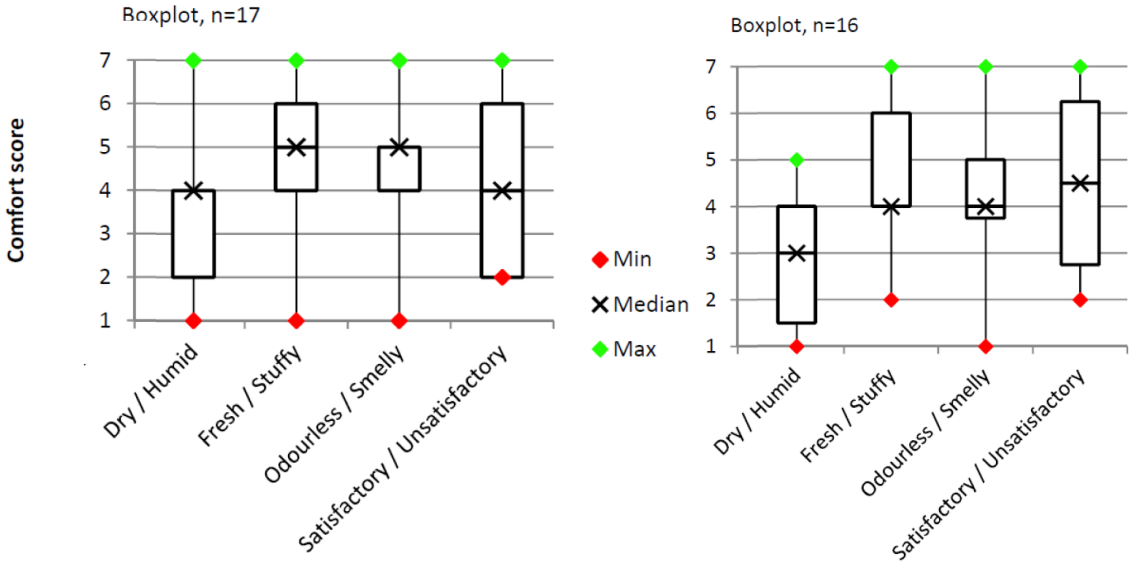

Figure 7: Results survey school A winter and summer

4 DISCUSSION

Regarding the indoor air quality in the new build sustainable schools, it can be said that the IAQ in schools A and B is good (most of the school hours between 800-1200ppm). In school C the IAQ is during a large part of the school hours insufficient (≥1200ppm). From the questionnaires of school A it followed that the IAQ in school A is reviewed by the staff as reasonably fresh and satisfactory. Compared to the actual measurement results the results of the questionnaire are in accordance. The results for IAQ in school A are categorized as class C, acceptable. School B shows quite similar results as school A. Also here the staff of the school reviews the IAQ as reasonably fresh and satisfactory, which is in accordance with the measurement results. The IAQ in school B is categorized in class B, Good. School C had the worst results regarding IAQ, most of the class hours in class D, which is unacceptable. But

the results of the questionnaire show quite neutral and stable comfort scores. So although the CO_2 concentrations inside the classroom are unacceptable, the staff does not find the IAQ uncomfortable. The scores for freshness and smelliness of the room do tend towards a bit stuffy and a bit smelly.
Clearly the ventilation of the three sustainable schools was rather disappointing as none of the schools reached class A or B. Strangely from the questionnaires is followed that the worst school based on the measurements is the school with the best perceived indoor air quality based on the questionnaires. That might be an indication that the room in which the measurements were done was not the average situation but in this case a bad example. From the questionnaires it follows that there is a slightly better perceived indoor quality in summer than in winter. As all schools had mechanical ventilation you would expect a very small difference between perceived summer and winter situation, which is the case.
To get an idea of the new schools performed better or worse than some older sustainable schools, who were not that sustainable as the new school concepts, a comparison was made with some schools of our former studies (Joosten 2004, van Bruchem 2005), see table 4.

Table 4. Some older sustainable schools for comparison

School	Date completion	Ventilation	Heating/cooling
Bruchem 3	2002	Hybrid ventilation system	Ventilated air pre-heated by thermal ceiling
Bruchem 5	2002	Exhaust-only ventilation	n.a.
Joosten C	1998	Balanced ventilation system	Central heating system with radiators
Joosten D	2000	Balanced ventilation system	Floor heating
Joosten F	2002	Balanced ventilation system	All air heating/cooling system

From the results of the comparison in Fig.8 it shows that there is not much difference in the perceived humidity, a slight improvement concerned the perceived freshness of the air, no real difference as to the perceived odour and also no real improved overall satisfaction. However when looking at the normalized CO2 concentrations, measured values recalculated to the standardized occupation of 32 pupils, there is a slight improvement, see Fig. 9

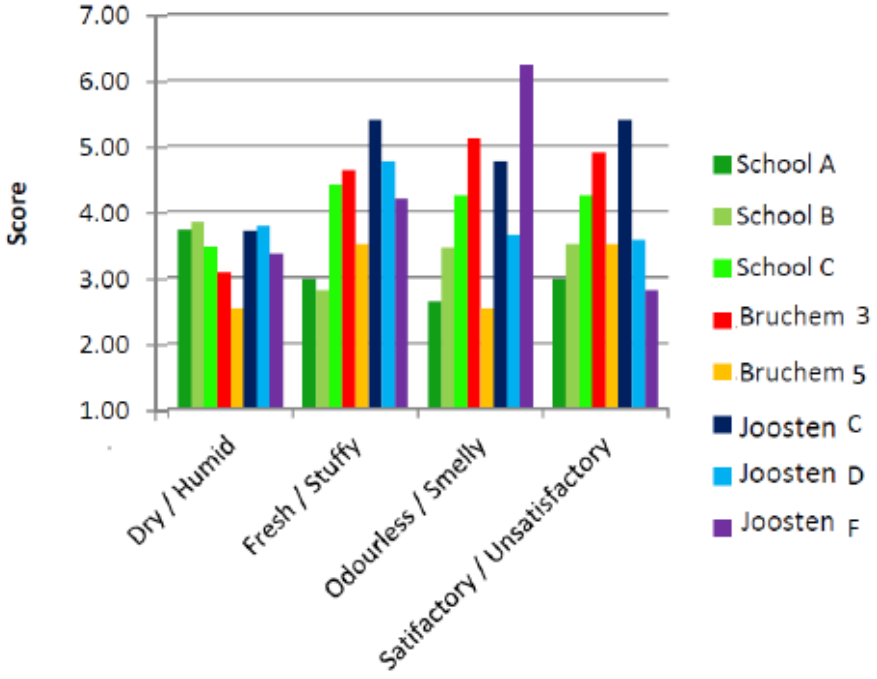

Figure 8: Perceived Indoor Air Quality aspects of sustainable schools

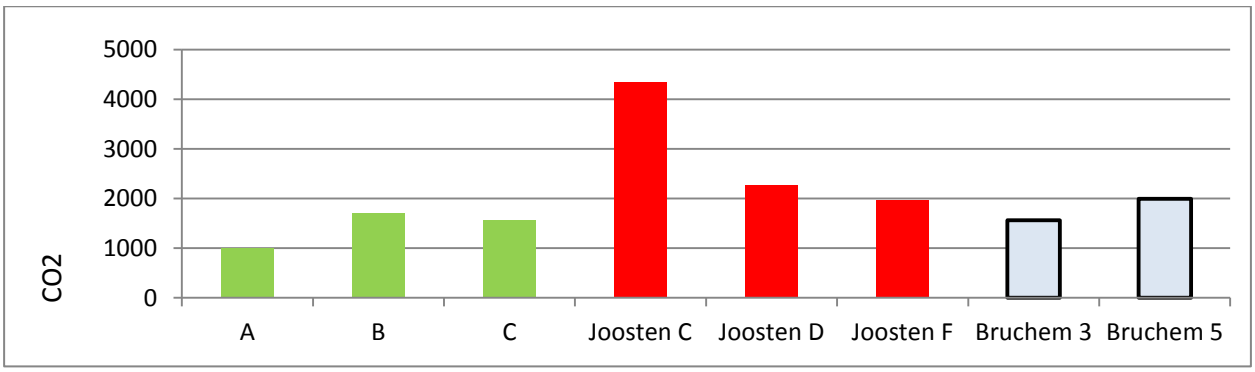

Fig 9. An overview of the normalized measured CO2 concentrations

5 CONCLUSIONS

the overall conclusion regarding IAQ is that the new build sustainable schools do not have the desired IAQ as stated in the program of demands or what was suspected during the design phase, despite of the fact that they were built with a focus on high sustainability and a high indoor air quality.

Table 5 . Claasification used in the Netherlands for school ventilation Isso 89 (2008)

Class	Description	IAQ
A	Very good	≤ 800 ppm
B	Good	≤ 950 ppm
C	Acceptable	≤ 1200 ppm

As visible in table 5, the program of demands of the investigated schools used similar values for IAQ as used in this research. Only it states that class C is below demands stated in the Dutch Building Code so class C isonly applicable for existing buildings. Since the measurements done in this research were all in newbuild schools, only the classes A and B are comparable with the results of this research. Looking at table 3 and 5 it is clear that none of the measured schools achieve an IAQ that is within the range of the classes stated in the program of demands for fresh schools. In all three schools the normalized CO_2 concentration is above 1000ppm. Looking at the development of the CO_2 concentration during atypical school day (Fig. 4), it is visible that during morning hours school B does have an IAQ which can be categorized in class B according to the program of demands for fresh schools. So it can be concluded that during parts of the day (only) school B meets the demands for fresh schools regarding CO2 concentrations, see table 6.

Table 6. Classification of the new highly sustainable schools

	Design value	Actual value
	IAQ (CO_2 [ppm])	
School A	B	C
School B	A	B
School C	n.a.	n.a.

When comparing the measurement results of this research with the results of earlier research it becomes clear that the IAQ in the new build sustainable schools does not differ (much)

from the IAQ in older less sustainable schools. Since the new build schools are built with a vision of high sustainability and a high indoor air quality, it is expected that the actual performance of the schools is slightly better and the actual CO_2 concentrations are slightly lower than older, less sustainable schools.

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