May 2021

Pilot project to better understand air quality at Parisian schools

2019-2020

AIRPARIF

L'Observatoire de l'air en Île-de-France

PILOT PROJECT TO BETTER UNDERSTAND AIR QUALITY AT PARISIAN SCHOOLS 2019-2020

May 2021

This initiative is funded by Bloomberg Philanthropies in partnership with the City of Paris.

Executive Summary

In July 2019, Bloomberg Philanthropies[1] and the City of Paris launched a pilot program to monitor air quality around the city's schools using innovative measurement tools. This project was carried out in partnership with Airparif, an independent association accredited by the French government to monitor air quality and keep policymakers and the general public informed of its status in the Ile-de-France region. The project also engaged expert technical teams from the City of Paris, such as the Parisian Service for Environmental Health and the Urban Ecology Agency. The California-based technology company Clarity, which specializes in a new generation of air quality sensors, supplied the monitoring devices.

This strategic partnership aimed to:

- Conduct a year-long, large-scale pilot project to evaluate the performance of sensors and other monitoring technologies in real-world conditions in a major European city, combining different monitoring technologies including: 138 micro-sensors, 11 weeks of measurement campaigns with diffusion tubes and a network of 16 automatic reference stations.
- Collect hyperlocal air quality data at 44 locations including nurseries, primary schools and middle schools, as well as the surrounding streets and classrooms.
- Gather important information and insights on the performance of monitoring technologies in real-world conditions to better inform the companies developing micro-sensors.
- Provide key data and information for policymakers, decision-makers and the city's technical experts.
- Supplement Airparif's existing information, data and tools measuring the city's air quality.
- Encourage information exchange and collaboration among various local and international stakeholders: Bloomberg Philanthropies (which supports innovation projects to tackle air pollution in Europe and around the world), various City of Paris services (environmental department, health, schools and nurseries, general secretariat), associations (including Respire and parents' associations), the technology company Clarity and air quality experts (Airparif in Paris and its London counterpart, the Environmental Research Group (formerly at King's College London, now at Imperial College London)).
- Build on the learnings of previous Urban Lab/Airlab experiments and micro-sensor competitions led by Airparif - and highlight improvements of low-cost sensor technologies.

The pilot study took place over the course of one year, from September 2019 to September 2020. During this time, partners jointly carried out the pilot project in the following steps:

- **Two Initial Test Phases:** Using a co-location at reference stations, two initial test phases effectively ruled out defective devices (approximately 10% per batch, which corresponds to feedback from Airparif and its partners in other experiments using micro-sensors). This testing phase prior to field deployment is crucial for any project using micro-sensors to ensure data quality control and assurance.

---

[1] *Bloomberg Philanthropies invests in 810 cities and 170 countries around the world to ensure better, longer lives for the greatest number of people. The organization focuses on five key areas for creating lasting change: the Arts, Education, Environment, Government Innovation, and Public Health. Bloomberg Philanthropies encompasses all of Michael R. Bloomberg's giving, including his foundation, corporate, and personal philanthropy as well as Bloomberg Associates, a pro bono consultancy that works in cities around the world. In 2020, Bloomberg Philanthropies distributed $1.6 billion. Michael R. Bloomberg was recently appointed United Nations Secretary-General's Special Envoy for Climate Ambition and Solutions. He is also a World Health Organization (WHO) Global Ambassador for Non communicable Diseases and Injuries.*

- **Micro-Sensor Sampling:** A total of 138 low-cost sensors supplied by Clarity were deployed in Paris, including 45 in schools. The sampling plan was carried out to cover the schools most exposed to air pollution, as well as sites located in different locations in relation to the pollution sources. This ensured a representative sample of the different types of air pollution exposure in Parisian schools and nurseries. The rest of the sensors were installed in the streets adjacent to the schools to assess variability in pollution concentrations measured in streets and schoolyards. Measurements were also taken at other points of interest, such as major intersections with potentially high concentrations in pollutants and next to Airparif's reference stations to verify measurements throughout the experiment.
- **Diffusion Tube Measurement:** Alongside the deployment of micro-sensors, NO_2 measurement campaigns were carried out using diffusion tubes. These measurements took place over 11 weeks during four time periods (October-November 2019, March 2020, June-July 2020 and September 2020) in 40 schools and 16 surrounding streets following the same sampling plan used for the micro-sensors. The objective was to assess the in-situ performance of the micro-sensors, provide reference information from the schoolyard to the street and measure the difference in exposure between these two environments.
- **Evaluation Period:** Seven months of data on the performance and capabilities of the micro-sensors for tracking fine particles in a background situation was compared with the results of the Airparif model maps, Hor'air, and also broadcast in *Paris.fr*. The objective was to assess the capability of the micro-sensors for supplementing or strengthening this device.

Project findings: Pollution levels in schoolyards and neighboring streets

For nitrogen dioxide (NO_2), the results obtained from the diffusion tubes for NO_2 show **that the levels measured in schoolyards are systematically lower than those measured in the streets. This reinforces the impact made by varying distances from schoolyards to streets, as well as the shield effect of buildings and walls. The only exception was seen at the Etienne Marcel School where there is no separation wall, and pollution levels are the same in the street and the schoolyard.**

- The tubes made it possible to estimate average exposure levels over the year and to compare them with existing regulations and limit values. Taking into account the uncertainty of reconstituting the annual averages, the estimated annual average NO_2 concentrations **in the 40 schoolyards (between 18 and 36 µg/m^3) are in accordance with the averages recorded on Airparif's reference network and almost all of them comply with the annual limit value (40 µg/m^3). For one of the schools, the CC Ville Pyrénées nursery, it is not possible to confirm that it complies with the limit value over the year due to its proximity to particularly busy traffic lanes and a lack of buildings shielding to pollution. However, this exceedance is estimated as "unlikely" with an annual average concentration.** At the adjacent streets, the measured concentrations are between 21 and 51 µg/m^3, which is consistent with the traffic stations of the Airparif network. However, it should be noted that some of the measurements took place in 2020, a year marked by the Covid-19 pandemic, which induced a reduction of human activities, and therefore pollutant emissions, during the lockdown and afterwards. The annual estimations may therefore have been slightly underestimated.

➔ Possible mitigation measures to limit the air pollution exposure in schools include:

- Adequate distance between traffic and other air pollution sources and schools.
- Shield effect of walls and buildings.

The results obtained in $PM_{2.5}$ from micro-sensors in schools show that the **concentrations in the schoolyards are similar to those measured by the background station of the Airparif network located in the Jardin des Halles - Paris 1er. This revealed that there is no particular influence of surrounding traffic on air pollution exposure in schools.** General pollution of the Paris area is the main cause of air pollution exposure in schools. As a result, these measurements largely comply with the European annual limit value as well as the European target value, set respectively at 25 and 20 µg/m³. However, the WHO's recommended limit of 10 µg/m³ is approached or even exceeded by a large number of schools, which is also the case in the whole Paris area. The lower concentrations measured in 2020 are partly due to the effects of the Covid-19 restrictions and reduced human activities.

➔ Measures with positive impact on air quality include:

- Permanent measures to limit traffic pollution, such as Parisian and metropolitan Low Emission Zones (LEZ), whose benefits for vulnerable groups including school children, have been highlighted by Airparif in previous studies[2].
- The renewal of motor vehicle fleets and phase-out of diesel cars accelerated by the establishment of the LEZ.
- Reduction of road traffic by encouraging active mobility (namely walking, cycling and public transport).

The data collected during this project didn't allow **a comparison to be drawn between the concentrations of NO_2 and $PM_{2.5}$ or establish a ranking of schools on their overall pollution exposure of the two pollutants**. The data collected shows that the concentrations of $PM_{2.5}$ are very homogeneous, due the multitude of pollution sources in the Paris area. In addition, micro-sensors also present more homogeneous results due to greater measurement uncertainties, given their limitations in measuring Ultra-Fine Particles.

Lessons learned

One of the objectives of the project was to collect localized data to complement Airparif's reference monitoring network and help identify areas where mapping can be refined. Depending on the reliability of this type of measurement, the sensor information could be integrated into data assimilation mapping to improve the representation of pollution levels in areas that are more difficult to assess with high precision, such as complex intersections.

Regarding the micro-sensors performance, only the results for fine particles in a background situation could be used for this study. Over the November 1, 2019 - September 30, 2020 period, the results showed some inconsistencies on NO_2 pollution concentrations which have made it impossible to use the data for this analysis. With regards to $PM_{2.5}$, Clarity developed a correction algorithm based on measurements from reference stations of the Airparif network. This algorithm greatly improved micro-sensor measurements compared to raw data. However, this algorithm was only effective for sites in a background situation (e.g., those located in schoolyards).

---

2 *Study on the Low Emission Zones in the Métropole du Grand Paris : https://www.airparif.asso.fr/bilan/2021/zone-faibles-emissions-mobilite-zfe-m-dans-la-metropole-du-grand-paris*

These learnings from the project are encouraging. They confirm the need for any micro-sensor network to be deployed alongside a reference network to validate the collected data and develop the right calibration to measure the concentrations from raw data.

The experiment confirms that the raw data collected by micro-sensors can present uncertainties, both on the accuracy and on the ability to capture the temporal variability of ground-level concentrations. The raw results require post-processing and calibration. The implementation of such a device requires the installation of sensors at the reference stations throughout the experimentation phase to develop these corrections.

The pilot project highlighted the need for any deployment of micro-sensor networks in ambient air to rely on a reference network during the various phases of implementation to ensure: the detection of defective devices before the deployment, the calibration of the devices (in particular to offset a drift over time, which was already perceptible in this one-year experiment) and post-processing of the raw data with an algorithm more suited to the location. It is therefore recommended to use a micro-sensor network alongside reference station data to adequately calibrate the sensors, monitor pollution and inform the public.

During this project, the data collected by the micro-sensors did not make it possible to improve the high-resolution mapping tools already used and developed by Airparif.

Although low-cost sensor technology is promising and abundant on the market, it still needs to mature to provide reliable measurements more aligned with the measurements of reference devices and provide accurate information in terms of variation in pollution levels and order of magnitude. Nevertheless, through the Urban Lab/Airlab experiments and the various Airlab micro-sensor challenges, an improvement of these technologies and their quality has been observed. This is also the case for the Clarity sensors during this project with the development and application of their smart calibration and the effective use of solar-powered panels. Since the 2018-2019 Urban Lab/Airlab experiment, the project has shown a significant improvement when it comes to the cost and installation time of these sensors, which eliminates the need for power supply connections, but still requires sufficient sun exposure and well-charged batteries at the time of installation.

For NO_2, a relevant correction will have to be applied to the micro-sensors to get closer to the reference values. For $PM_{2.5}$, micro-sensors are limited in their ability to measure concentrations in proximity to traffic. The sensors are not capable of measuring ultra-fine particles, especially those from road traffic. Clarity has since developed a promising fix for traffic sites after the project was completed, but this is not reflected in this study and is therefore too late to be evaluated by Airparif.

Cost and benefit assessment of different monitoring technologies

Compared to conventional methods, micro-sensors use a technology that is still in development and cannot replace a reference measurement network with automatic reference devices and an efficient mapping system. Micro-sensors must work in tandem with reference networks, and sharp expertise in air pollution and knowledge of the local situation is required to analyze and interpret the data. However, when they provide reliable measurements, micro-sensors can be used to supplement a monitoring network to provide new information and insights on air quality, particularly near traffic and locations that are difficult to model such as traffic intersections, or to multiply measurement points during measurement campaigns, in the same way as equipment such as diffusion tubes for gases.

In terms of costs, even though the micro-sensors are less expensive to buy than the reference analyzers, their lifespan is short (1 year to 18 months) and they have additional costs linked to data calibration and acquisition. In addition, they remain more expensive and less reliable than diffusion tubes for nitrogen dioxide, which also require less expertise and can be used to make an initial state, calibrate models, develop maps and assess impacts with measurement campaigns and actually complete a network of reference stations, as is the case for Airparif. However, these devices only provide daily information, and most often weekly, and unfortunately do not exist for particles - but micro-sensors can provide a solution.

The environmental impact of micro-sensor networks must also be considered, particularly the large volume of additional data they produce and the obsolescence of their cells after 12-to-18 months. The life cycle of a micro-sensor is currently not evaluated; it is a point that should be specified by suppliers.

These devices are not necessarily low-cost and "low-expertise", especially when used outdoors. However, it is important to highlight that micro-sensors perform differently depending on their use[3] , pollutants measured and the environment in which they are placed. They remain great educational and monitoring tools that can be used to raise awareness about air quality and inform policymakers. This full-scale experimentation with a series of monitoring devices (measuring stations, high-resolution modeling, diffusion tubes, supplemented by a network of micro-sensors) carried out in partnership with Bloomberg Philanthropies, the City of Paris, Airparif and Clarity builds important learnings for other global cities looking to deploy low-cost monitoring campaigns and further inform policies to advance clean air and tackle pollution.

[3] *Results of the 2019 micro-sensors challenge: https://www.airparif.asso.fr/actualite/2020/resultats-du-challenge-microcapteurs-2019*