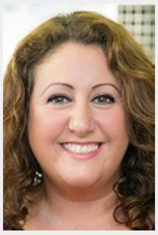
Cool and healthy classrooms with SchoolVent ventilation

This article is a summary of the paper 'SchoolVent pilot ventilation system with indirect adiabatic cooling and high efficiency filtering' presented at 2022 in Delft [1]. Part of the text of this paper was used to prepare this article.

PIET JACOBS
TNO, the Netherlands
piet.jacobs@tno.nl



ELIANE KHOURY
VFA Solutions,
the Netherlands

MARIUS KLERK
LUCAM,
the Netherlands

MICHEL VALKEMA
LUCAM,
the Netherlands

Climate change is causing hotter summers. Especially in schools this can cause high indoor temperatures, lower learning performance and during heat waves also the need to close the school. Introducing ventilation systems with (passive) cooling can prevent this and has also the advantage that the windows can be kept closed during the lessons. Closed windows reduce noise disturbance from outside and in combination with fine filters can greatly reduce the indoor fine particulate matter concentration. Using evaporative cooling and electrostatic filtering we demonstrated that this can be done in an energy efficient way, minimizing further climate change.

Keywords: class room, evaporative cooling, electrostatic filtering, $PM_{2.5}$.

Performance requirements

In the Netherlands the so called Dutch Fresh Schools program requirements [2] (PvE frisse scholen) have been set up for the indoor climate in schools. They consist of three classes which are comparable to the energy labelling system. The class C requirements are based on the minimum legal requirements, class B refers to a good indoor climate and class A an excellent climate. See **Table 1** for a summary. All requirements should be met during 95% of the occupied time.

Table 1. *Summary Fresh School program requirements [2].*

	Class C	Class B	Class A
CO_2	1200 ppm	950 ppm	800 ppm
Summer temperature	< 27°C	< 26°C	< 25,5°C
Winter temperature	> 19°C	> 20°C	> 21°C
Filter quality	> F5	> F6	> F7

The goal of this field study was to develop and to demonstrate a school ventilation system that meets the class A specifications of the Dutch Fresh Schools program requirements for CO_2, summer temperature, winter temperature and $PM_{2.5}$.

Pilot test

After successful laboratory tests [2] a pilot has been started on the Montessori Lyceum in Zeist. This school is located at less than 50 m distance from a busy highway. Most classrooms are naturally ventilated. Before installation of the SchoolVent system and before COVID-19 this had led to CO_2 peak concentrations in winter of almost 4000 ppm in January 2019. In summer high temperatures caused the school to close typically 3 days a year. The SchoolVent Air Handling Unit has been installed on the roof and was connected to 5 classrooms, see **Figure 1**. The conditioned air is blown in the classrooms with a T-shaped airsocks.

In principle the system works as a Variable Air Volume (VAV) system. Based on both CO_2 concentration and room temperature, the amount of air per classroom is controlled with valves. To prevent heating and cooling from working against each other, the radiator controls are equipped with servo motors that are also controlled via the SchoolVent system. Monitoring was carried out in the 5 pilot classrooms (N2–N6) and an additional reference classroom (N7) without the SchoolVent system.

Performance during heating season

Figure 2 shows that for a typical school day all classrooms equipped with the SchoolVent system meet the class A requirement of 800 ppm CO_2. In the reference classroom N7 at 8:45 h the CO_2 concentration rises to about 500 ppm and remains constant until 9:45 h. During this time the temperature drops from 19.8 to 18.7°C. Most likely ventilation was achieved by open windows and at 9:45 h the windows were closed because the temperature in the classroom became too low. This results in a temperature rise up to 20.6°C. However, this is at the cost of a high CO_2 concentration of 2339 ppm. This example shows the dilemma between thermal comfort and indoor air quality in naturally ventilated classrooms. The thermal comfort in the reference classroom does not meet the class C requirement.

Performance during summer season

Figure 3 shows the effect of the indirect adiabatic cooling on the supply and room temperature of classroom N6 on a warm day. Around 14:00 h the

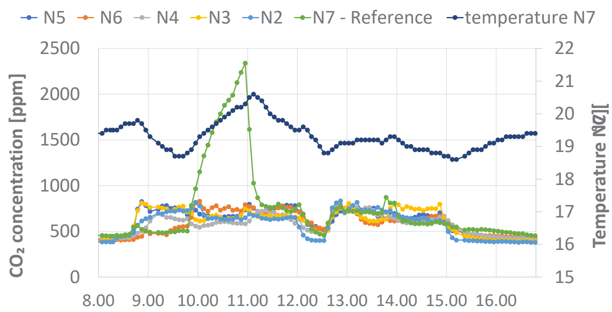


Figure 2. CO_2 concentrations on December 3, 2020 in classrooms N2 – N6 equipped with the SchoolVent system and the reference classroom N7 for which also the room temperature is shown (right axis).

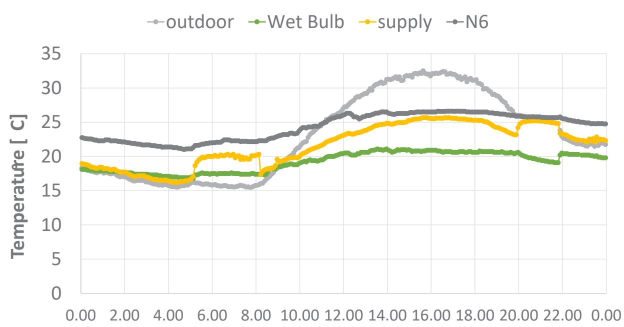


Figure 3. Outdoor, wet bulb, supply and indoor temperature in classroom N6 on September 15th, 2020

Figure 1. SchoolVent air handling unit with insulated ducting.

supply temperature is about 6,5 K lower than the outdoor temperature. The air flow towards classroom N6 amounts then 2000 m³/h. This creates a cooling capacity of 4,4 kW and keeps the indoor temperature at class A level.

Filter performance

The efficiency of the ASPRA filtration system in the Air Handling Unit (AHU) has been determined with two Grimm particle counters (model 11-R and 1.109). One was placed in outdoor air and the other in the AHU downstream the filter section. At a flowrate of 3000 m³/h the minimum efficiency amounted 92% and at 5500 m³/h this dropped to 82%. At 3000 m³/h the EN1822 requirements of an E10 filter (>85%) and almost of an E11 filter (>95%) were met. With regard to $PM_{2.5}$ at this flowrate 94.5% reduction is achieved.

The pilot is executed with a combination of a thin grid as a prefilter and an ASPRA electrostatic filtration system comprising of active charging and electrostatic precipitation section followed by a F7 plate static filter as particle collector. The pressure drop, over this filter combination, amounts 150 – 180 Pa at 10.000 m³/h. By optimizing the pre filter and selecting a plate filter with deeper pockets, we expect that the pressure drop can be lowered to 70 – 100 Pa. For reference, the pressure drop of a typical E10/E11 filter at this flow is about 300 Pa, which leads to much higher fan energy and noise.

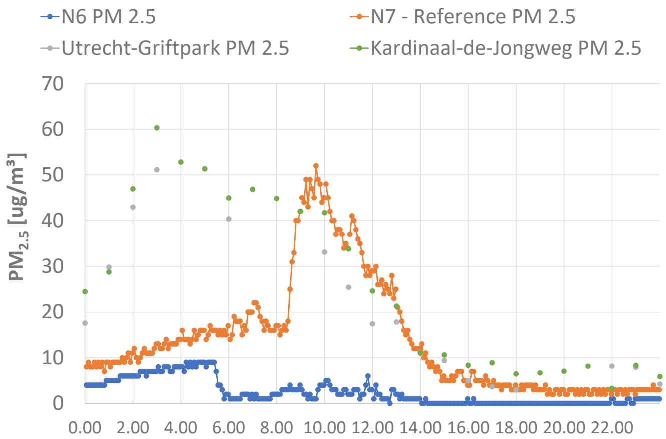


Figure 4. Fine particulate matter in classroom N6 and reference classroom N7 on 23 sept 2020.

An example of the effect of the ASPRA filtration system on the fine particulate matter in the classrooms is shown in **Figure 4**. In classroom N6 at 5:45 hour filtered fresh air is blown in. This reduces the $PM_{2.5}$ concentration. In reference classroom N7 around 8:30 hour the windows are opened. Because of this the indoor $PM_{2.5}$ concentration rises towards the outdoor concentration as measured by two nearby national outdoor air quality measurement stations.

During a three-week monitoring period in classroom N6 equipped with the SchoolVent system the $PM_{2.5}$ concentration was 70 to 96% lower than in the naturally ventilated classroom N7, see **Table 2**. The daily averaged concentration in N7 was comparable with the two nearby outdoor air quality measurement stations.

Table 2. *Daily averaged $PM_{2.5}$ during class time (8.30 – 15.00 h) in classroom N6, N7 and two outdoor air quality measurement stations.*

		$PM_{2.5}$ [ug/m³]		reduction	$PM_{2.5}$ ambient [ug/m³]	Kardinaal
		N6	N7	[%]	Griftpark	de jong weg
week 49	Mon 30 nov.	9.8	44.9	78.1%	45.3	50.3
	Tue 1 dec.	1.3	6.0	77.6%	6.2	6.8
	Wed 2 dec.	3.3	18.9	82.6%	12.8	16.0
	Thu 3 dec.	2.0	10.9	81.3%	13.4	16.7
	vrij 4 dec.	0.1	1.3	96.0%	0.6	6.1
week 50	Mon 7 dec.	1.7	8.0	78.2%	16.0	21.6
	Tue 8 dec.	2.6	11.4	76.9%	18.2	21.9
	Wed 9 dec.	4.8	22.1	78.3%	22.2	28.5
	Thu 10 dec.	3.7	12.4	70.6%	15.2	19.9
	Fri 11 dec.	2.9	9.7	70.4%	13.2	17.2
week 51	Mon 14 dec.	2.1	8.9	76.1%	16.0	21.6
	Tue 15 dec.	2.5	11.3	77.5%	17.5	21.7
	Wed 16 dec.	4.8	22.7	79.0%	21.8	26.9
	Thu 17 dec.	3.7	12.7	70.5%	15.4	20.6
	Fri 18 dec.	2.8	9.5	71.0%	12.7	16.1

Positive feedback

Installation of the SchoolVent system has lowered the energy consumption for heating and improved the indoor climate in an existing school. In the renovated class rooms the air quality and especially the thermal comfort in winter and summer has improved to class A.

The students and teachers have given positive feedback on the system. The automatic temperature and CO_2 control was appreciated. When the temperature rises in the summer, the pilot system is very comfortable because the temperature can be cooled a few degrees. Also the thermal comfort improvement during winter was important as the monitoring period was carried out during the COVID-19 period in which the windows in the other classrooms were opened for sufficient ventilation, which caused much draught and thermal comfort complaints. Some teachers also reported health improvements in the pilot classrooms. This might be caused by the high ventilation and the much lower PM concentration.

The positive feedback has led to the installation of the system in another 14 classrooms during 2021 on the Montessori Lyceum. ■

Acknowledgement

The project was carried out with the Top Sector Energy Subsidy from the Ministry of Economic Affairs. Further the Province Utrecht has contributed by assisting in finding the pilot location and has financially contributed to the installation costs.

References

[1] Piet Jacobs et al 2022 IOP Conf. Ser.: Earth Environ. Sci. https://doi.org/10.1088/1755-1315/1085/1/012025.

[2] PvE frisse scholen: https://www.rvo.nl/onderwerpen/verduurzaming-utiliteitsbouw/maatschappelijk-vastgoed/onderwijsgebouwen-po-en-vo.