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2023 Edition

Microsensors Challenge 2023

November 2023

Summary

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The 2023 AIRLAB Microsensors Challenge

Airparif and AIRLAB unveiled the winners of the 2023 AIRLAB Microsensors Challenge on November 23rd, 2023, during an international event held simultaneously in Bangkok and in Paris. For the first time, the tests have been conducted both in France and in Thailand, in order to better understand the impact of meteorological conditions, and different levels and sources of pollution, on the performance of microsensors. The Challenge results show that microsensors perform differently depending on weather conditions, as well as pollution levels, particularly for particulate pollution.

The evaluation campaign took place over a period of three and a half months, from March to June 2023. While overall participation by microsensors manufacturers was maintained at a similar level as for the previous edition, this in itself was a break of the trend of a significantly growing number of evaluated sensors with each edition. In late 2022 and early 2023, the microsensor market was still being affected by the global supply chain crisis. This had an impact on the Challenge as many participants asked for delivery extensions, and multiple candidates withdrew or could not deliver for at least one evaluation environment. The second most frequent reason of the stagnation in participation was a misalignment between the Challenge calendar and the participant's next product release cycle – products being ready for evaluation in this edition becoming obsolete by the time of the results publication because of a new generation of products being released at the end of 2023. As the latter reason was never an issue in previous editions this could also be an indication of an increase in the R&D cycle length of manufacturers since the last edition (due in part to the COVID-19 pandemic and again to supply chain strains).

For this fourth edition, Airparif and its partners studied the impact of new parameters on the performance of microsensors, and more specifically: higher pollution levels; different emission profiles; different weather conditions, including higher temperatures and humidity.
Outdoor air tests in France were carried out by Atmo Hauts-de-France in Tourcoing, and in Thailand by the National Institute of Metrology Thailand (NIMT) and the Asian Institute of Technology (AIT), on the roof of the Alliance Française building, in Bangkok. Airparif supervised all of the performance tests and evaluations.

The 2023 edition of the AIRLAB Microsensors Challenge was organised with the support of the Clean Air Fund, the Agence Française de Développement (AFD), the French Ecological Transition Agency (ADEME), Bloomberg Philanthropies, the French Embassy in Thailand and the Alliance Française of Bangkok. It was carried out with the technical collaboration of the Asian Institute of Technology, Atmo Hauts-de-France, the Bangkok Metropolitan Administration, the Scientific and Technical Center for Building (CSTB) / Indoor Air Quality Observatory (OQAI), the Swiss Federal Laboratories for Material Science and Technology (EMPA), the Interprofessional Federation of Atmospheric Environment (FIMEA), the National Institute of Metrology Thailand (NIMT) and the World Meteorological Organisation.

In 2023

Categories

In the context of the Challenge, the category of a sensor is defined as its intended use or application. There are eight categories in this Challenge. As in the previous edition, the categories have been organized into three main groups, based on the intended field of application: outdoor air, indoor air and citizen air. The latter concerns applications that target pollution levels to which people are personally exposed in the course of their daily activities.

Outdoor Air (OA)
- Monitoring (OA-M)
- Awareness (OA-A)
- Vehicular (OA-V)

Indoor Air (IA)
- Monitoring (IA-M)
- Awareness (IA-A)
- Piloting (IA-P)

Citizen Air (CA)
- Exposure (CA-E)
- Awareness (CA-A)

The AIRLAB Microsensors Challenge takes a holistic approach to the evaluation of air quality sensors by combining 23 sub-criteria grouped into 5 major macro-criteria relating to:

- Accuracy
- Utility
- Usability
- Portability/Form factor
- Cost

The fourth edition of the Microsensors Challenge aimed to consolidate and refine its evaluation process by leveraging the experience accumulated over the first three editions (i.e. in 2018, in 2019, and in 2021) and to push the inherent limitations of a challenge format in terms of generalizability of its results by diversifying evaluation environments.

New features of this edition

The evaluation sites

To cover the different categories of the Challenge, five different evaluation sites were used: two outdoor static sites (temperate climate and tropical climate), an indoor site, and two mobile sites. For the tests in Bangkok, a dedicated reference station was designed and built on the roof of the Alliance Française building in Bangkok, in collaboration with the National Institute of Metrology of Thailand (NIMT), the Asian Institute of Technology (AIT), and the Bangkok Metropolitan Administration (BMA) which provided access to the air quality data from its surrounding reference monitoring station in order to allow for cross-comparison. Another static outdoor site was deployed in Tourcoing, Northern France by Atmo Hauts-de-France.

In parallel with Tourcoing and Bangkok deployments, the indoor air site was deployed in Paris, in a new extension of the Airparif Metrology Laboratory which allows a better control of the experimental conditions. The sensors were exposed to a multitude of stimuli: cigarettes, candles, incense, cleaning products, paint, and cooking, during the same period.

For the outdoor air vehicular evaluations, Airparif equipped a vehicle with sensors participating in this category, and reliable, high-performance PM and NO_2 analysers, and performed experiments over 15 days, by driving the vehicle on the same trajectory on the inner and outer rings of Paris.

Finally, for the citizen air category, Airparif used an equipped backpack and a pool of volunteers to carry the sensor during their regular commutes over 15 days as well.

The life cycle analysis

For the first time in the Challenge history, an analysis of the environmental impact of the microsensors tested was carried out, using life cycle analyses. For the 2023 edition of the AIRLAB Challenge, candidates were asked to complete a questionnaire on the environmental footprint of their proposed sensor. Multiple elements have been considered: device composition (metal, plastic, electronic components, battery), the number of suppliers, the distance between the supplier and distributor, recyclability, packaging weight, etc.

Most participants made the effort to provide the requested data, with varying degrees of completeness. Their answers indicate that the primary environmental impact of microsensors is associated with their manufacturing and distribution processes rather than with their period of use.

One of the objectives of this analysis was to provide a rough comparison between the environmental impacts of microsensors and reference stations. However, it should be noted that the analysis carried out as part of the 2023 Microsensors Challenge cannot amount to a direct comparison between those two types of monitoring equipment, due to differences in their intended applications, including the functional unit and data quality.

It is suggested that the use of microsensors

could be more environmentally-friendly than reference analysers if not limited to short durations (projects lasting a few months) and using a number of sensor units fitter to, and not exceeding, the actual requirement.

Results and lessons learned

The simultaneous tests in outdoor air in France and Thailand allowed to highlight differences in the performance of microsensor systems depending on the deployment environment (temperate climate in Tourcoing, and tropical climate in Bangkok).

Better performance in more particulate-polluted environments

The results of this new Challenge show, overall, a better performance of microsensors for particulate matter monitoring in Bangkok, compared with Tourcoing. This phenomenon is due to the higher levels of these pollutants in Bangkok. The size of the particles also influences the systems performance, with a distribution being shifted towards larger sizes in Bangkok (i.e. the $PM_{10}/PM_{2.5}$ ratio is more important). The nature of the particles is also different, and comprises more telluric particles in Bangkok. This combination of factors takes the microsensors further into their comfort zone relative to their detection limits.
Generally speaking, for particles, the quality of measurement is equivalent to that of the previous edition of the Challenge, whereas progress has been noted for each of the previous editions.

Variable performance for gas monitoring

For gas measurements, nitrogen dioxide (NO_2) and ozone (O_3), performances have varied greatly between the two monitoring sites, depending on the ability of the manufacturers' compensation algorithms to handle differences in climatic conditions. Indeed, temperature and humidity can highly influence microsensors' performance, but there are other influencing factors such as cross-sensitivity with other pollutants between the two sites.
In the case of carbon dioxide (CO_2) measurements, for which the existing measuring technology is generally considered mature, we observed an unexpected level of variability in performance levels across the different evaluated sensors. CO_2 measurements are taken in indoor air.

Stagnating costs

Despite inflation and sourcing difficulties, the cost of the microsensors tested has generally stagnated compared with the previous edition, ranging from €100 to €12,000 per microsensor. The notion of "low-cost sensors" is therefore open to question.

New results for this edition

The measurement of volatile organic compounds (VOCs) shows better results compared with previous editions, even if there is still room for improvement as accuracy remains problematic.
This is the first edition of the Challenge to provide usable results for formaldehyde.
It is also the first time in the history of the Challenge that a microsensor has been evaluated for measuring black carbon. Its performance is comparable to that of reference analysers, and it allows to discriminate between tracers from biomass combustion and tracers from road traffic.

All the results per sensor, category of use and pollutant are freely available on the AIRLAB website via an interactive platform. It offers a navigation through the results of the Challenge, allowing searches by criteria and comparisons between the different sensors.

- airparif.shinyapps.io/2023ChallengeResultsEN

International Microsensors Challenge

AIRLAB

Laureate 2023 Edition

- Most accurate multi-pollutant sensor:
  - Outdoor: **Kunak Air Lite** - Spain (Overall)
    Kunak Air Pro - Spain (Overall)
    Bettair Static Node - Spain (Overall)
  - Indoor: **Ethera Mini XT basic** - France (France)
  - Indoor under €500: **AirGradient ONE** - Thailand (France)
- Outdoor Air:
  - Monitoring: **Magnasci SMOGGIE** - Romania (France)
    Ethera NEMo - France (Thailand & Overall)
  - Awareness: **Magnasci SMOGGIE** - Romania (France & Overall)
    AirGradient Outdoor - Thailand (Thailand)
- Indoor Air (Monitoring & Awareness & Piloting):
  - **Atmotech Atmotube** - United States (France)
- Best accuracy:
  - $PM_{2.5}$ - Outdoor: **Airly PM-NO2-O3** - United States (Overall)
  - $PM_{2.5}$ - Indoor: **Kunak Air Lite** - Spain (France)
  - $PM_{2.5}$ - Indoor under €500: **AirGradient ONE** - Thailand (France)
  - O_3 : **Kunak Air Pro** - Spain (Overall)
    Kunak Air Lite - Spain (Overall)
    Bettair Static Node - Spain (Overall)
  - CO_2 - Indoor: **Zaack QAI®** - France (France)
  - CO_2 - Indoor under €500: **Envira NANOENVI IAQ** - Spain (France)
  - VOCs - Indoor: **IQ-Air AirVisual Flex** - Switzerland (France)
  - VOCs - Indoor under €500: **Atmotech Atmotube PRO** - United States (France)
- Special Jury Prize:
  - **ACOEM C-12 Carbon Sensor** - France

The AIRLAB Microsensors Challenge: a rigorous and independent evaluation

Air quality is a major health, economic and social issue. According to the World Health Organization, outdoor and indoor air pollution is responsible for 7 million premature deaths worldwide every year. In this context, there is an increasing demand from authorities (but also private companies and citizens) to produce and have access to air quality data. The issue of data quality and reliability is therefore crucial, in order to inform public policy, and implement effective actions to improve air quality.
The development of connected devices has found applications in the measurement of air quality, and it is evolving quickly, both through sensing technology and algorithms. Remarkable progress in sensor technologies over the last two decades has opened the door to a wide range of potential new applications based on air quality measurements. The market is now awash with sensors that are steadily becoming smaller and cheaper, very few of which have been subject to any data quality certification process. Devices are found in cities, buildings, vehicles, and even on people. However, understanding their performance, and knowing which product to choose for which use, is not straightforward.

Faced with the growing development of microsensor technology, Airparif, the independent air quality observatory for the greater Paris region, and AIRLAB, its open innovation laboratory, have been organizing the Microsensors Challenge since 2018. The goal of this international Challenge is to provide a rigorous and independent evaluation of the performance of microsensors, thanks to a panel of international experts, and under real conditions of use.

So far four editions of the Challenge have taken place (in 2023, 2021, 2019 and 2018), and have allowed a completely independent evaluation of 164 devices. Through this Challenge, Airparif and AIRLAB allow manufacturers to have their solutions evaluated by a jury of independent international experts on both metrological and ergonomic aspects.

The objectives of the Microsensors Challenge are to:
• Link sensors and their use in different categories,
• Provide information to choose the most relevant sensor by category,
• Establish a technological state of the art
• Support innovation

AIRLAB, open innovation laboratory

This Challenge is part of AIRLAB' activities. Launched in 2016 by Airparif and its partners, AIRLAB brings together a community that is committed to improve air quality. Large companies, SMEs and start-ups, research institutes, local authorities, citizens: everyone brings ideas, skills, resources, and means. AIRLAB contributes to protect the health of citizens, to support innovative companies and to develop employment by promoting the development and implementation of solutions to air pollution in Ile-de-France region. It also encourages their promotion at national and international level.
AIRLAB is supported by its founding members (Airparif, Ile-de-France Region, City of Paris, Greater Paris Metropolis, Ile-de-France Mobilités, Veolia, Engie, Icade, SNCF) and all of its partners, a list of which is available on its website www.airlab.solutions.

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