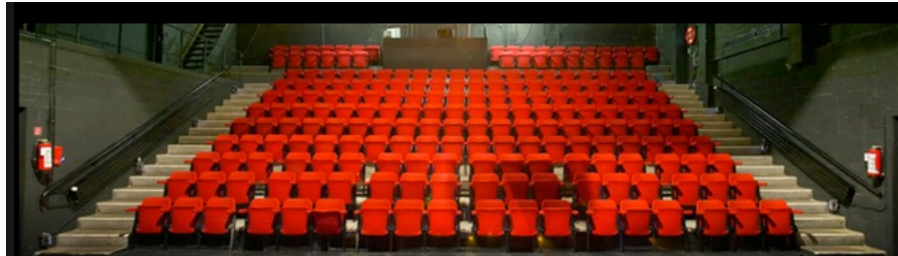


When Ellona meets ReSPR

Arca Theatre – Ghent – A Case Study



The Arca Theatre - Ghent



The Context



- The Arca Theatre is a small drama theatre in Ghent (Belgium) with seating for audiences of up to 200 patrons.
- Arca is one of three theatres in a network of live-performance venues.
- Arca was one of hundreds of venues that were closed during the Covid-19 Pandemic. These included but were not limited to gyms, cinemas, restaurants, public swimming pools, schools, and so on.
- With the possibilities of these venues and other public spaces opening up, the Belgian Government mandated the reporting to patrons (by visual display) the air quality in these spaces.
- The key air quality measurement required by the government was the amount of carbon dioxide (CO₂) present in the air within the space. This was due to its view that the Covid-19 virus propagates in situations where CO₂ exceeds 1000 parts per million (ppm).
- The mandate set a range of 900-1200 ppm at which point the owner/manager of the facility was required to increase the ventilation within the space so as to disperse the CO₂ and reduce the risk of viral transmission.

The Problem



- The Arca Theatre had a very high roof space but it had limited opportunities for cross ventilation.
- There was no air-conditioning system.
- The windows were fixed closed.
- Some additional ventilation was possible if the exit doors along the side walls were opened – but this was problematic when a live drama performance was in session. The potential for external light and noise creating visual and audible nuisances was undesirable and disrupted the performance.

The Solution



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- While we agree that the level of CO₂ in a public space is an important indicator of the potential for a virus to flourish, the work done by our partner Ellona through their [Viral Transmission Index](#) has demonstrated that the risk of viral transmission is increased by a combination of four factors:
 - i. CO₂,
 - ii. Temperature,
 - iii. Humidity, and
 - iv. Particulate Matter
 - Our solution needed to work within the constraints of
 - the architectural design of the Arca Theatre,
 - its existing ventilation configuration,
 - theatre management’s budget for compliance and/or remediation,
 - what we know about the 4 factors of viral transmission, and
 - the government mandate to measure, manage, and report to patrons on the levels of CO₂.

The Solution


- Airandé proposed that our solution for the Arca Theatre would provide the means by which theatre management could:
 - i. detect, measure, monitor, and manage the government-mandated CO₂ levels,
 - ii. display the CO₂ levels (in ppm) to theatre patrons,
 - iii. increase ventilation by mechanical circulation of the air, and
 - iv. capture and reduce particulate matter from the air in the theatre.
- Airandé's proposal to theatre management was to install
 - i. the Ellona POD2 in order to:
 - a. facilitate compliance with the government mandate, and
 - b. measure, manage, and report on the four environmental factors for viral transmission.
 - ii. 9 x ReSPR FLEX units and 1 x ReSPR ONE unit in order to:
 - a. increase ventilation by mechanical circulation of the air,
 - b. capture and reduce the particulate matter in the air, and
 - c. purify the air and surfaces in the theatre through the removal of bacteria and other sources of microbial contamination.

The Solution



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- Our solution was tested for efficacy and effectiveness
 - i. baseline testing = an empty theatre,
 - ii. in-situ testing and reporting to patrons on the levels of CO₂,
 - iii. in-situ testing and reporting to theatre management on the 4 indices of environmental conditions that encourage viral transmission.

The Testing

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- Objective and Method
 - Comfort analysis (temperature, humidity, comfort index)
 - Air quality analysis (CO₂, PM, IQA, Index)
 - Conclusions and recommendations

The Testing

- Context
 - Test of the ELLONA POD2 from 15/01/2022 to 03/02/2022
- Objective
 - Monitor and measure the air quality inside the Arca Theatre impact of the ReSPR technology on it
 - Monitor compliance with the Belgian government mandate
 - Make recommendations
- Method
 - Comparison of overall environmental quality with and without ReSPR air purification technology



The Testing

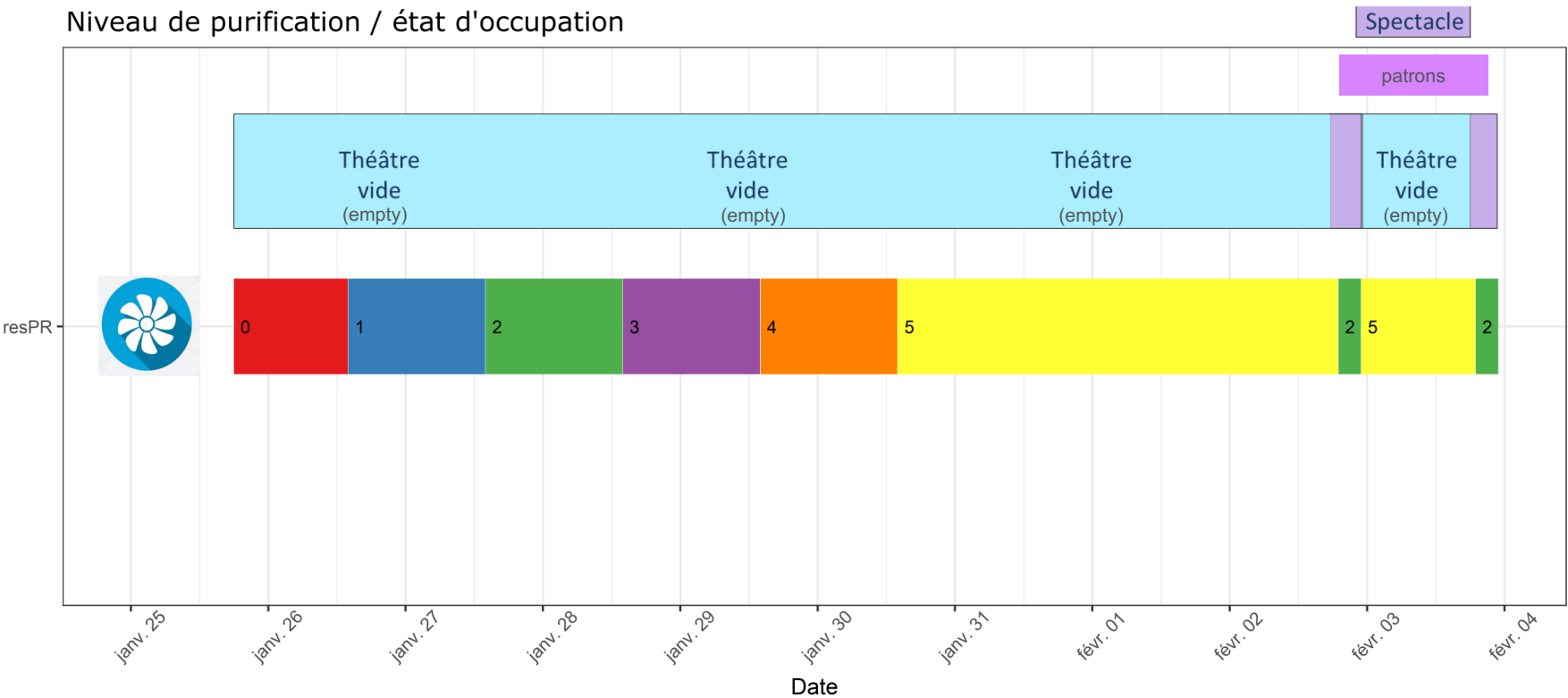
- The Process
 - Installation of the ELLONA POD2 alongside ReSPR test units
 - 2 Test Scenarios
 - i. Empty Theatre (January 25 to February 2),
 - ii. Reduced capacity shows (as per government direction),
 - February 2nd from 8:00pm to 10:00pm (45 patrons),
 - February 3rd from 8:00pm to 10:00pm (45> patrons),
 - iii. ReSPR installation
 - 3 x ReSPR FLEX on each of internal left and right walls,
 - 3 x ReSPR FLEX on the overhead gantry used for lighting,
 - 1 x ReSPR ONE in the Female bathroom.
 - iv. ELLONA installation
 - Inverted on the overhead gantry.
- Testing Staff:
 - M Mertens (Airandé)
 - R Pasqua, PhD (Ellona)
 - P Van Deneede (2Go4Green)



Test Schedule

Level of purification/state of occupation

Niveau de purification / état d'occupation



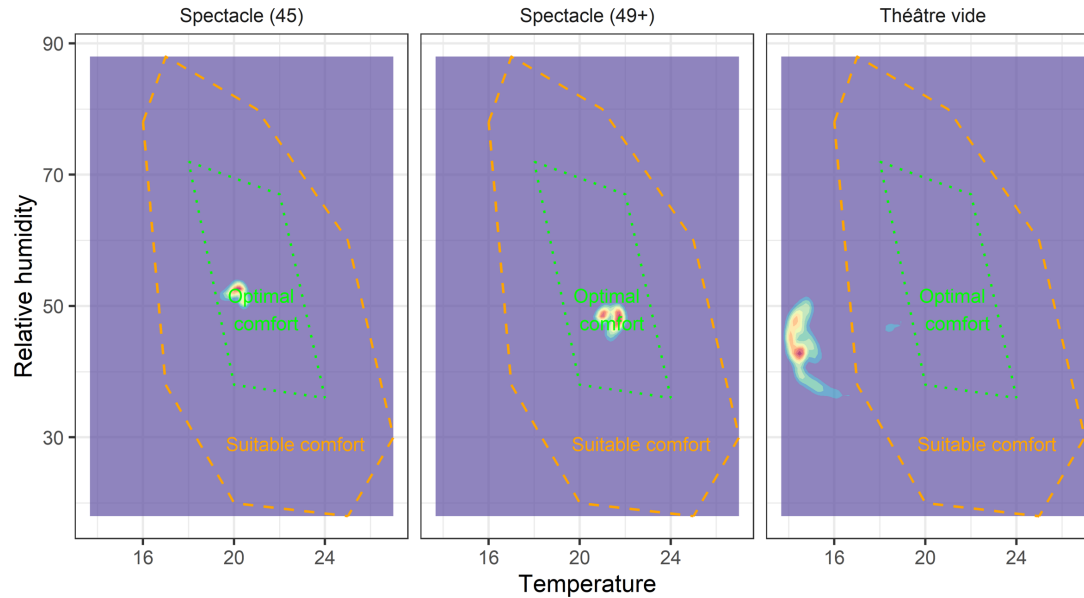


- **Comfort**

Temperature, humidity, noise and Ellona indices

Temperature and humidity analysis

Correlation of environmental parameters



The observed temperature and relative humidity levels vary according to the state of occupation of the theater. As expected, when the theater is empty the comfort is not optimal while during the shows the comfort is optimal.

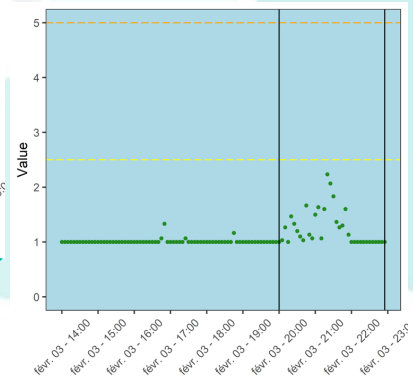
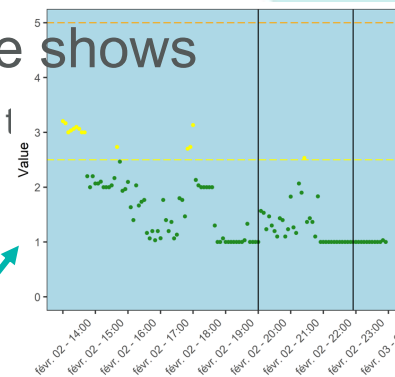
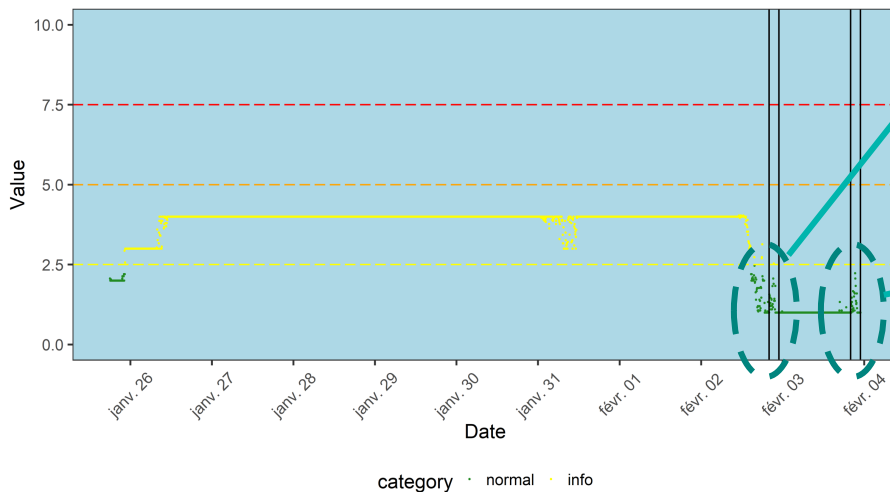
It is interesting to note that there is a remarkably low variability during the entire duration of the performances, thus optimizing maximum comfort.

The values used for the definition of comfort ranges refer to the criteria recommended for the presence of people in a moderate thermal environment.

Physical measurement	Comfort range	Reference
Temperature	20 - 22 °C	NF X35-203 / ISO 7730
Humidity level	40 - 70 %	NF X35-203 / ISO 7730

Comfort index: it is optimal during the shows

Observation of the evolution of the indices calculated by 1



The Ellona comfort index considers noise and light levels in correlation with temperature and humidity.

Ellona indices are defined from 1 to 10 with 4 levels of alert:

Normal : from 0 to 2.5

Info : from 2.5 to 5

Warning : from 5 to

7.5

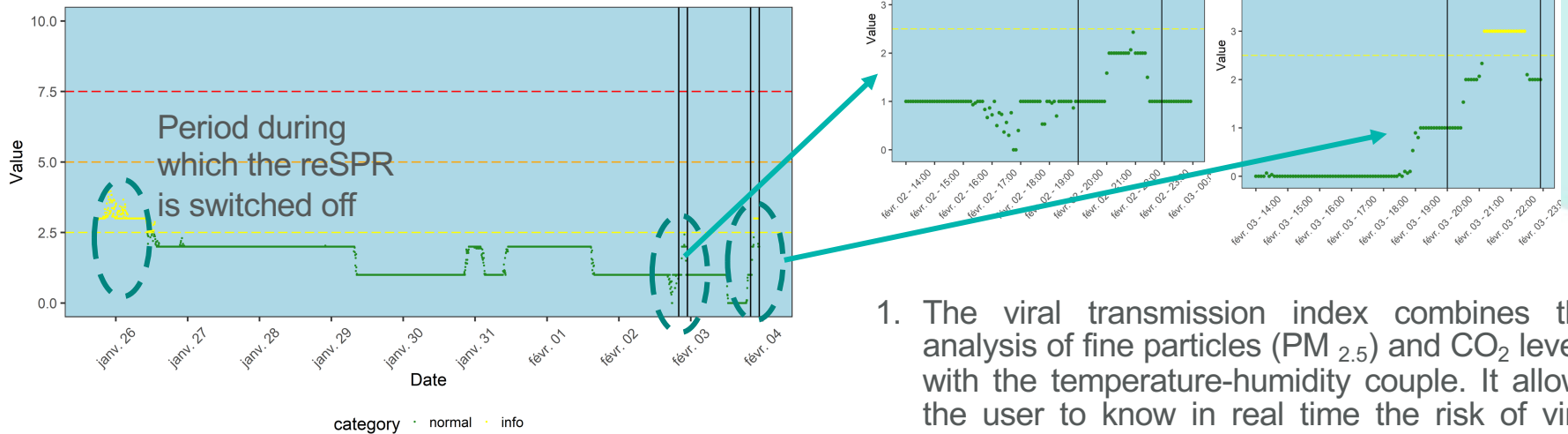
Critical : from 7.5 to

10

The analysis of the trend of the comfort index confirms the observation made earlier: during the performances (black lines in vertical) the index is optimal.

Viral index is strongly enhanced by ReSPR and is maintained despite a slight increase during shows

Observation of the evolution of the indices calculated by the POD2



1. The viral transmission index combines the analysis of fine particles (PM_{2.5}) and CO₂ levels with the temperature-humidity couple. It allows the user to know in real time the risk of viral transmission if a virus is present in a closed space.
2. It is interesting to see that the risk of viral propagation decreases with increasing purification level by the ReSPR technology. During the shows (black lines in vertical) the index increases slightly but remains in low levels (< 5).

Ellona indices are defined from 1 to 10 with 4 alert levels:

Normal : from 0 to 2.5

Info : from 2.5 to 5

Warning : from 5 to 7.5

Critical : from 7.5 to 10



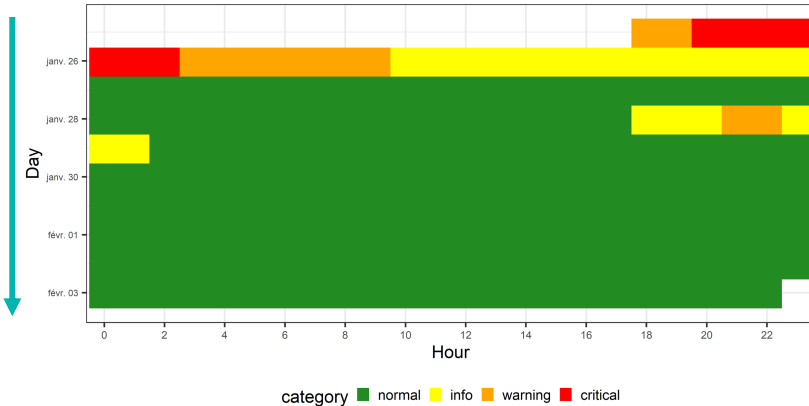
- Air quality

Fine particles

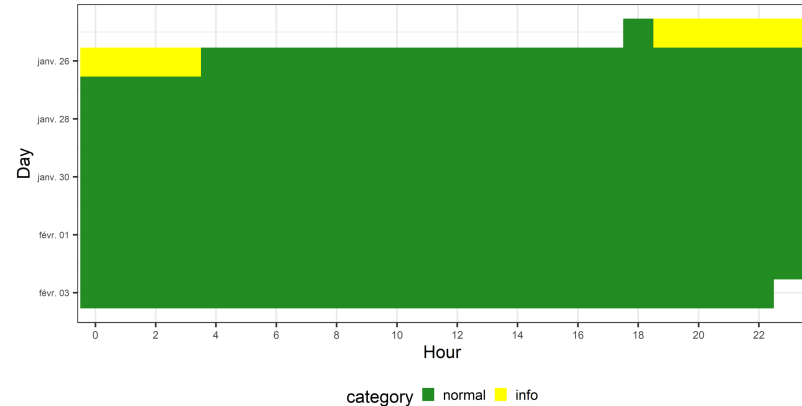
Evolution of the presence of dust

Thresho Id	Value retained		No integration	Comments/Rationale
	PM10 µg/m	PM2.5 µg/m		
Bottom	25	12	Daily average	SEI
Medium	35	17		SES
Top	50	25		Regulatory value applicable in France

Hourly Mean of PM 2.5



Hourly Mean of PM 10



The levels of fine particles decrease considerably in correspondence with the use of the ReSPR air and surface purifier technologies. It is possible to observe the effect of the change in the purification level on a long-term basis as well. It would be interesting to check if there was any particular activity reported on the evening of February 28 when an increase in fine particles was measured.

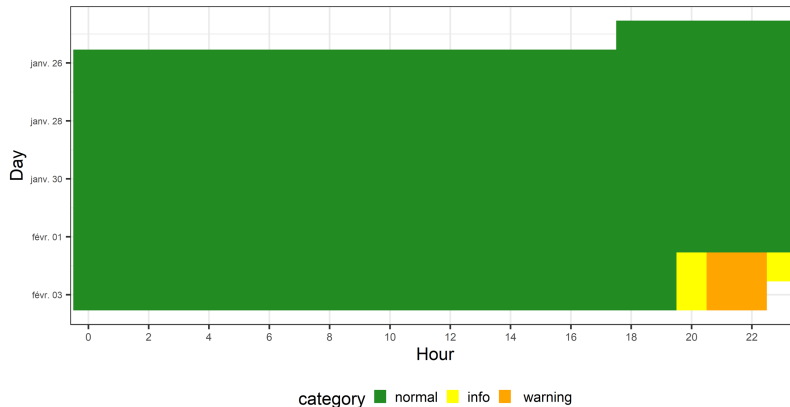
Carbon Dioxide (CO₂) - Containment Index

Evolution of the concentration

Seuil	Valeur retenue		Pas d'intégration	Commentaires/justification
	mg/m ³	ppm		
	< 1530	< 850	Moyenne sur la période journalière d'exposition	Qualité de l'air excellente à bonne
Bas	1530 - 1800	850 - 1000		Qualité de l'air modérée
Moyen	1800 - 2700	1000 - 1500		Qualité de l'air basse avec un effet sur la performance psychomotrice (prise de décision, résolution de problèmes)
Haut	> 2700	> 1500		Qualité de l'air basse

* Calculé à partir des ppm et CNTP (25°C)


Hourly Mean of CO₂



Carbon dioxide concentration levels are globally still below 850 ppm (hourly average) which is the first alert level.

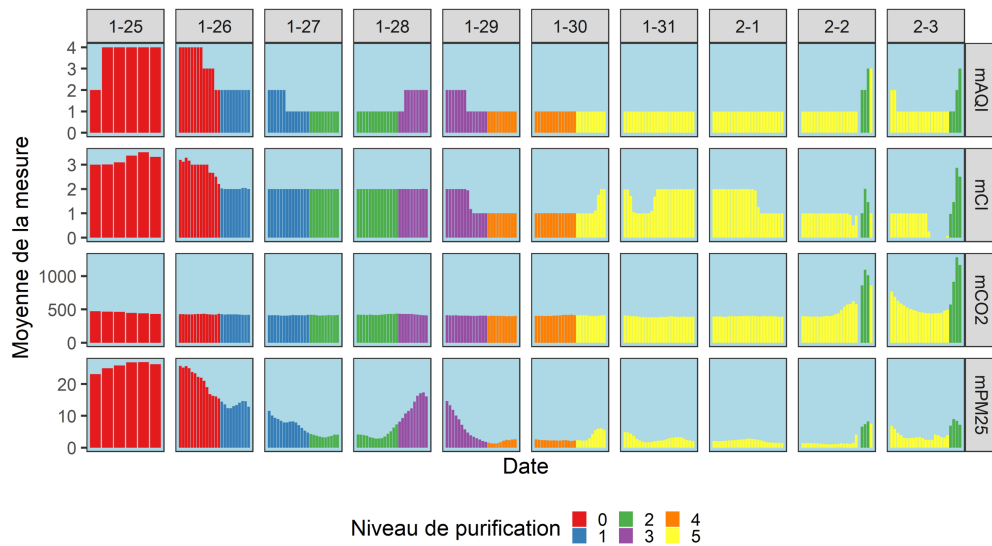
During the performances an increase of the level is measured in correspondence with the presence of the public and the decrease of the purification power level which brings to level 2 the concentration of CO₂. An improvement of the air conditioning system flow rate could be recommended but is not necessary.

It is also interesting to observe that less than 2 hours after the February 2 show the hourly average concentration level had dropped below 850 ppm.

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- Conclusions and recommendations

Quantification of the purification impact

Comparison of average measurements



The empty theater without purification is considered as a reference (red bars). The impact of the purifier on the measurements can then be quantified by looking at the difference between this reference and the other measurement periods. During the performances, the purifier was only used with a level 2.

Thanks to the use of the POD2 Ellona and as shown before, the impact of the purification is quantifiable on the level of comfort felt and on the air quality in the theater.

In the visual here on the left, it is possible to observe how the use of the ReSPR purifier allows to improve the average level of the different measurements coming from the POD2, in particular :

- Air Quality Index (AQI)
- Containment Index (CI)
- Level of fine particles (in $\mu\text{g}/\text{m}^3$)

The only exception is the CO_2 measurement (in ppm) which is strongly correlated with the presence of the public. A test with audience without purifiers would properly quantify the impact of ReSPR on carbon dioxide removal.

Recommendations



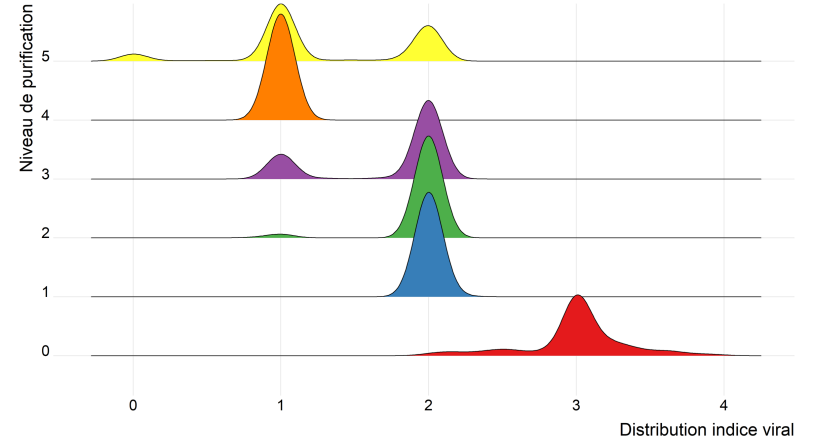
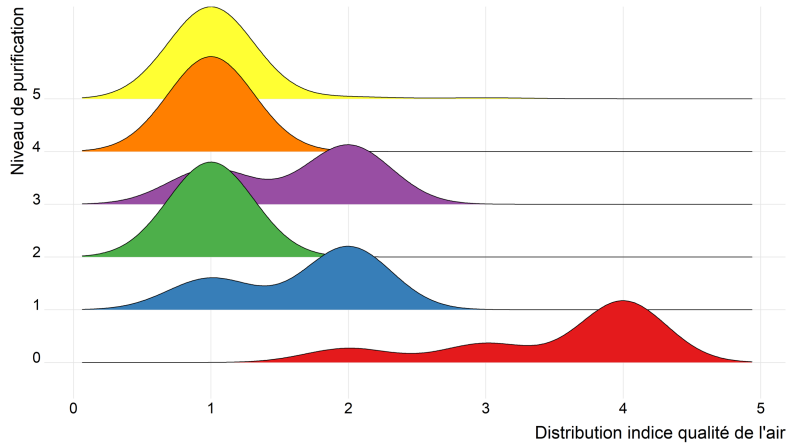
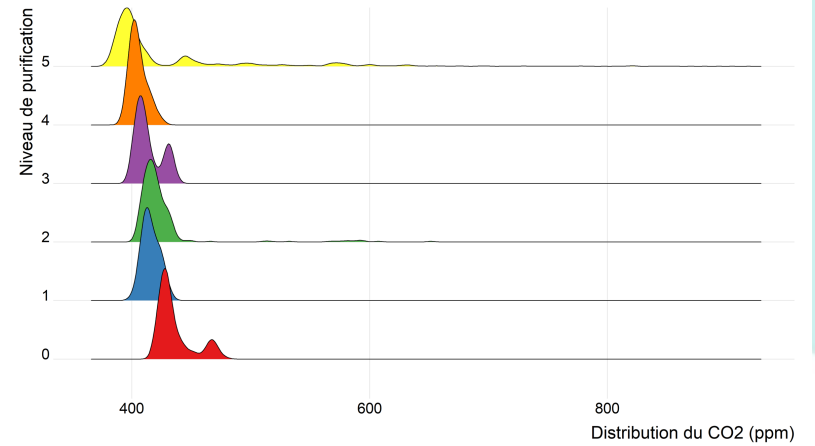
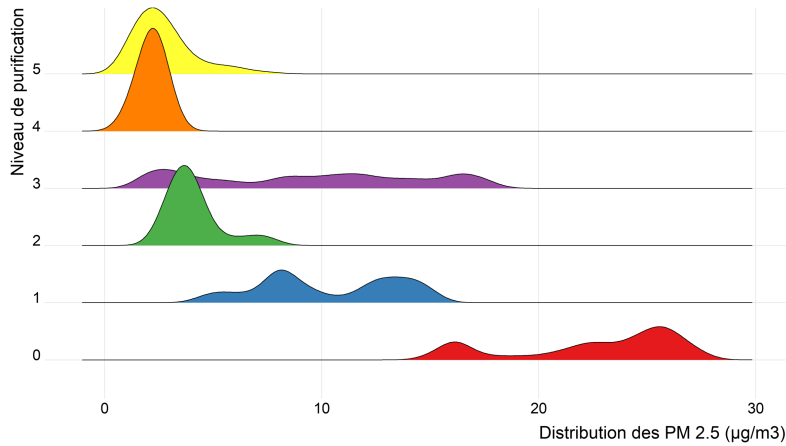
1. The air quality in the theater has been improved by the presence of the ReSPR units mainly on the reduction of the levels of particulate matter.
2. Comfort analysis (temperature, humidity, comfort index) are optimal even during the shows except for the CO₂ level.
3. The viral index is strongly enhanced and the increased reduction of the risk of viral transmission is achieved through the presence of the ReSPR units.
4. We recommend an acceleration of the airflow slightly before (1h) and during the 2/3 of the show. This was achieved by slightly adjusting the fan speed of the ReSPR FLEX units up and then down as per the recommendation.

Disclaimer



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Appendix: distribution of measurements with the empty theater



Arca Theatre – Case Study

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