Report of deployment of Air Quality Monitor in the city of Girona

From 14th of February until the 16th of May.

Bettair Cities S.L.
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Contents

Deployment in Girona

Four bettair® static nodes were deployed in the city of Girona. The deployment included four areas with different layout and different pollution profiles.

The nodes installed are the prototype of the version 2 of the bettair® static nodes. The nodes include the following sensors:

- Nitrogen Dioxide (NO_2)
- Ozone (O_3)
- Nitrogen Monoxide (NO)
- Carbon Monoxide (CO)
- Particle Matter (PM_1, $PM_{2.5}$ and PM_{10})
- Temperature
- Relative Humidity
- Atmospheric Pressure
- Ambient Noise Level

The nodes were installed in the following locations:

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Escola de Música

Google Maps
Coordinates: 41.976380, 2.816529
Node: BETN00013 - 0294

Parc del Migdia

Google Maps
Coordinates: 41.972936, 2.818256
Node: BETN00010 - 1175

Plaça de l'Hospital

Google Maps
Coordinates: 41.980942, 2.820670
Node: BETN00014 - 2258

Núria Terés i Bonet

Google Maps
Coordinates: 41.975638, 2.801347
Node: BET02000 - BETN00009 - 8844

CAQI Analysis

The data for each location was processed per hour and the Common Air Quality Index (CAQI) was calculated[1]. Normally the CAQI considers only the main pollutants (NO_2, O_3 and PM_{10}) but in this case we have included all the rest of available measurements, namely NO, CO, $PM_{2.5}$ and PM_1.

The Air Quality Index (AQI) was calculated for 1-hour averages of measured concentration for each of the pollutants. Then, the CAQI was determined as the worse (maximum) among those indexes. Hence, the CAQI is always associated to the dominant pollutant.

The following tables show the average CAQI per day, together with the dominant pollutant, for the four locations during the 14 weeks of deployment.

Escola de Música

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	-	-	PM2.5	52.6	PM2.5	43.1	O3	18.2	O3	19.9	O3	20.8	PM2.5	31.8
Tuesday	-	-	PM2.5	57.6	PM2.5	51.7	O3	18.7	PM2.5	29.7	O3	19.9	O3	22.1
Wednesday	-	-	PM2.5	58.0	PM2.5	55.1	PM2.5	28.9	PM2.5	32.5	O3	17.0	O3	16.3
Thrusday	-	-	PM2.5	64.9	PM2.5	53.5	O3	19.9	PM2.5	36.8	PM2.5	16.8	PM2.5	18.0
Friday	PM2.5	33.6	PM2.5	52.8	PM2.5	49.2	PM2.5	21.1	PM2.5	30.1	PM2.5	22.2	PM2.5	22.0
Saturday	PM2.5	37.1	PM2.5	43.4	PM2.5	54.4	PM2.5	33.1	PM2.5	37.1	PM2.5	27.3	PM2.5	24.9
Sunday	PM2.5	46.2	PM2.5	37.7	PM2.5	54.3	PM2.5	37.0	PM2.5	22.8	PM2.5	23.6	PM2.5	31.8

[1] For more information please refer to ANNEX II.

	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13		Week 14	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	PM2.5	32.0	PM2.5	24.7	PM2.5	27.0	O3	32.5	O3	17.5	O3	19.5	NO2	18.8
Tuesday	PM2.5	37.5	PM2.5	18.2	PM2.5	24.6	O3	25.0	PM2.5	16.5	PM2.5	21.8	O3	19.1
Wednesday	PM2.5	28.5	NO2	17.5	PM2.5	25.3	O3	27.4	O3	21.3	PM2.5	31.7	O3	20.1
Thursday	O3	22.2	NO2	26.1	PM2.5	26.4	O3	28.9	PM2.5	21.5	O3	19.5	NO2	20.9
Friday	O3	19.4	PM2.5	41.3	O3	32.5	NO2	17.6	PM2.5	24.1	NO2	21.8	-	-
Saturday	O3	25.0	PM2.5	42.3	O3	31.2	O3	21.8	O3	20.6	NO2	15.9	-	-
Sunday	O3	18.9	PM2.5	32.6	O3	33.1	O3	24.9	O3	26.5	O3	18.6	-	-

Parc del Midgia

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	-	-	PM2.5	55.1	PM2.5	45.6	O3	24.3	O3	26.3	O3	24.4	PM2.5	35.7
Tuesday	-	-	PM2.5	61.1	PM2.5	53.0	O3	21.0	PM2.5	32.9	O3	23.3	O3	27.8
Wednesday	-	-	PM2.5	61.9	PM2.5	58.8	PM2.5	34.0	PM2.5	36.5	O3	21.2	O3	21.2
Thrusday	-	-	PM2.5	69.1	PM2.5	55.6	O3	22.0	PM2.5	42.0	O3	18.7	PM2.5	21.1
Friday	PM2.5	50.6	PM2.5	55.7	PM2.5	52.0	PM2.5	28.6	PM2.5	32.7	PM2.5	22.1	PM2.5	25.1
Saturday	PM2.5	53.3	PM2.5	46.6	PM2.5	58.1	PM2.5	39.9	PM2.5	43.6	PM2.5	28.2	PM2.5	27.0
Sunday	PM2.5	50.8	PM2.5	40.2	PM2.5	58.9	PM2.5	40.9	PM2.5	25.2	PM2.5	24.6	PM2.5	35.0

	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13		Week 14	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	PM2.5	35.1	PM2.5	27.7	PM2.5	33.0	O3	35.3	O3	23.3	O3	23.3	O3	23.8
Tuesday	PM2.5	41.8	PM2.5	21.7	PM2.5	27.3	O3	30.5	O3	21.6	PM2.5	24.5	O3	23.9
Wednesday	PM2.5	34.9	PM2.5	20.3	PM2.5	29.5	O3	31.2	O3	23.3	PM2.5	39.1	O3	25.7
Thursday	O3	21.6	PM2.5	28.6	PM2.5	31.6	O3	32.7	O3	24.6	O3	24.4	O3	30.4
Friday	O3	21.8	PM2.5	50.6	O3	37.3	O3	22.6	PM2.5	26.7	O3	19.4	-	-
Saturday	O3	27.6	PM2.5	51.9	O3	36.6	O3	24.1	O3	23.8	O3	15.9	-	-
Sunday	O3	19.1	PM2.5	39.4	O3	36.1	O3	27.1	O3	30.1	O3	23.8	-	-

Plaça de L'Hospital

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	-	-	PM2.5	33.4	PM2.5	29.9	O3	23.8	O3	26.4	O3	26.6	PM2.5	22.1
Tuesday	-	-	PM2.5	41.0	PM2.5	36.1	O3	22.4	PM2.5	20.7	O3	26.3	O3	28.4
Wednesday	-	-	PM2.5	44.7	PM2.5	41.1	O3	25.9	NO2	22.0	O3	23.3	O3	21.5
Thrusday	-	-	PM2.5	50.2	PM2.5	36.7	O3	25.3	PM2.5	22.8	NO2	20.7	O3	19.6
Friday	NO	32.8	PM2.5	39.3	PM2.5	34.1	NO2	20.9	NO2	22.3	NO2	21.7	O3	19.0
Saturday	PM2.5	33.9	PM2.5	30.1	PM2.5	40.5	PM2.5	21.8	PM2.5	24.3	NO2	22.7	O3	21.5
Sunday	PM2.5	28.3	PM2.5	25.5	PM2.5	39.2	PM2.5	24.1	O3	26.1	NO2	19.6	PM2.5	20.9

	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13		Week 14	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	PM2.5	22.1	NO2	20.7	O3	27.1	O3	37.2	O3	23.4	O3	24.4	O3	22.1
Tuesday	PM2.5	24.9	NO2	20.9	O3	25.5	O3	30.0	O3	19.0	O3	21.5	O3	21.6
Wednesday	O3	25.2	NO2	20.2	O3	25.9	O3	31.5	O3	23.3	PM2.5	25.0	O3	23.7
Thursday	O3	24.9	NO2	24.8	O3	28.7	O3	32.9	O3	22.3	O3	24.1	O3	26.5
Friday	O3	23.1	PM2.5	28.8	O3	39.4	NO2	24.0	NO2	20.9	NO2	22.3	-	-
Saturday	O3	28.3	PM2.5	28.1	O3	36.3	O3	23.3	O3	22.6	NO2	18.7	-	-
Sunday	O3	22.5	O3	26.0	O3	38.5	O3	29.7	O3	32.7	O3	23.3	-	-

Núria Terés i Bonet

	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	-	-	PM2.5	46.1	PM2.5	39.0	O3	24.2	O3	24.6	O3	23.6	PM2.5	26.2
Tuesday	-	-	PM2.5	54.6	PM2.5	45.1	O3	19.5	PM2.5	27.5	O3	23.5	O3	28.8
Wednesday	-	-	PM2.5	56.4	PM2.5	49.4	PM2.5	27.6	PM2.5	28.8	O3	23.6	O3	21.5
Thrusday	-	-	PM2.5	60.8	PM2.5	51.0	O3	22.5	PM2.5	35.1	O3	21.5	O3	19.0
Friday	PM2.5	40.3	PM2.5	52.7	PM2.5	43.5	NO2	18.4	PM2.5	30.5	O3	18.7	O3	20.9
Saturday	PM2.5	45.6	PM2.5	38.7	PM2.5	52.7	PM2.5	30.2	PM2.5	36.6	PM2.5	23.0	PM2.5	23.1
Sunday	PM2.5	40.2	PM2.5	36.4	PM2.5	50.3	PM2.5	32.4	PM2.5	24.5	PM2.5	20.2	PM2.5	28.5

	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13		Week 14	
DAY	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI	DOMINANT GAS	AQI
Monday	PM2.5	27.8	PM2.5	22.0	O3	28.4	O3	38.0	O3	21.3	O3	26.4	O3	24.4
Tuesday	PM2.5	34.4	O3	19.8	O3	24.8	O3	31.7	O3	22.2	O3	22.8	O3	24.2
Wednesday	PM2.5	30.0	O3	19.5	O3	26.7	O3	32.5	O3	26.2	PM2.5	29.9	O3	28.5
Thursday	O3	24.8	NO2	19.3	O3	29.4	O3	33.8	O3	23.3	O3	25.7	O3	33.3
Friday	O3	22.5	PM2.5	38.9	O3	38.8	O3	24.4	PM2.5	21.3	O3	19.4	-	-
Saturday	O3	28.0	PM2.5	39.5	O3	36.7	O3	24.5	O3	25.4	O3	15.6	-	-
Sunday	O3	20.4	PM2.5	30.5	O3	39.2	O3	28.6	O3	32.0	O3	26.1	-	-

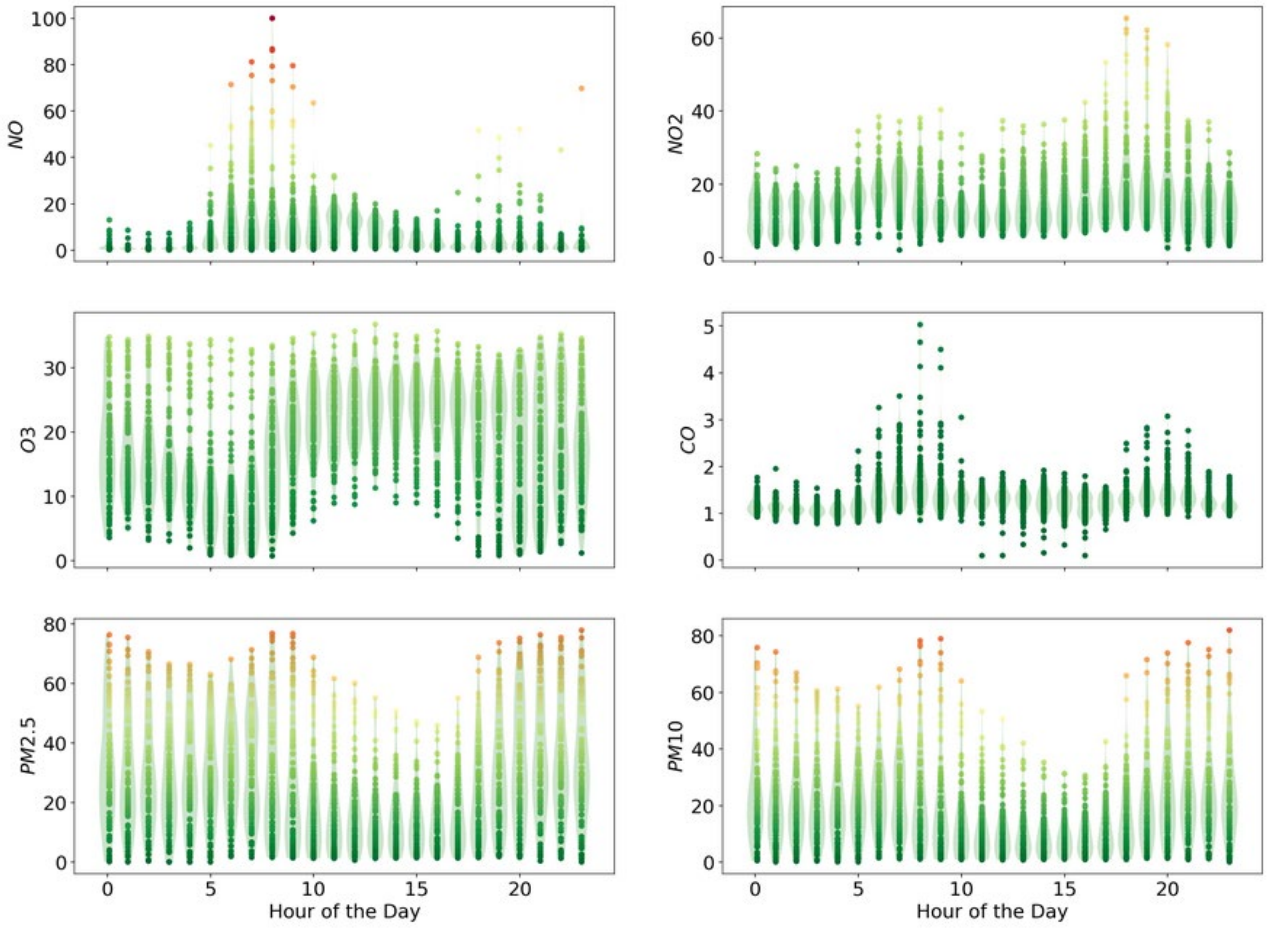
It can be observed:

- The first three weeks (in calendar days) were clearly the most polluted ones. During this time, the dominant pollutant was $PM_{2.5}$, reaching moderate levels of pollution.
- During the next two weeks the pollution levels decreased significantly, being $PM_{2.5}$ still dominant for the CAQI but alternating days of worse O_3 conditions. Also NO2 made an appearance, especially in Plaça de l'Hospital.
- From the 6th week , O_3 became the dominant pollutant, despite some alternation with $PM_{2.5}$ and NO_2, depending on the location. Although the AQI daily averages remained low, there was a clear episode of higher pollution levels between weeks 9 and 11.
- The pollution levels in Parc del Migdia were the highest, while the lowest were in Plaça de l'Hospital.

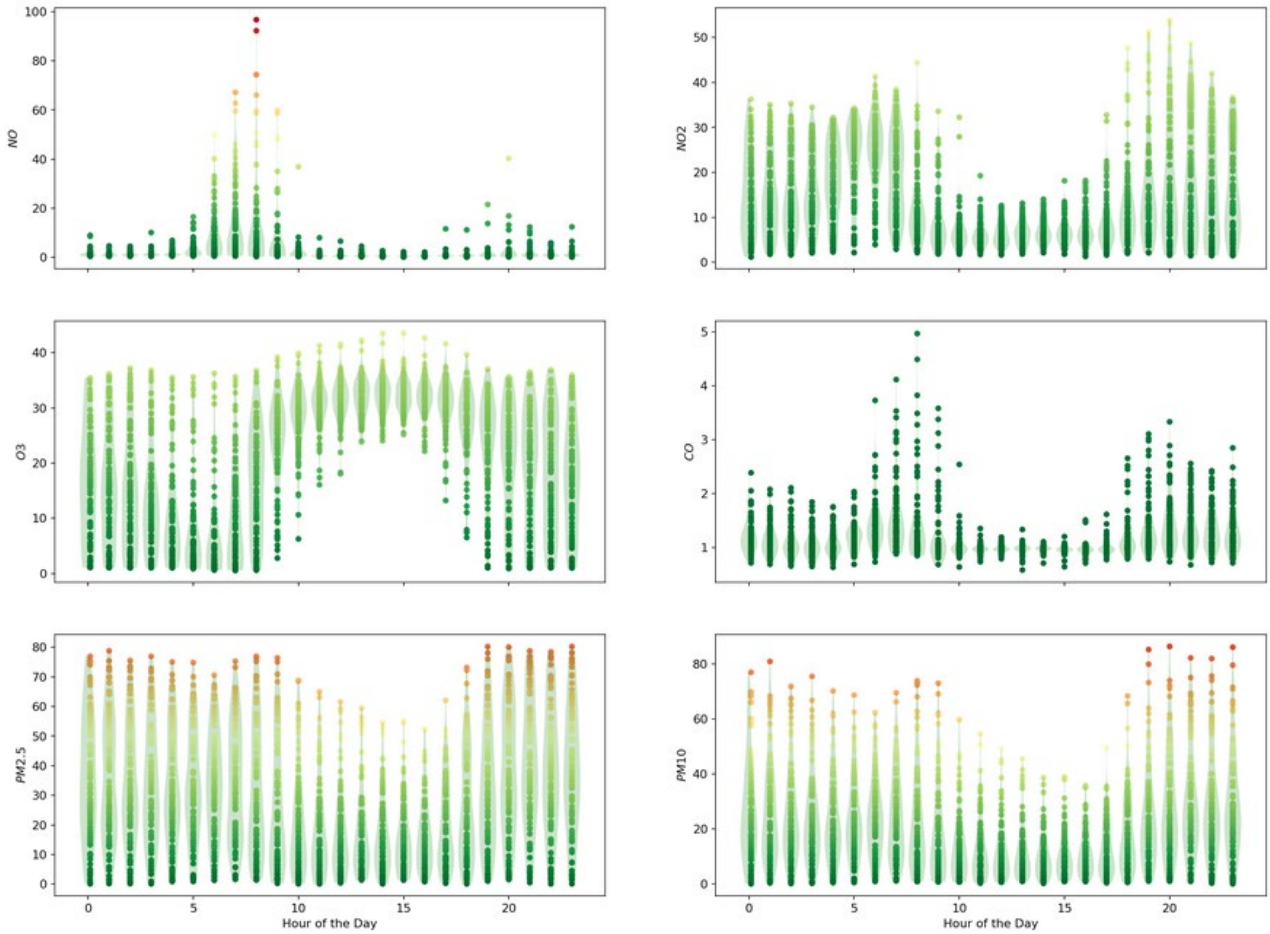
AQI hourly average per pollutant during the Day

The following plots show how the AQI per hour for each pollutant is distributed along the day. (we have excluded PM_1 since it is highly correlated to $PM_{2.5}$)

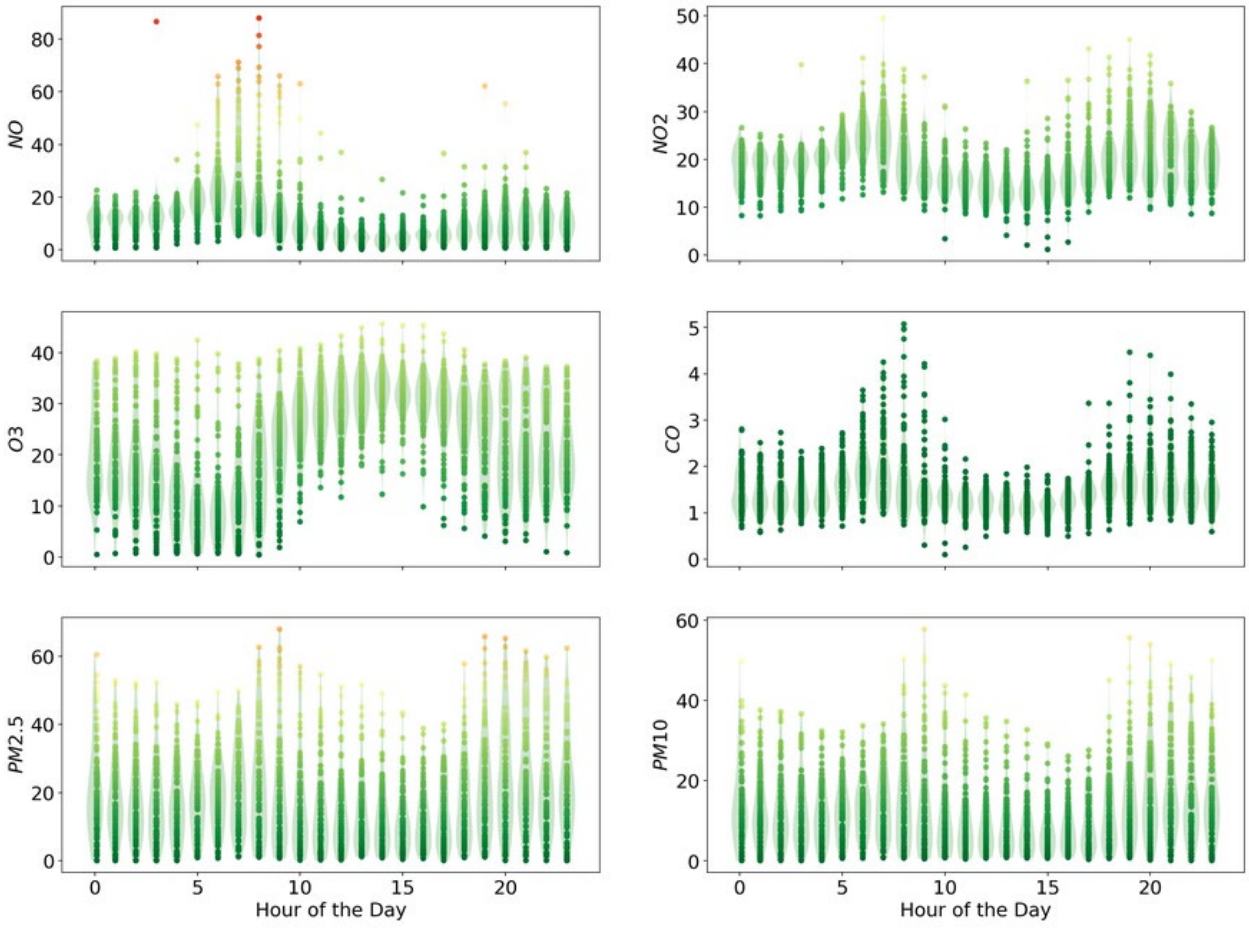
Escola de Música



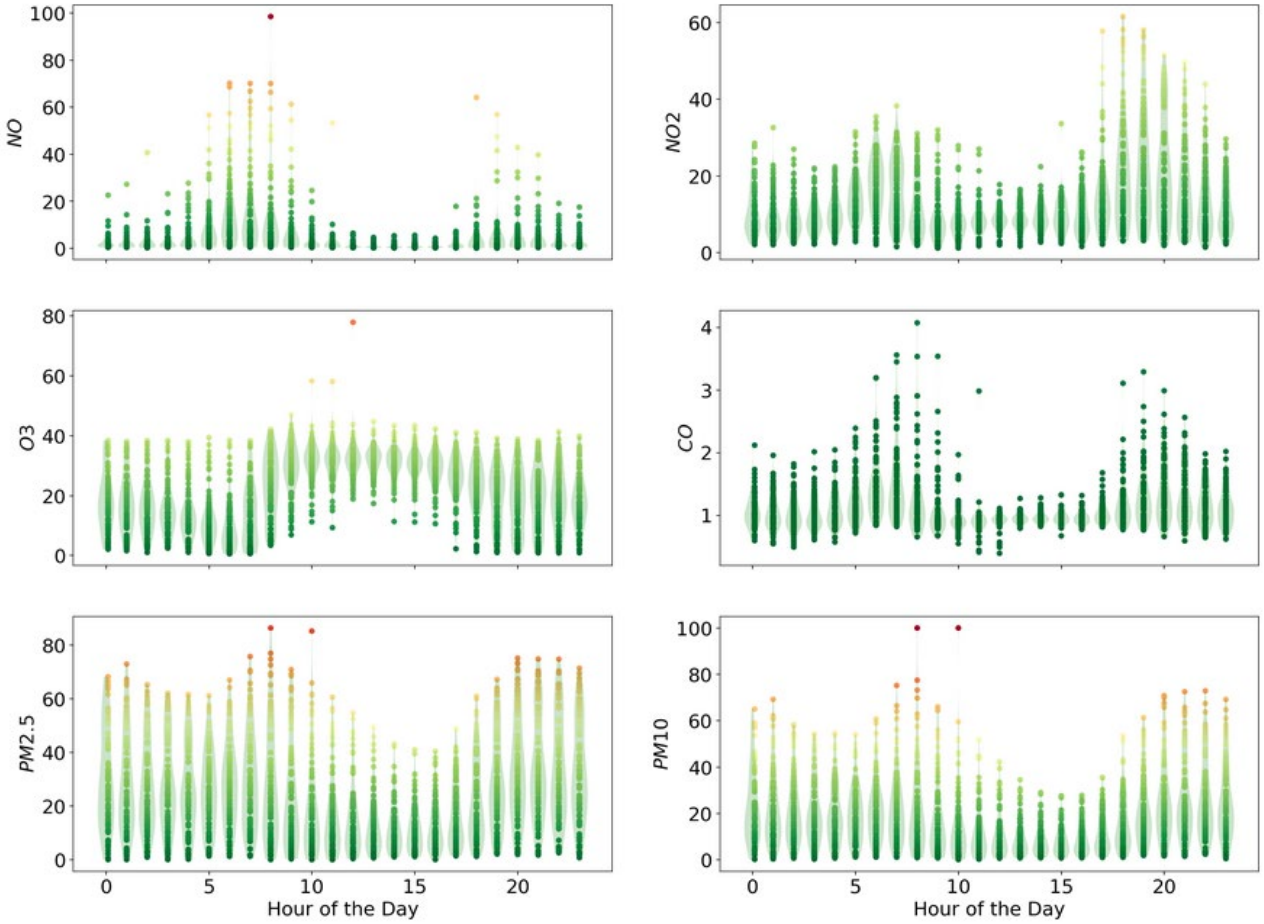
Parc del Midgia



Plaça de L'Hospital



Núria Terés i Bonet



We can observe:

- CO and NO pollution levels were higher during the mornings, with major peaks concentrating around 8 am. They also increased in the evenings.
- The same happened for NO2 and Particulate Matter, although it seems that the evenings had higher pollution levels in this case.
- This is a common behaviour of these by-products of combustion, for which daily cycles correlated to traffic intensity are quite easy to spot.
- O3 concentrations were higher during the day. This is also expected because O_3 is mainly generated as a result of chemical reactions activated by sunlight.
- PM pollution did not decrease at night as much as it did during the day between peak hours. This may be explained because winds are usually weaker at night, favouring stagnation.
- Hourly CAQI for PM reached moderate and even bad levels in multiple days and different hours. NO pollution was high during the early mornings as well.

Summary

A pollution episode can be observed during the first weeks of the pilot (from the 18th of February until the 3rd of March).

In general, the air quality of the city is good, with CAQI consistently low or very low if we analyse day averages. However, is moderate during some hours, especially the mornings, probably due to traffic.

The node installed in *Parc del Migdia* recorded the highest concentration levels, followed by *Escola de Música*. This agrees with these locations being surrounded by highly transited streets, although we could have expected a green area to be less polluted. On the other hand, the node in *Plaça de l'Hospital* recorded the lowest pollution levels. The same order is preserved if we analyse monthly averages, shown in the next table, instead of values per day.

Month	Escola de Música	Parc del Migdia	Plaça de l'Hospital	Núria Terés i Bonet
February	49.1	54.1	35.9	46.9
March	27.7	31.4	24.4	27.4
April	26.6	30.7	27.1	28.6
May	21.4	25.2	23.4	25.3

However, the fact that the CAQI is being determined by the dominant pollutant can partly mask the big picture. As we have seen, the pollution levels for PM, when dominant, were much higher than that of the rest of pollutants, If we do not take them into account and look at the individual AQI for each pollutant, we can see that *Plaça de l'Hospital* had the worst air quality. This can be seen in next table, showing the AQI averages for the whole observed time period.

	Escola de Música	Parc del Migdia	Plaça de l'Hospital	Núria Terés i Bonet
CO	1.3	1.2	1.5	1.1
NO	6.6	2.9	11.7	4.4
NO2	15.6	13.2	18.8	12.7
O3	18.0	21.4	22.2	22.1
PM1	17.0	20.0	11.6	15.4
PM2.5	25.7	29.0	18.1	24.0
PM10	18.8	20.2	12.3	17.5

Conclusions

It can be clearly observed that a deployment like the one provided by bettair® provides detailed information of the air quality of the city even with a deployment of only 4 nodes. Comparing this data with the only station that the city had, the advantages of bettair® are clear. Much more detailed information.

It is worth to mention that the bettair® nodes provide high accuracy due to a proprietary methodology that allows to increase the accuracy of the electrochemical sensors to over 90% when compared to traditional equipment.

ANNEX - Pollutans and Sources

$PM_{2.5}$ - Fine particulate matter (<2.5µm) - Dominant

Sources

Main sources are combustion processes (e.g. power plants, indoor heating, car exhausts, wildfires), mechanical processes (e.g. construction, mineral dust) and biological particles (e.g. bacteria, viruses).

Effects

Fine particles can penetrate into the lungs and bloodstream. Short term exposure can cause irritation of the airways, coughing and aggravation of heart and lung diseases, expressed as difficulty breathing, heart attacks and even premature death.

PM_{10} - Inhalable particulate matter (<10µm)

Sources

Main sources are combustion processes (e.g. indoor heating, wildfires), mechanical processes (e.g. construction, mineral dust, agriculture) and biological particles (e.g. pollen, bacteria, mold).

Effects

Inhalable particles can penetrate into the lungs. Short term exposure can cause irritation of the airways, coughing, and aggravation of heart and lung diseases, expressed as difficulty breathing, heart attacks and even premature death.

CO - Carbon Monoxide

Sources

Typically originates from incomplete combustion of carbon fuels, such as that which occurs in car engines and power plants.

Effects

When inhaled, carbon monoxide can prevent the blood from carrying oxygen. Exposure may cause dizziness, nausea and headaches. Exposure to extreme concentrations can lead to loss of consciousness.

NO - Nitrogen Monoxide

Sources

Main sources are fuel burning processes, such as those used in industry and transportation.

Effects

Exposure may cause increased bronchial reactivity in patients with asthma, lung function decline in patients with COPD, and increased risk of respiratory infections, especially in young children.

NO_2 - Nitrogen dioxide

Sources

Main sources are fuel burning processes, such as those used in industry and transportation.

Effects

Exposure may cause increased bronchial reactivity in patients with asthma, lung function decline in patients with COPD, and increased risk of respiratory infections, especially in young children.

O_3 - Ozone

Sources

Ozone is created in a chemical reaction between atmospheric oxygen, nitrogen oxides, carbon monoxide and organic compounds, in the presence of sunlight.

Effects

Ozone can irritate the airways and cause coughing, a burning sensation, wheezing and shortness of breath. Additionally, ozone is one of the major components of photochemical smog.

ANNEX II - Air Quality Index

The Air Quality Index measures the severity of air pollution and the health implications as shown in the table above. Anything over 100 is considered to be hazardous and likely to cause serious health issues.

Air quality in European cities is presented in an easily understandable way by converting all detailed measurements for a city into a single relative figure: The Common Air Quality Index (or CAQI)[2]. To enable the comparison between cities three indices are available with a different time scale:

- An hourly index: which describes the air quality today, based on hourly measurements and updated every hour,
- A daily index: which stands for the general air quality situation of yesterday, based on daily values and updated once a day,
- An annual index: which represents the city's general air quality conditions throughout the year. This index is based on the pollutants year average concentrations compared to annual limit values. It is updated once a year.

The Hourly and daily indices

These indices have five levels using a scale from '0' (very low) to '> 100' (very high). It presents a relative measure of the amount of air pollution. The calculation is based on three pollutants of major concern: PM_{10}, NO_2, O_3. It can also take the pollutants $PM_{2.5}$, CO and SO_2 into account if these data are also available.

In order to make cities more comparable, independent of the nature of their monitoring network two situations

are defined:

- City Background, representing the general air quality in an agglomeration (based on urban background monitoring sites),
- Roadside, representing the air quality in streets (based on roadside monitoring stations)

[2] For more information about CAQI please refer to: http://airqualitynow.eu/download/CITEAIR-Comparing_Urban_Air_Quality_across_Borders.pdf

CAQI Scale and Health Implications

CAQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 – 25	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
50 -75	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
75-100	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
100	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
100-150	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
150+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion