IAQ-label for Belgian public spaces: Monitoring in 11 public spaces

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ABSTRACT

In 2022, a new law was passed by the Belgian federal government with the purpose to enhance the indoor air quality in public spaces in the aftermath of the COVID-19 pandemic. This new law, among other things, requires publicly accessible spaces to apply a CO_2 meter and provides the option to have an IAQ label in place that informs the visitor about the indoor air quality of that space. Since then, the Belgian Federal Public Health Service has been developing the more detailed, practical implementation of this new law, in consultation with stakeholders and research institutes.

In support of the development of the IAQ label a measurement campaign was set up to obtain a better understanding of the IAQ achieved in public spaces. There is typically a lack of this data since public buildings such as restaurants, bars, sports infrastructure or theaters are studied less frequently in IAQ literature than e.g. offices or dwellings.

In this new monitoring campaign, measurements of CO_2, Temperature, RH, PM2.5 and PM10 were carried out in 11 Belgian public spaces with a variety of functions for a duration of at least 7 days in March 2024. At the same time the spaces were inspected to obtain information about the use, potential sources of pollutants and possible ventilation systems in place.

The measurements show a broad range of IAQ-parameters depending on use, presence of specific sources and presence of a ventilation systems in the building. Specific sources of PM can dramatically change the indoor concentration to levels well above WHO Air Quality Guidelines for extended periods of time. Bars/restaurants have obtained the worst IAQ-parameters while most other locations, all equipped with mechanical ventilation systems, were able to achieve acceptable CO_2 and PM levels. The measurements highlight the complexity in the development of one consistent label applicable for all public spaces.

KEYWORDS

IAQ in Public Spaces – Measurements - Particulate Matter – CO_2

1 INTRODUCTION

Belgium has passed a law in 2022 aiming to enhance the indoor air quality in publicly accessible spaces in the aftermath of the COVID-19 pandemic (FOD Health, 2022). Part of this legislation focusses on raising awareness about indoor air quality in the general population as they are often not aware of the risks linked to high pollutant concentrations indoors. This law, among other things, will provide an official label and underlying certification procedure that allows publicly accessible spaces to quantifiably showcase the efforts done to maintain good Indoor Air Quality (IAQ).

Since then, the Belgian Federal Public Health Service has been developing the more detailed, practical implementation of this new law, in consultation with stakeholders and research institutes. The focus of the implementation first lied in locations that proved most challenging during the COVID-19 pandemic e.g. Bars, Restaurants, Theatres. In support of the development of the IAQ label a measurement campaign was set up to obtain a better understanding of the IAQ achieved in such public spaces. There is typically a lack of this data since public buildings such as restaurants, bars, sports infrastructure or shops are studied less frequently in IAQ literature than e.g. offices or dwellings. This paper reports on the measurement campaign and discusses results.

2 MONITORING CAMPAIGN

Measurements were originally planned and executed in 18 locations. Locations were randomly selected within the target functions based on availability and willingness of owners to participate. After checking the data quality and omitting cases that did not have a minimum duration of 7 days of effective acquired data, 11 locations were kept in the final dataset. The selected measurements took place between 7/03/2024 and 28/03/2024 with most spaces located near Ghent. Analysis of the outdoor temperature measurements gathered from open-acces local weatherstation Vlinder 71 (VLINDER UGent, 2024) indicate a rather cold period with an average value of 9.6°C and a 95th percentile value of 14.2°C. Window opening is therefore expected to be limited.

All locations were measured with *NEMo diagnosis* loggers (Ethera Labs, 2024) with the following measured parameters: Temperature (T), Relative Humidity (RH), Carbon Dioxide (CO_2) and two size ranges of Particulate Matter (PM2.5 & PM10). Table 1 summarises the technical information of the NEMo logger.

Table 1 Summary of the data from the technical datasheet of the used NEMo Loggers (Ethera Labs, 2022)

CO_2	Detection method: Non Dispersive Infrared spectrometry (NDIR) Measuring range: 0 to 5000 ppm Resolution: 1 ppm Accuracy: ± 30 ppm ± 3 % of reading value Automatic Calibration algorithm (400ppm reference)
PM2.5/10 *(10: calculated)*	Detection method: Laser-based light scattering Measuring range: 0 - 1000 µg/m3 Resolution:1 µg/m3 Accuracy: PM2.5: 10µg/m3 (<100µg/m3) or ± 10% of reading value (>100µg/m3). PM10 (calculated): 25 µg/m3 (<100µg/m3) or ± 25% of reading value (>100µg/m3)
Temperature	Measuring range: -55°C to +125°C Accuracy: ± 2°C from -25°C to 100°C (± 0.5°C after calibration)
Relative Humidity	Measuring range: 0 to 95 % Accuracy: ± 3 % from 11% to 89% (± 7 % for the rest of the range)

General descriptive data of each case was gathered with special attention to possible sources of particulate pollutants. For all cases information was gathered on opening hours and the possible presence of a mechanical ventilation system. Only in one case the technical specifications of the ventilation system were available, including design flow rates of outdoor air. In none of the locations air cleaning systems were in place.

2.1 Description of the spaces

2.1.1 Bar KM

Bar KM is a bar in a rural area of Flanders. It is a popular place for local organizations, small groups, to meet (e.g. Billiard, Card-games, Darts). Connected to the bar, there is a multi-purpose room which is used when additional seating is needed and where a *Boltra* course is present. According to the owner, you can expect 3 types of visitors: the regulars at the bar, the weekly visitors of local organisations and, during the day, ad-hoc bike-tourists. It does not have any means of mechanical ventilation.

2.1.2 Bar VO

Bar VO is a relatively large bar and restaurant in the city center. It is part of a heritage building with high ceilings. They serve food and drinks which results in peak occupancy during lunch and dinner-time but will have customers all-day. The owners of this location have invested in a state-of-the-art variable airflow (CO_2 controlled) balanced mechanical ventilation system. The owners have also installed a CO2-sensor with public display near the counter.

2.1.3 Bar VM

Bar VM is a bar situated next to two sport halls, a series of outdoor sport fields and a school. It serves as the place where groups go to have a drink after their sporting session but also as lunchroom for the school and space where kids can go play when the weather is bad. This makes for an intensively used location with a high number of unique customers that do not stay in the space very long. The bar has an air based heating system coupled to a mechanical balanced ventilation system. The system recirculates air to achieve the necessary airflow for heating. The mechanical airflow system was installed in 1990 and was never updated to newer airflow requirements.

2.1.4 Bar OW

Bar OW is a bar in the city center. It is open from early noon to after midnight but as it is a popular bar for university students to have a seated drink, peak occupancy occurs in the evening and night hours. Candles are lit in the evening for lighting and atmosphere. The bar does not have a mechanical ventilation system and windows need to stay closed after 22u to limit noise disturbances of the neighbours.

2.1.5 Bar VL

Bar VL is a bar linked to a soccer-field and soccer-club. It is only open in the evening when there is soccer practice and bi-weekly during the weekend when there is a soccer match. The building does not have a mechanical ventilation system but trickle-vents are placed above most of the windows to allow for naturally driven airflow even when windows are closed.

2.1.6 Gym WB

Gym WB is a fitness room that is accessible 24/7. Although always accessible ,occupancy is highest during the evening hours. This gym is purpose built with a mechanical balanced ventilation system.

2.1.7 Gym SP

Gym SP is a fitness room open during the day and evening. It is located in the underground level of a building in the city-center. Only the entrance is connected to outdoor air, accessible via a staircase from the street. Therefore the possibility of infiltration and natural airflow is limited. The building has a mechanical ventilation system.

2.1.8 Waiting room hospital

The hospital waiting room functions as a place for people in attendance of their scheduled appointments. The patients come and go, but the space is occupied continuously. There is a mechanical ventilation system present.

2.1.9 Store (sporting goods)

The store is a warehouse-type building, purpose built as store. It is only open during the day and is equipped with a mechanical ventilation system.

2.1.10 University restaurant

The university restaurant is open for lunch and evening meals. Peak occupancy is during lunch with a smaller peak in the evening. The hot dishes are served from a heated counter. Behind this counter there is a kitchen used to prepare fries with a separate local exhaust (industrial range hood). Both are situated in a space which is the same overall space as the measured lunchroom. A CO_2 controlled balanced mechanical ventilation system is present.

2.1.11 University Cafeteria

The university cafeteria is a place where sandwiches, soup and coffee can be bought. There is some space to sit and reside for some time but most people are only present for a short duration as they take-away lunch. The cafeteria is open during the day but with peak occupancy during lunch. The building is purpose-built with a state-of-the-art mechanical ventilation system.

3 RESULTS

Table 2 reports the key figures of the measured parameters during the opening hours of the different locations. The key figures are:

- 5% percentile (P5)
- 25% percentile (P25)
- Mean / 50% percentile (P50)
- 75% percentile (P75)
- 95% percentile (P95)
- Average (Avg.)
- Standard Deviation (St. dev.)

The key-figures for PM2.5, PM10 and CO_2 are also visualised as box-plots where the min and max values are replaced by the P5 and P95 values in Figure 1 and Figure 2. It was necessary to plot the results of Bar KM separately as the PM2.5 and PM10 values were an order of magnitude higher. Locations without mechanical ventilation system are indicated in another colour.

On the same graph the WHO 1-day average (AQG Day) and yearly average Air Quality Guideline (AQG Year) values are shown as dotted lines for PM2.5 and PM10 (World Health Organisation, 2021). For CO_2, the new IAQ legislation defines two reference levels A at 900 ppm and B at 1200 ppm, these refence levels are also shown as dotted lines.

With regards to **CO_2**, only 5 out of 11 locations manages to have a P95-value below the upper reference level of 1200 ppm. The median value (P50) is above the lower reference level of 900 ppm for 4 out of 11 locations, this means that more than half of the time the occupants are exposed to air which is not meeting the legal reference A. For two of those, Bar OW and Bar KM, the median value is even above the 1200 ppm reference value.

Table 2 Key figures of measured parameters during opening hours

		Bar KM	Bar VO	Bar VM	Bar OW	Bar VL	Gym WB	Gym SP	Waitin room	Store	Univ Rest.	Univ Lunch
	P5	761	417	442	526	453	437	570	472	480	515	405
	P25	987	543	775	880	625	617	910	511	593	540	428
	P50	1358	691	1030	1559	792	768	1172	545	642	590	492
CO2	P75	1848	786	1608	2477	1178	928	1551	611	741	841	597
	P95	3847	942	2732	3441	1694	1231	2190	815	908	978	730
	Avg.	1598	678	1277	1702	918	786	1279	581	669	686	523
	St.dev	873	165	750	957	407	228	531	110	123	177	107
	P5	38	5	6	4	1	1	0	1	0	0	1
	P25	68	6	7	10	2	1	1	1	1	1	2
	P50	96	8	10	17	3	2	2	2	1	10	3
PM2.5	P75	148	12	13	29	5	3	3	4	2	28	5
	P95	227	20	23	42	9	4	6	9	3	55	8
	Avg.	114.3	10.6	11.6	19.9	4.0	2.0	2.1	3.5	1.4	17.1	3.8
	St.dev	65.5	12.9	6.2	13.2	2.4	1.2	1.9	3.5	1.0	18.8	2.4
	P5	45	6	7	5	2	1	0	1	0	0	2
	P25	80	7	8	11	3	1	1	1	1	2	3
	P50	107	9	11	18	4	2	2	3	2	12	4
PM10	P75	169	13	14	31	6	4	5	6	5	35	6
	P95	246	21	24	44	10	8	9	12	10	72	9
	Avg.	129.0	11.6	12.6	21.3	5.0	3.1	3.2	4.4	3.1	22.1	4.8
	St.dev	70.8	13.1	6.3	13.6	2.4	2.5	3.0	4.2	3.2	25.1	2.4
	P5	21.5	23.0	17.0	20.0	17.0	19.0	19.5	18.0	21.5	21.5	20.5
	P25	22.0	24.5	19.0	21.0	19.0	20.0	20.0	22.5	22.0	23.0	20.5
	P50	22.5	25.0	20.0	21.5	20.0	21.0	20.5	23.0	22.5	23.0	21.5
T	P75	23.0	25.5	21.0	22.5	20.5	21.5	20.5	24.0	23.0	23.5	21.5
	P95	24.0	26.0	22.0	23.5	21.5	22.0	21.0	24.5	24.0	24.5	22.0
	Avg.	22.5	24.7	19.9	21.7	19.8	20.7	20.3	22.6	22.4	23.0	21.2
	St.dev	0.7	0.8	1.7	1.0	1.4	1.0	0.5	1.8	0.8	0.9	0.6
	P5	51	27	38	50	46	43	45	41	34	32	34
	P25	55	31	51	58	53	47	53	43	38	36	38
	P50	59	38	58	62	57	58	61	45	42	39	40
RH	P75	63	41	63	66	61	64	66	47	47	41	46
	P95	67	44	70	71	69	68	69	53	49	50	48
	Avg.	59	36	56	61	57	56	59	46	42	39	41
	St.dev	5	5	9	6	6	8	8	4	5	5	5

With regards to PM2.5 **Bar OW** and **Bar KM** have mean measured values (P50) during opening hours above the AQG Day which indicates unacceptable IAQ. The **University restaurant** has a lower value but still has a significant portion of its distribution above the AQG Day limit.

The trends in PM2.5 and CO_2 levels are similar which suggests that in most cases the PM2.5 sources are linked to the activities of occupants and a reverse correlation with the air change rate of the space. The **University restaurant** is an exception where CO_2 values are low compared to the measured PM values. This indicates that the people present and their activities are not the main source of PM. We suspect that the kitchen appliances (e.g. deep fryers) in the connected space act as a source of PM although local exhaust is provided (industrial range hood). **Gym SP** on the other hand shows relatively high CO_2 values compared to measured PM

values. However, also in **Gym WB** low PM values were measured indicating a lack of PM sources in these spaces but high CO_2 production rate because of the high intensity of the human activity levels. This trend is most outspoken in Gym SP because of smaller ventilation flow rates for the given occupancy and activity levels.

The conclusions for PM10 are similar to the conclusions for PM2.5 given the clear relation of both measured values which is due to the fact that PM10 is an extrapolated value of the PM2.5 data. Because of higher AQG values of PM10 the results are less problematic with regards to healthy indoor air quality.

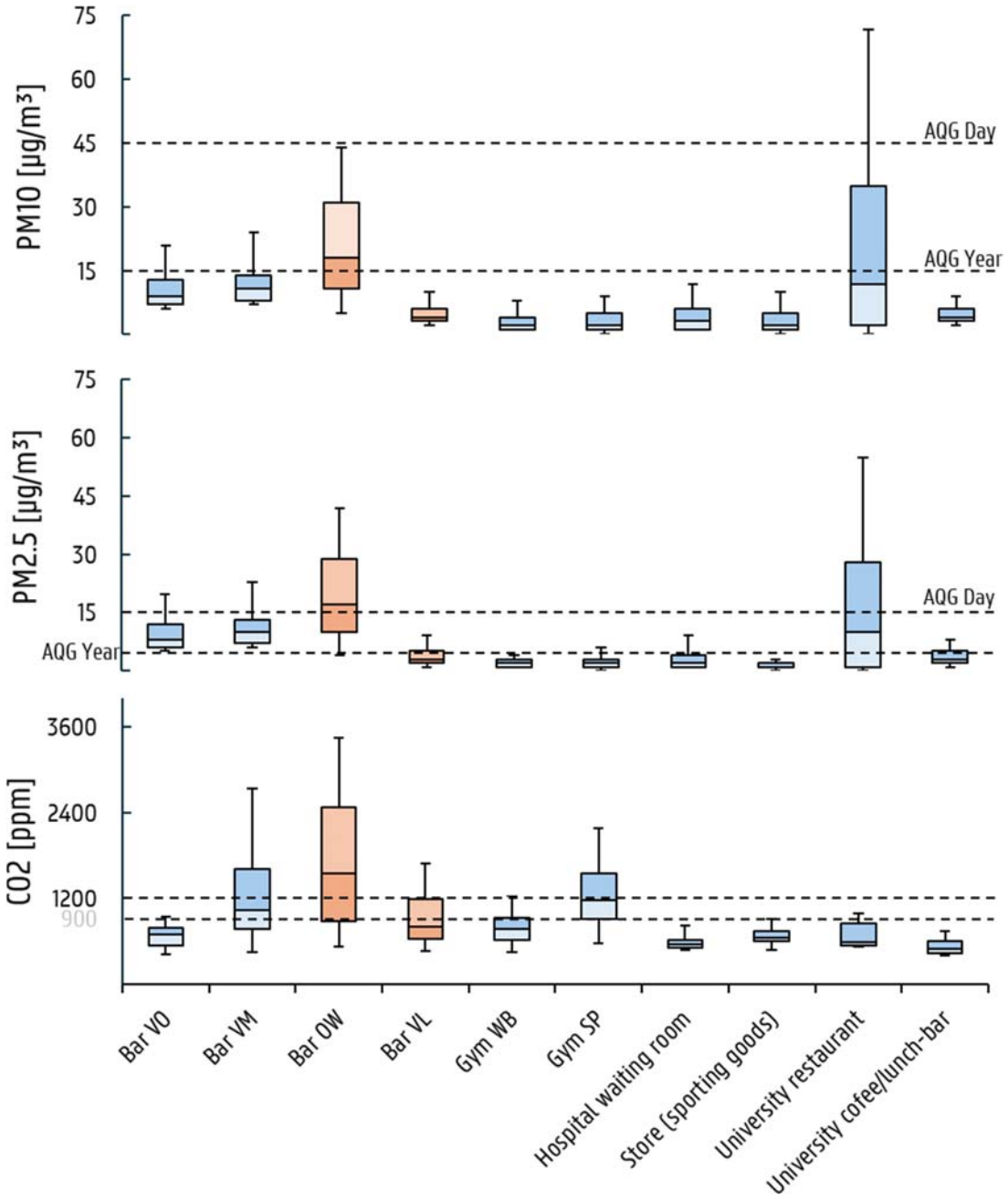

Figure 1 Boxplots of the CO_2, PM2.5 and PM10 concentrations during the opening hours of all the measured locations except for BAR KM. The orange boxplots signify cases without mechanical ventilation system.

Finally, the measurements in **Bar KM** indicate a total disregard of IAQ in this place. PM2.5 and PM10 measurements are all above the limits for at least 95% of the time that the bar is open for the general population. Also the CO_2 levels are high with a P5-value of 761 and a mean measured value (P50) of 1358ppm. Although we have not observed it in place, we suspect that this bar does not obey the no-indoor-smoking policy which is in place in Belgium. The indoor air quality in this location is unacceptable on all accounts.

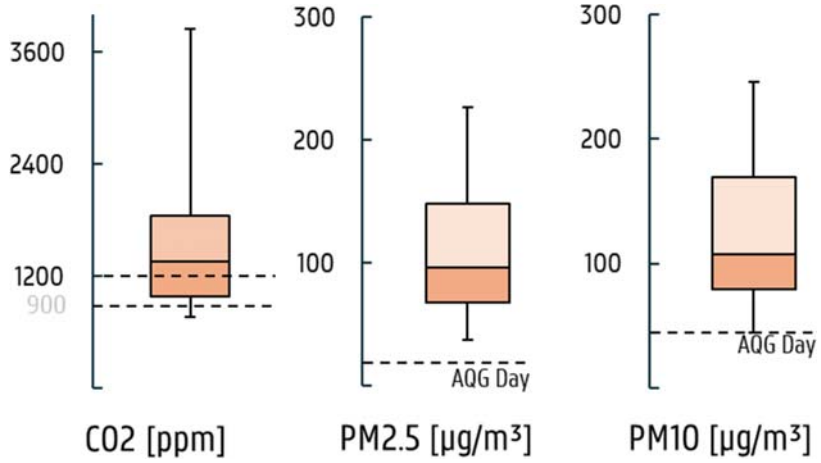

Figure 2 Results for BAR KM with high PM2.5 and PM10 values.

4 CONCLUSIONS

Overall **Bar KM** and **Bar OW** perform worst with regards to CO_2, PM25 and PM10 measurements. This is as expected since these are the cases without any dedicated provisions for ventilation. The measured **Bars** and **Gyms** have the tendency to perform worst with regards to IAQ even if a mechanical ventilation system is present but with low PM values in the Gyms due to the lack of sources. The presence of specific PM sources (e.g. fryers in student restaurant, suspected smoking in Bar KM, candles in Bar OW) can shift the measured PM values upwards dramatically, well above the WHO air quality guideline values. The other locations were all equipped with mechanical ventilation that managed the IAQ effectively for the occupation and activities present. This suggests a correct sizing and operation of the systems in these locations.

The measurement campaign confirms that the locations selected as priority locations by the Belgian Federal Public Health Service, namely bars and restaurants, are indeed more likely to have low IAQ and have a low airflow/person ratio. The development of an IAQ-label can prove challenging as giving an overall score or appreciation of the indoor air quality, especially the health aspect, purely based on CO_2 levels can underestimate the impact of PM when specific sources are present. A label based on a range of priority pollutants should be considered as alternative, possibly also including specific VOCs (e.g. Formaldehyde)

It should be noted that based on only three parameters and a relatively short measurement period clear differences in IAQ levels can be observed. Combined with observations and technical information general trends and results can be understood and explained. Technical information about the HVAC systems, e.g. ventilation airflow rates of the ventilation system were not often readily available to the tenants.

5 ACKNOWLEDGEMENTS

We would like to acknowledge the master students engineering: architecture at Ghent University who took part in the special topic *IAQ labelling* for gathering information and measurements at the different locations. We also acknowledge the company Airscan BV for helping with the logging equipment.

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Wet van 6 november 2022 betreffende de verbetering van de binnenluchtkwaliteit in gesloten plaatsen die publiek toegankelijk zijn, 2022034199, Federale Overheidsdienst Volksgezondheid, Veiligheid en Veiligheid van de Voedselketen, Belgisch Staatsblad—Moniteur Belgique 88761 (2022). https://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=nl&la=N&cn=2022110604&table_name=wet

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