AIR QUALITY AND AIR PURIFIERS IN CLASSROOMS

:

RESULTS OF THEEXPERIMENTATION IN THE SCHOOL

ANATOLE FRANCE ELEMENTARY SCHOOL OF SAINT-OUEN

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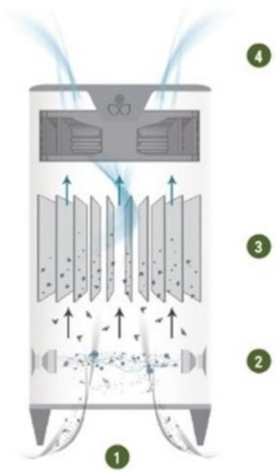
1. BACKGROUND

As part of the participatory budget of the Ile-de-France Region voted in 2021, the municipality of Saint-Ouen, the association RESPIRE and the company TEQOYA, French manufacturer of purifiers, conducted an experiment to assess the impact of air purifiers on air quality in two classrooms of the elementary school Anatole France.

This experimentation is carried out with a purifier model called ALANA, co-developed by TEQOYA and the indoor air quality manufacturer ALDES. This equipment uses an electrofiltration technology, which consumes little energy and does not require consumables (filters to be replaced).



1. The air loaded with polluting particles is sucked in by the ALANATM device.

2. The pollutant particles are electrically charged by the negative ions produced inside the device.

3. The particles are electrostatically attracted to the polarized plates and are thus trapped inside the device.

4. The air, purified and free of polluting particles, is diffused out of the unit by a high performance fan.

The measurement protocol implemented is as rigorous as possible, in a context of *field* experimentation over several months. The experiment was conducted between January and June 2022.

This report presents the experimentation and its results.

2. METHODOLOGY

2.1 Contacts mobilized for the experimentation

- **Sabrina DECANTON** (1st deputy mayor of Saint-Ouen, delegated to the Ecological Transition, Mobility, Nature in the city and Relations with the metropolis)
- **Sophie PICOT (**education and child department of the city of Saint Ouen)
- **Kamel OUSSADANE and Stéphane ANANIAN** (technical services of the city of Saint Ouen)
- **Sophie PIQUEMAL and Camille SIMONET** (teachers at Anatole France elementary school)
- **Tony RENUCCI (**RESPIRE association)
- **Pierre GUITTON** (TEQOYA)

2.2 Location of theexperiment

The experiment takes place in the Anatole France elementary school at 7, rue Fernand Hainaut, 93400 Saint Ouen.

Figure 1: photograph of the Anatole France school

The choice of the school was proposed by the municipality of Saint-Ouen. Indeed, the Anatole France school is located in the immediate vicinity of the construction works of the Olympic Village of the 2024 Olympic Games, and is within reach of a potentially higher than normal particle pollution.

The experimentation concerns two classrooms. These rooms are contiguous and very similar in size, exposure and openings. Here is their approximate location (blue blocks at the bottom left of the image), on the second floor of the building:

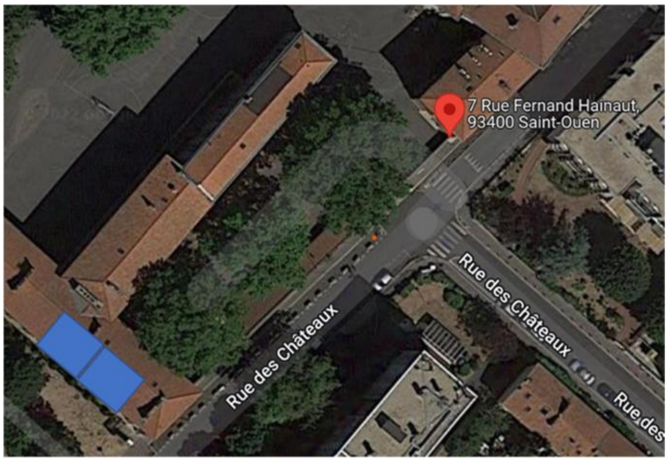


Figure 2: Google Maps aerial view of the Anatole France school

2.3 Description and use of the premises

The following are the dimensions and configurations of the two adjoining classrooms:

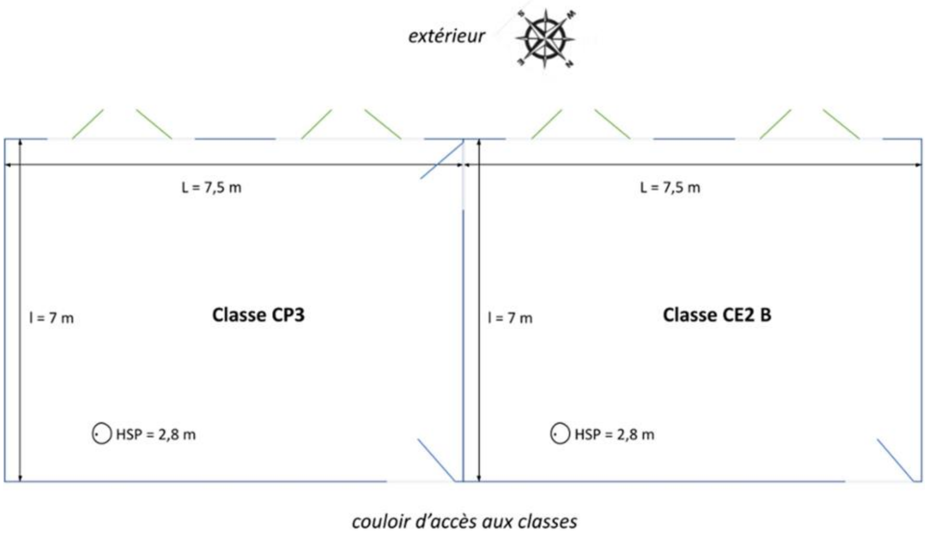


Figure 3: Representative diagram of the two classrooms in the experiment

It is to be noted that these rooms do not have mechanical ventilation: only the opening of the openings allows to ventilate them.

For each, the number of students is as follows:

- CP 3 : 14
- CE2 B : 18

Class attendance times are as follows:

- 8:30am - 10am
- 10:15 am - 11:45 am
- 1:30 - 2:30 pm
- 2:45 - 4:15 pm

2.4 Device in the rooms

The two classrooms used for this experiment are called CP 3 and CE2 B.

Each room was equipped as follows:

- 2 RESPIRE particle micro-sensors model Plantower PMS 7003 (the measurement of the PM2.5[1] is the air quality indicator used for this index experiment)
- 1 CO detector$_2$ and noise detector (provided by ALDES, which allows to detect the level of presence in the classrooms and to make the results more reliable)
- 3 ALANA air purifiers

Their layout is identical in each room:

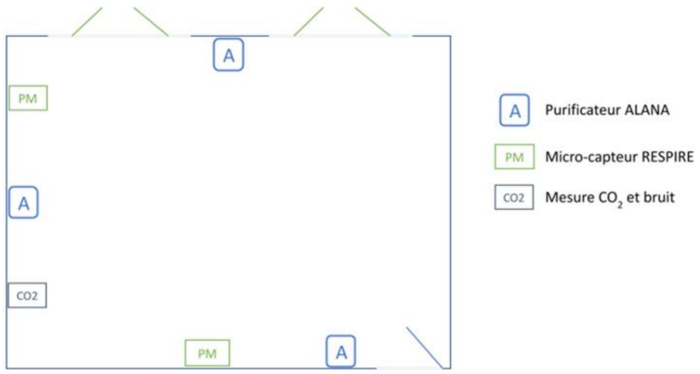


Figure 4: Representative diagram of the air renewal and pollution measurement system in each classroom

Wall sockets have been installed for the power supply of all the devices. All the equipment is installed at a height of between 1.7 and 2 meters, so as not to be within the reach of children and to leave the wall spaces free for the teaching aids (see photographs below).

[1] PM2.5 represents the mass concentration of particles with an aerodynamic radius less than 2.5 micrometers.

Figure 5: Photograph of the interior of the CE2 B classroom

Figure 6: Photograph of the interior of the CP 3 classroom

Figure 7: Photograph of the interior of the CP 3 classroom

2.5 Conduct of the measurement campaign

The experimentation took place in 4 phases:

Phase	Durati on	Class CP 3	Class CE2 B
1	January 3 to 5 April 2022	Purifiers ALANA extinguished	ALANA Purifiers switched off
2	April 7 to 31 May 2022	ALANA Purifiers in operation	ALANA Purifiers turned off
3	June 2 to 14 June 2022	ALANA Purifiers turned off	ALANA Purifiers in operation
4	June 16 to July 1, 2022	ALANA Purifiers in operation	ALANA Purifiers in operation

The first phase was used to observe the initial state in order to obtain neutral measurements of pollution in real conditions to which to refer for the experimentation.

The RESPIRE sensors are in operation during the whole experiment.

The interpretation of the measurements made must be carried out taking into account certain precautions related to the ventilation of the classrooms:

- Classroom windows are open for a significant portion of the day;
- During each interclass, the two windows of each classroom are opened (including during the first winter period of the experiment, because of the sanitary protocol against Covid-19);

- During relatively warm periods (from the end of April onwards), at least one of the two windows remains open during class, or even both, as in the CP 3 class;
- The students are sometimes on the move (and therefore do not occupy their room), so it is desirable to identify the days of presence in the classroom because the presence or absence of students and their teacher has a significant impact on indoor air quality (intake of particles from outside through open windows or due to human activity).

3. OBJECTIVES

The present study aims to fulfill several objectives:

- To highlight the added value of electrofiltration air purifiers on indoor air quality via an efficiency test campaign in schools under real conditions;
- Develop recommendations for public stakeholders and the general public to prefigure a future national legal framework for the installation and use of electrofiltration air cleaners in schools.

4. RESULTS

4.1 Initial phase: assessment of air quality in classrooms before installation of purifiers

As mentioned above, the **PM2.5** index is the air quality criterion used in this study. We recall that the WHO recommends not to exceed 5 µg/m3 on average, and 15 µg/m3 over a day:

In order to construct a reliable estimate of the $PM_{2.5}$ index outside the school area, we averaged the concentrations of this index provided by the two AIRPARIF stations closest to the school:

The graph below shows the correlation between the daily average[2] of the PM index$_{2.5}$ outside (measurements of the concentrations of the AIRPARIF stations) and that inside each class (measurements of the RESPIRE sensors):

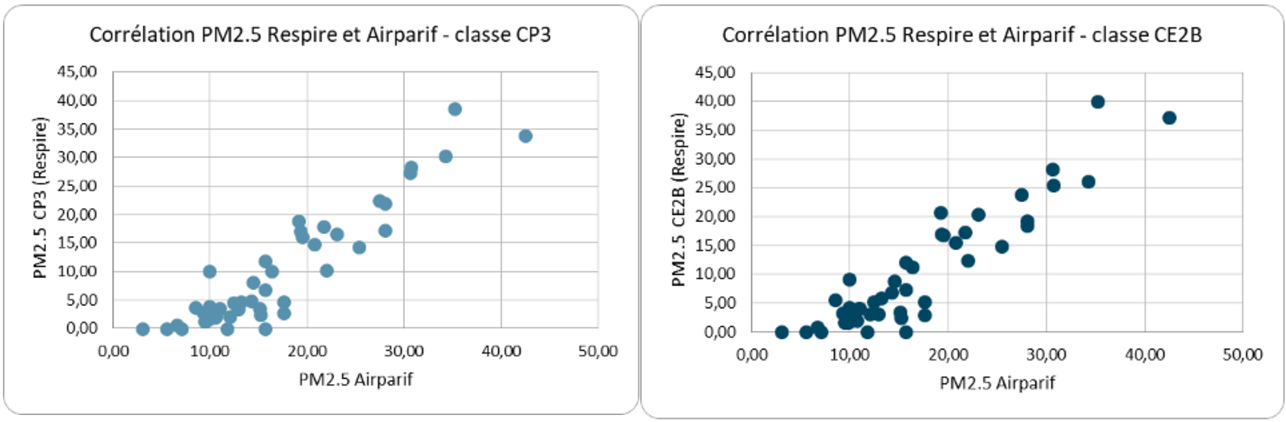


Figure 8: Graphs showing the correlation between Respire and Airparif measurements in each class

These data allow us to measure a ratio between indoor pollution and outdoor pollution[3] of the average class to outdoor pollution. We measure that it is about 50% (50% for CP 3, 54% for CE2 B), i.e. we find inside the classrooms about half of the outdoor pollution, during the day, before the installation of air purifiers.

1st result: On average, the air quality in the classrooms is strongly correlated to the outdoor air quality.

We then study the levels of particulate pollution compared to the exposure thresholds recommended by the WHO.

It can be seen that the $PM_{2.5}$ index measured exceeds the recommended WHO threshold (5 µg/m3) almost every day outdoors and around 50% of the days in each classroom during the experiment (see graph and table below).

[2] By daily average, unless otherwise stated, we mean the average over the 8:00 a.m. to 5:00 p.m. time slot, which is considered the period of interest because it is the period of occupancy of the premises by the students and/or the teacher.

[3] More precisely, this ratio is calculated according to the formula PM2.5indoor/PM2.5outdoor, using the indoor measurements made during the campaign and the outdoor measurements provided by AirParif.

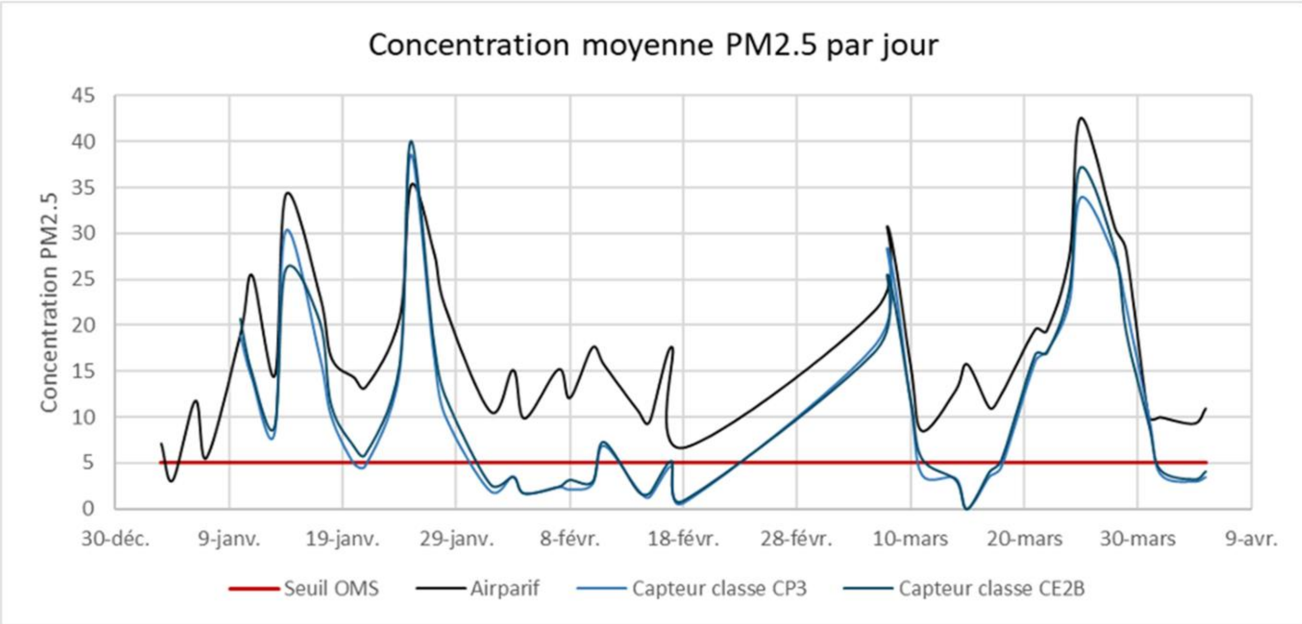


Figure 9: graph showing the evolution of the average concentrations of $PM_{2.5}$ per sensor in comparison with the WHO threshold and the Airparif measurements and as a function of time

Number of PM2.5 days > 5 µg/m3 over a 45-day class period in the first quarter of 2022		
Airparif	CP 3	CE2 B
44	22	27

Figure 10: Table showing the number of days when the WHO threshold for PM concentrations was exceeded$_{2.5}$ by sensor during the experiment

2nd result: The level of pollution in both classes regularly exceeds the values recommended by the WHO.

Finally, over the course of a day, there is a strong variability in air quality depending on the time of day and from one day to the next (see graph below).

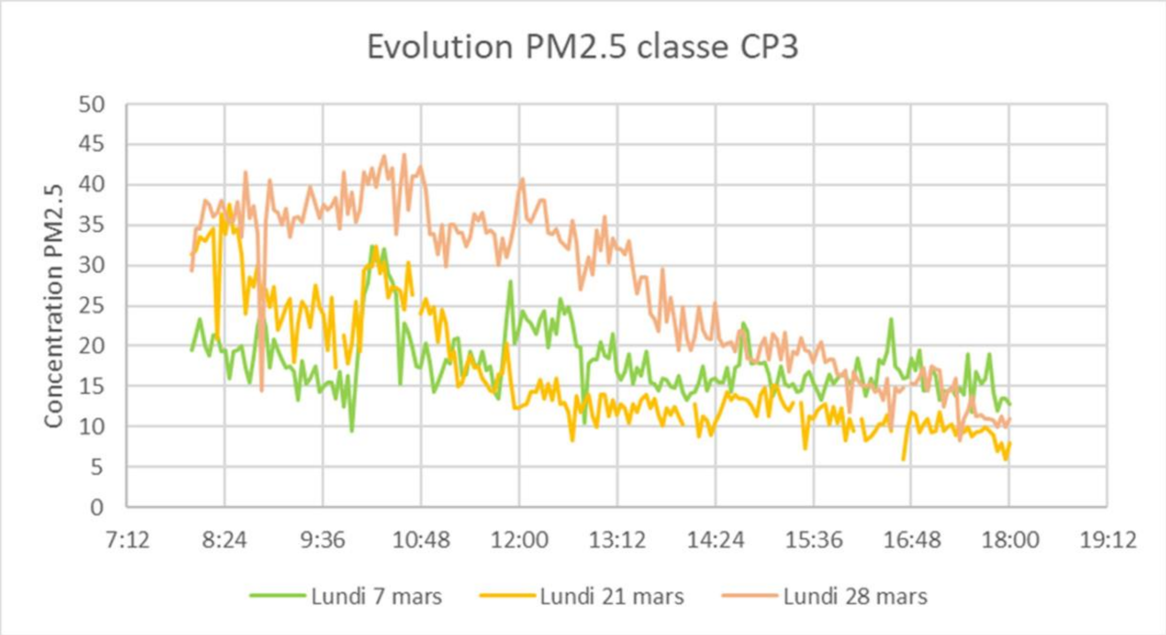


Figure 11: Graph showing PM2.5 concentrations as a function of time and day on the Mondays of March 7, 21 and 28, 2022

Result [3]: There is no replicable daily profile due to the high variability of air quality measurements per hour or per day.

4.2 Influence of air cleaners on classroom air quality

We compared the daily average of $PM_{2.5}$ concentrations during the different phases of the experiment. This daily average was measured during the period of occupation of the rooms (8h-17h).

It was not possible to conduct measurements "with / without purifier" over short periods (1h to 2h) for the following reasons:

- high variability of measurements and absence of a regular profile (see previous observations on the initial phase);
- fast" daily cycle of class activity (the occupation phases last 1h30);
- Difficulty for RESPIRE and TEQOYA to be present during class (disruption) or to ask teachers to intervene on the devices for performance analysis on short cycles.

The measurement campaign demonstrates three results (see graph below):

1. When no purifier is running, the CE2 B class is 11% more polluted than the CP3 class in relative deviation [4]. This can be explained in particular by a larger number of students in CE2 B class;

2. After the purifiers were put into operation in CP 3, the difference increased significantly: 56% relative difference, or **45 points of variation compared to the phase without purifiers**;

3. After the use of the purifiers in CE2B class (and stop in CP 3), the difference is reversed: - 32 % of relative difference or **43 points of variation compared to the phase without purifiers**.

[4] The relative air quality difference between the two classes is calculated by the formula (PM2.5CE2B-PM2.5CP3)/PM2.5CP3

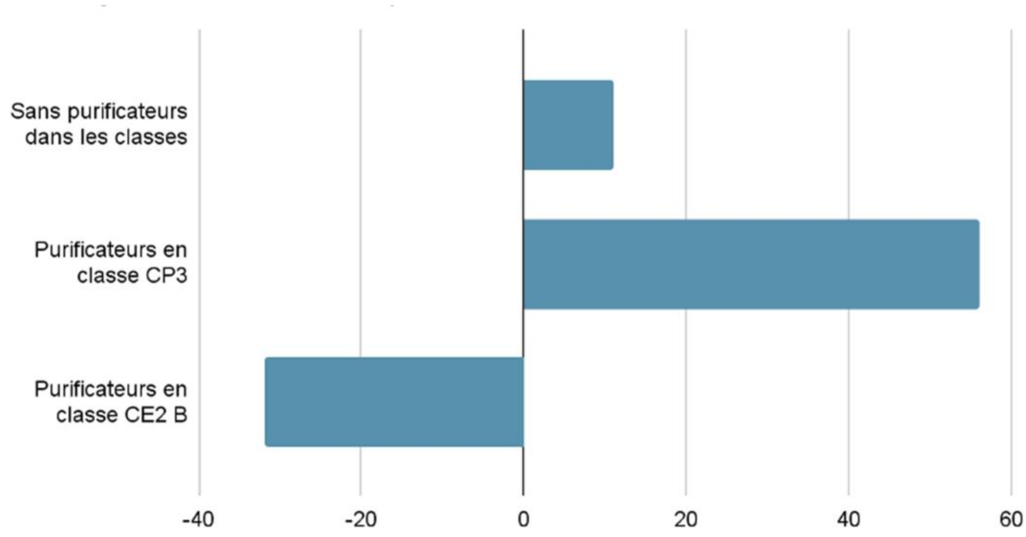


Figure 12: Graph showing the difference in average PM concentration$_{2,5}$ between third grade B and third grade 3 classes over one day with and without the purifiers operating

Thus, a significant and similar influence of the purifiers is measured during the two distinct phases of purifier commissioning in the two classes.

Result [4]: The level of $PM_{2.5}$ concentrations in a classroom with purifiers operating decreases by an average of 44% compared to a classroom without purifiers operating over a school day.

We also compared the indoor/outdoor pollution ratio5 of the classrooms before and after the air purifiers were installed. It can be seen that this ratio drops by 30% when the classrooms are purified. Indeed, the ratio in both classrooms exceeds 50% before purification, and drops to 35% when the purifiers are turned on (see graph below).

[5] ratio PM2.5indoor/PM2.$_{5outdoor}$

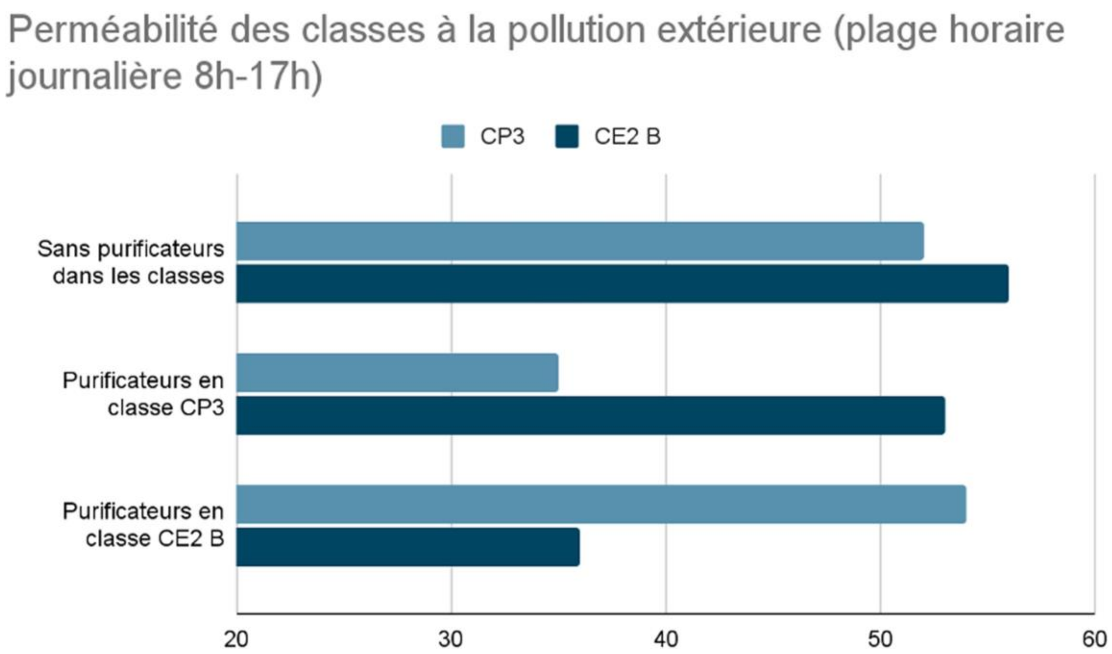


Figure 13: Graph showing the ratio of indoor to outdoor PM2.5 (in %) in each class, for each test period

Result [5]: The ratio of indoor pollution to outdoor air pollution in a classroom decreases by 30% when the purifiers are in operation.

5. SUMMARY OF RESULTS

- **On a daily average, air quality in classrooms is strongly correlated with outdoor air quality.**
- **The level of pollution in both classes regularly exceeds the values recommended by the WHO.**
- **There is no replicable daily profile due to the high variability of air quality measurements per hour or per day.**
- **The level of $PM_{2.5}$ concentrations in a classroom with purifiers operating decreases by an average of 44% compared to a classroom without purifiers operating over a school day.**
- **The ratio of indoor pollution to outdoor air pollution in a classroom decreases by 30% when the purifiers are in operation.**

6. CONCLUSION

The campaign of measurements carried out allows to demonstrate a real effectiveness of the air purifiers by electrofiltration in the classrooms of the school.

We find that **the concentration of PM2.5 particles decreases by 44% on average in a classroom with an electrofiltration air cleaner compared to a classroom without one.**

This result is all the more interesting as it was obtained during **a semester when the classroom windows are often open** (winter months, sanitary protocol, inter-class breaks), especially in the spring when the purifiers were put into operation, favoring the entry of external pollutants.

On the other hand, the feedback from the professors is also satisfactory. They emphasize that the acoustic comfort, despite the noise of the purifier in operation, is acceptable during classes and consider the use and maintenance of the device to be very simple.

7. RECOMMENDATIONS

We make 5 recommendations that aim to propose a strategy for deploying air cleaners to improve air quality in confined environments:

1	Conduct a national campaign to test the effectiveness of air purifiers in ERP (schools, senior residences, sports and cultural venues, etc.), observing several technologies (HEPA filters, electrofiltration, etc.) and demonstrating their added value to improve indoor air quality
2	Generalize the installation and use of air purifiers in the ERP, in particular by the law
3	Create a national fund dedicated to financing the purchase of purifiers for communities
4	Encourage the establishment of epidemiological cohort studies to improve knowledge of the effects of air cleaners on the prevention of seasonal and respiratory epidemics (influenza, bronchiolitis) and even Covid-19
5	Establish a protocol for the use and good practice of purifiers explaining the use and maintenance of these devices to the general public and educational personnel