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AirLabs Case Study

Reducing air pollution exposure inside Marylebone Station

Air pollution in London

Air pollution in London contributes to over 9,000 premature deaths each year, equally divided between exposure to particulate matter (PM) and nitrogen dioxide (NO_2)*. In addition air pollution has been linked to diabetes, asthma, allergy, learning disabilities, lost productivity and many other negative outcomes. $PM_{2.5}$ levels are commonly above the EU exposure limit in London, while NO_2 levels are worse than other developed cities like New York and Madrid, and nearly as bad as concentrations found in Beijing and Delhi. Research has shown that pollution concentrations vary considerably from one location to another, and that there are particular exposure hot spots, for example a vehicle in traffic, a busy road, or a building with poor indoor air quality.

The EU annual mean limit value for $PM_{2.5}$ is 25 µg/m^3, while for NO_2 it is 40 µg/m^3**; the World Health Organization sets an even more stringent guideline value for annual mean $PM_{2.5}$ of 10 µg/m^3***.

Airlabs and Marylebone collaboration

AirLabs was approached by the sustainability team of BNP Paribas in July 2017 after they saw the AirLabs Body Shop clean air bus shelter project. BNP Paribas wanted to create clean air zones that would have a positive impact on their local community. With their office located immediately next door to Marylebone Station, AirLabs proposed the installation of several clean air zones inside the station that could impact thousands of people every day - including BNP Paribas employees and clients.

Air quality at Marylebone Station

Marylebone Station in London is an air pollution hot spot because large numbers of people visit the station every day. In addition to being subjected to the already high ambient pollution levels in London, the station is near the highly polluted Marylebone Road. Further, several platforms hosting diesel trains are located within the common station building.

AirLabs deployed three AirNode air quality monitoring systems in Marylebone Station during October 2018. The results are shown in Figure 1.

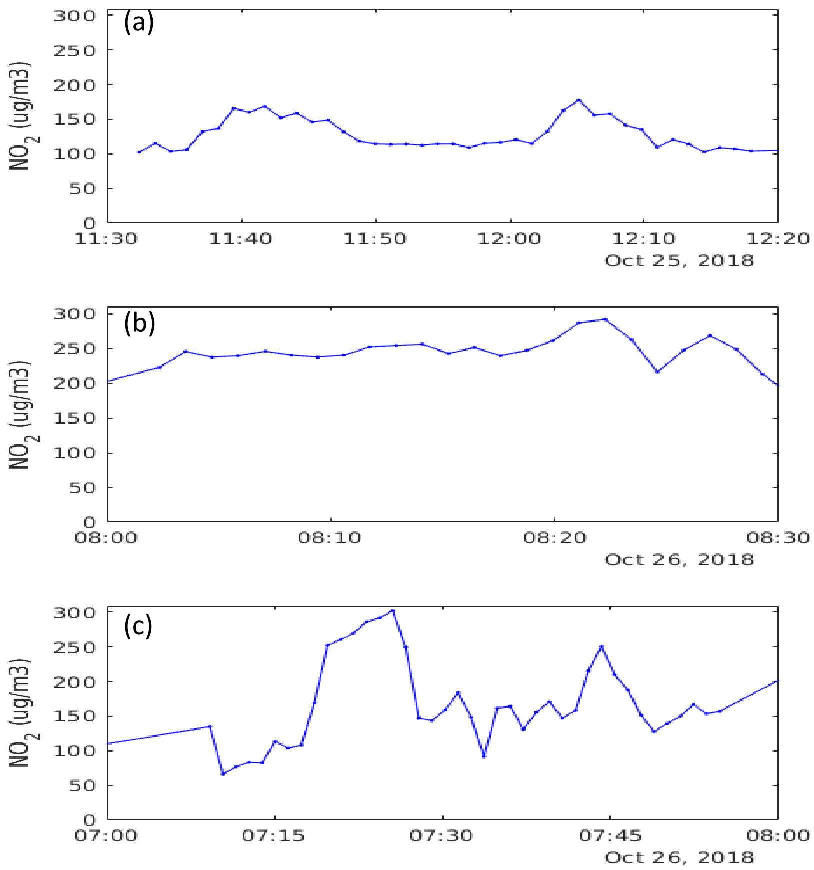


Figure 1. NO_2 concentrations in Marylebone Station: (a) In the main station during off-peak hours; (b) In the main station during morning peak hours; (c) On the train platform during morning peak hours.

Key findings:

- NO_2 levels between 100 and 170 µg/m^3 were observed within the main station during off- peak hours
- Higher levels of NO_2 were seen during peak hours (more than 200 µg/m^3)
- Transient plumes with extremely high NO_2 levels -exceeding 300 µg/m^3 - associated with individual engines were measured at the train platforms
- $PM_{2.5}$ concentrations of up to 55 µg/m^3 were observed in the main station
- Higher levels of $PM_{2.5}$ were measured deep into the station (near Starbucks) than were seen at the train platforms
- Growth and coagulation of ultra-fine nano particles that are not detected by the AirNode could explain the observed distribution

Designing the solution

On surveying the station, several hollow cylindrical advertising casings, operated by JCDecaux, were identified throughout the concourse as potential locations to install air cleaning technology. Although the space available within these advertising casings imposed a significant constraint on the total amount of air that could be processed each hour, it was determined that the technology designed by AirLabs could still provide efficient localised cleaning in highly occupied areas within the station.

Engaging Chiltern Railways, who operate the station and who were working on initiatives of their own to reduce air pollution for customers and employees, was an important part of the initiative. The result was a highly collaborative project, incorporating AirLabs technology into a high profile, high footfall, location.

Design details: AirLabs AirBeam and airflow simulations

In an effort to reduce air pollution exposure at Marylebone Station, AirLabs designed the AirBeam, a compact, high airflow dual-filter air cleaning unit designed to be installed within the JCDecaux cylindrical advertising casings at the station.

The four cylindrical advertising casings selected for installation of the AirBeam units were determined as having the greatest impact on commuters in the station. Inside each of these four casings, three AirBeams were installed. Each AirBeam containing two high-performance filters: an electrostatic precipitator (ESP) filter, which removes particulate matter, and the AirLabs Nano Filter, which removes gaseous pollutants such as nitrogen dioxide and ozone. A duct extractor fan in each AirBeam ensures optimal airflow due to the constraints on unit size imposed by the advertising casings, so that substantial volumes of air can be processed continuously. The three AirBeams within each cylinder are connected to a single custom-designed air outlet that delivers and focuses the clean air in a specific direction. Based on AirLabs' expertise in airflow engineering, coupled with an analysis of people movement within the station, the outlet was designed to have the maximum impact on air quality in the zones of the station where population density and residence time are greatest. Each cylindrical advertising casing delivers over 2000 m^3/hour.

Figure 2 shows the design detail of the AirBeam, along with an AirBeam unit installed inside one of the cylindrical advertising casings.

Figure 2. Detail of the Airlabs AirBeam cleaning unit (left); the AirBeam installed within a Cylindrical billboard in Marylebone Station (right).

To determine the anticipated impact of the AirBeam cleaning system on the pollution in Marylebone Station prior to installation, and to help define the design requirements, it was necessary to understand how air moves within the station. To do this, AirLabs used computational fluid dynamics (CFD), an advanced computer modelling technique that simulates the complex patterns of airflow and pollutant movement throughout the station, taking into account the sources of polluted air on a typical day.

To perform the CFD simulations, a computer-aided design (CAD) model geometry of the station was required; the model we created for this purpose is shown in Figure 3. This CAD model provides a simplified representation of the station that incorporates the important structural details of the station, including the locations of the cylindrical advertising casings, and allowed us to use CFD to generate a detailed picture of airflow within the station.

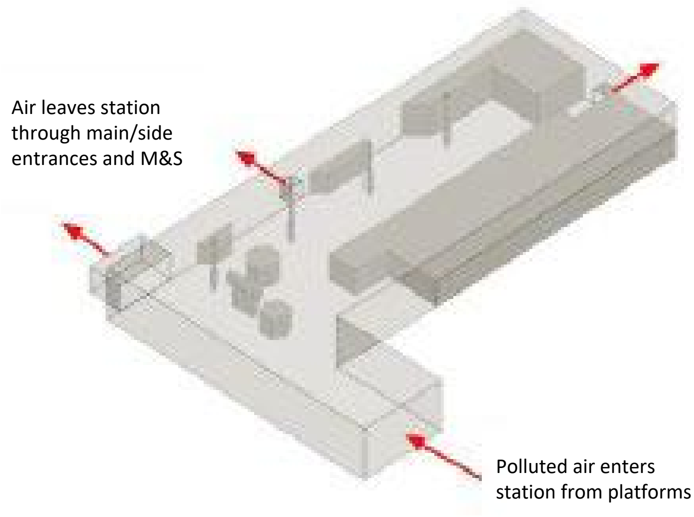


Figure 3. The CAD model of Marylebone Station, showing the locations of the four cylindrical advertising casings with AirBeams installed. The polluted air enters the station from the platforms and exits through several openings.

Prior to performing the CFD simulations, detailed measurements of airflow were taken at multiple locations in the station to provide critical information to the CFD model. These measurements supply initial and boundary conditions for the model to ensure that the simulations provide accurate representations of the airflow throughout the entire station.

Polluted air, with NO_2 levels of 200 $\mu g/m^3$ typical of the levels seen in the station during peak hours, enters the station from the train platforms. Air typically leaves the station through the main entrance way, but also through the M&S shop door and the side entrance to the station.

Results from the CFD simulations are shown in Figure 4. Polluted air (NO_2 of 200 µg/m^3) is depicted in red, while air with NO_2 concentrations of 100 µg/m^3 (50% removal) and 150 µg/m^3 (25% removal) are depicted in green and yellow, respectively.

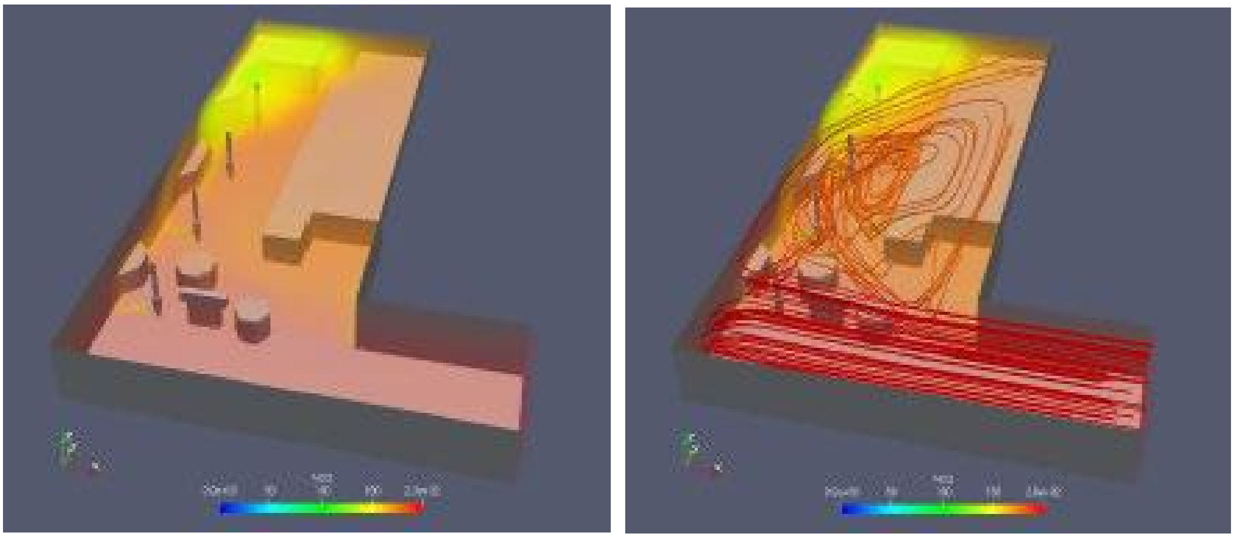


Figure 4. CFD simulations of airflow and NO_2 levels in Marylebone Station: NO_2 concentration (left); airflow streamlines and NO2 concentration (right).

Clean air is delivered from the AirBeams, which have an overall NO_2 removal efficiency of 83%, and is blown towards the seating areas adjacent to the wall. Within a few metres of each individual AirBeam cylinder, the NO_2 levels are around 100 µg/m^3 (50% removal). The airflow, however, transports the cleaned air in a broad circulation around the main hall area, and a region of cleaner air accumulates in the zone of relatively low airflow at one end of the station by the Starbucks outlet. In this zone, the NO_2 levels are in the 100-150 µg/m^3 range (i.e., 25- 50% removal).

Measuring pollution in the clean air zones: results

The efficiency and area of effect of the AirBeam air cleaning system was assessed in field measurements using the AirLabs AirNode air quality sensor. A total of three AirNodes were deployed. Each AirNode features an array of sensors to monitor $PM_{2.5}$, PM_{10}, ozone, NO_2, and other physical/chemical parameters; however, the specific focus of the measurements was $PM_{2.5}$ and NO_2.

Measurements were performed on 30 October 2018, on which the AirBeam flow was reduced due to the outlet grill configuration, and on 2 November 2018, when all AirBeams were running at full flow capacity. The AirNodes were located as follows:

- AirNode#1 was kept in untreated background
- AirNode#2 was kept at the AirBeam outlet
- AirNode#3 was placed at various locations downwind of the AirBeam

Measurements taken on 2 November 2018 are shown in Figure 5. The key results from the field measurements are:

- $PM_{2.5}$ levels in the untreated area varied between 20 and 55 µg/m^3
- NO_2 levels in the untreated area varied between 60 and 145 ppb (113 and 273 µg/m^3)
- NO_2 and $PM_{2.5}$ levels were reduced by 75% and 70%, respectively, at the AirBeam outlet compared to the untreated ambient.
- At a distance of almost 2m from the AirBeam the levels of NO_2 were still approximately 35% lower than the untreated ambient.

Note: The AirNodes were pre-calibrated and the calibration was validated by lab calibration in AirLabs' Copenhagen laboratory.

It should also be noted that the reference 'untreated' air measurements were performed in an area where the AirBeams may actually have slightly decreased the air pollution. As a result, the measured pollution reduction is likely to underestimate the true performance of the system. Nevertheless, the measurements revealed a decrease in pollution levels that is entirely consistent with the CFD simulations of airflow in the station based on pollution removal by the AirBeam system.

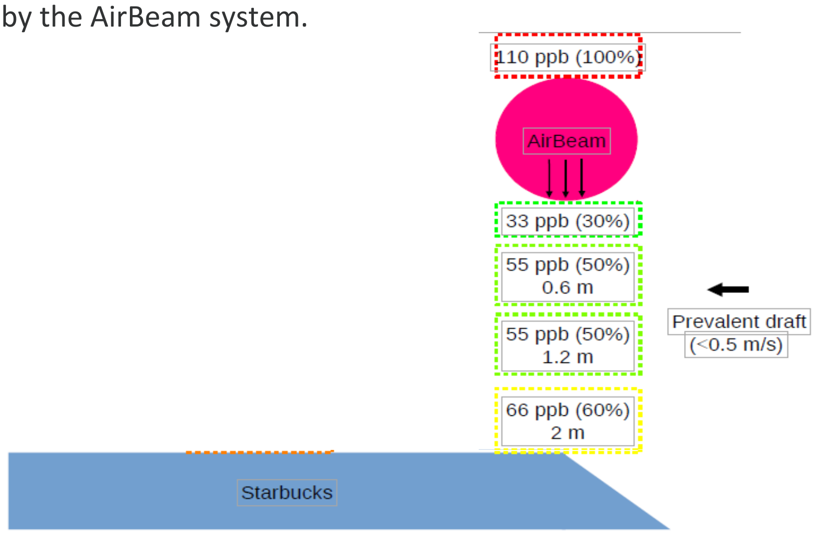
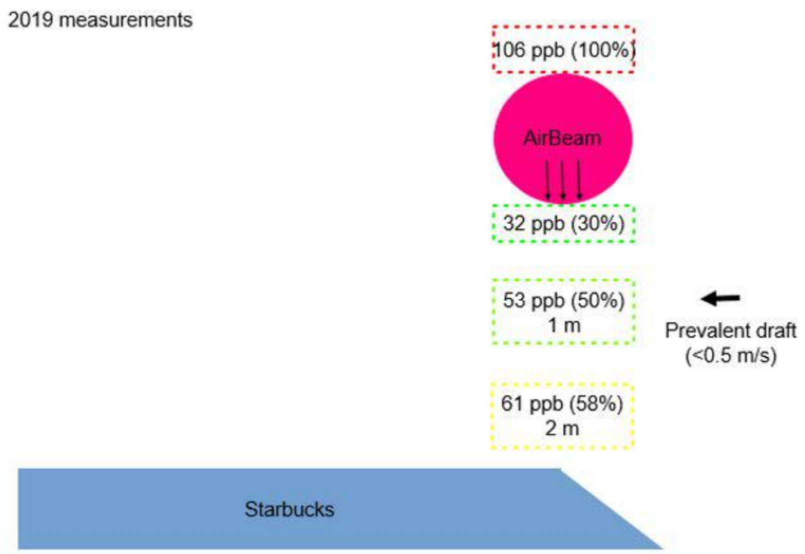


Figure 5. AirNode measurements of NO_2 on 2 November 2018.

2019 data validation

A year after the launch, repeat measurements were conducted by AirLabs to see how the system was performing. A repeat testing procedure was completed between 28th and 31st October 2019, the results of which are shown in Figure 6.

Results were highly positive, with removal rates of 85% for $PM_{2.5}$ and 70% for NO_2, thus proving the reliability and continued performance of the AirBeam system.



About AirLabs

Airlabs is a leading pioneer in clean air technology. With more than 90% of the world's population exposed to unsafe levels of air pollution, Airlabs' mission is to deliver measuring, monitoring and cleaning solutions that provide valuable insight, enable action and clean polluted air to make it safe for people to breathe.

Its international team of atmospheric chemistry scientists, airflow engineers and sensor specialists has developed cutting edge and scientifically proven solutions for use by government, business and individuals to tackle the growing problem of urban air pollution.

Airlabs is headquartered in London, has its R&D labs in Copenhagen and also operates from offices in Santa Monica, Boca Raton and Singapore..

References

*King's College London, 'Understanding the Health Impacts of Air Pollution in London', H. Walton, D.Dajnak, S. Beevers, M. Williams, P. Watkiss and A. Hunt, 2015.

**EU Air Quality Directive, 2008/50/EC.

**World Health Organization, 'WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide - Global update 2005 - Summary of risk assessment', WHO/SDE/PHE/OEH/06.02, 2005.