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Microsensors Challenge 2019

January 2020

Microsensors Challenge 2019: announcement of the results

***Paris, January 21, 2020* - the winners of the «2019 Microsensors Challenge» were rewarded by Airlab partners at the end of the international workshop on teachings and challenges related to microsensors measuring the air quality organized by Airparif and the AFD. This new international edition has allowed willing manufacturers to have their solutions evaluated by using Airparif's know-how and an independent evaluation composed by a jury of French and international experts. It thus makes it possible to enlighten the potential users regarding the adequacy and the performances of the product with respect to the intended uses.**

The rise of connected sensors for air quality monitoring

More and more experimental and innovative projects are developing around miniaturized air quality sensors, aimed at equipping cities, buildings, vehicles and citizens. However, there is currently no regulation for these technologies, which represent a market in full development and which arouse the interest of the various stakeholders: authorities, citizens, NGOs, economic actors... whatever the continents. What are the performances of these **devices according to the uses? How do their performances evolve over time? What have been the technological evolutions since the last edition of the challenge?** The objective of this initiative is to highlight innovations while providing information and choice criteria for users according to their needs in relation to these new technologies.
For the AFD, these questions are omnipresent in many of the emerging and developing countries where it supports the authorities. In these countries, there are often very significant levels of pollution, an incomplete or nonexistent monitoring system, and limited technical and financial resources: the stakes are high around these measurement devices, which form the basis of public policies for the improvement of air quality.

34 Microsensors screened by the teams of Airparif for 4 months, under the aegis of an international jury

At the end of a selection phase, the **34 sensors were made available by the voluntary manufacturers, half of which were foreign companies. These evaluations covered 44 parameters on average, 15 pollutants were studied, and this during 4 months in the Paris region (in a metrology laboratory, on mobility in vehicles and on people, as well as on Airparif stations). This represents more than 50 million processed data.**

These tests were conducted under the aegis of an international jury composed of members of the first edition (Airparif, ATMO Auvergne-Rhône-Alpes, ATMO Grand Est, CSTB, EMPA, FIMEA, OQAI and VEOLIA), to which were added the French Development Agency, the World Meteorological Organization, Engie and EDF, the Network of Research Partners of the Île-de-France Region DIM QI², the Commission for Atomic Energy and Alternative Energies and two new Air monitoring associations: ATMO Hauts-de-France and ATMO Normandie. This 2019 edition has been financially supported by the French Development Agency, EDF, ENGIE, the Network of Research Partners of the Île-de-France Region DIM QI² and Véolia. An important technical support was provided by Bruitparif for the measurement of the noise level of the sensors and by the CSTB for evolving the indoor air

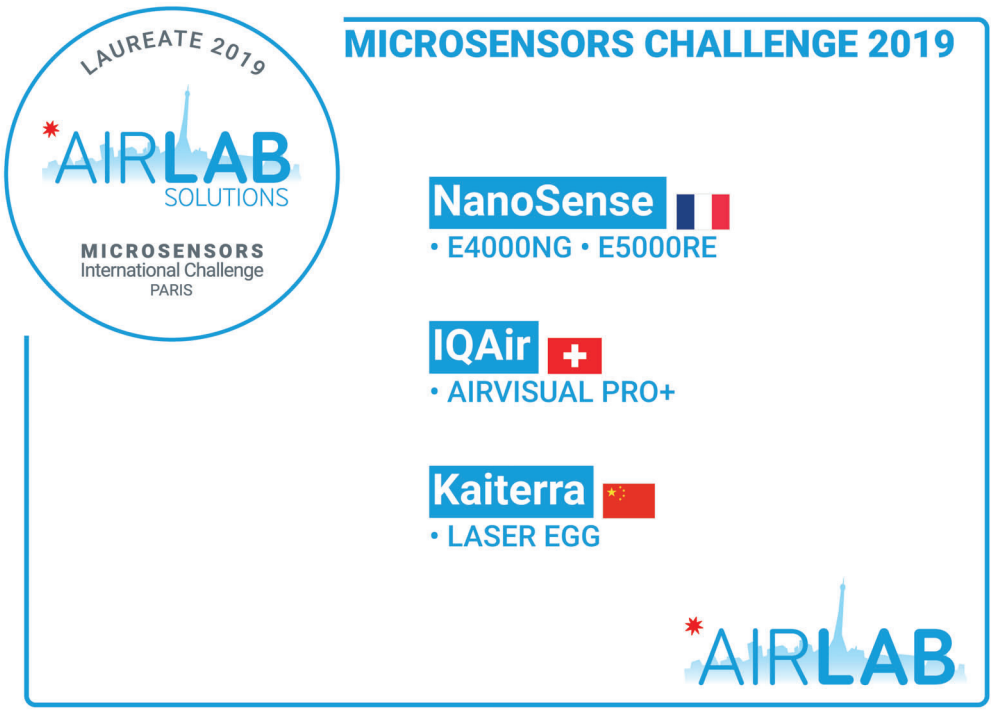
measurement tests.
Each sensor was competing for one or several uses (measurement in outdoor air or indoor air, fixed or mobile measurement, public awareness, etc.) and was evaluated according to five criteria: the accuracy of the measurement, the ergonomics, the relevance of the measured pollutants compared to the use, cost and suitability of the solution in the competing category (congestion, interoperability, handling, data management). The results are presented in the form of a star number ranging from 1 (lowest level) to 5 (highest performance).

The results of this 2019 edition: Four award-winning sensors of the 2019 Challenge

4 sensors marketed by 3 companies are at the top of the bill of this second edition and are the winners of this challenge with a result of 4.5 out of 5 stars:
• In the category «Indoor Air - Piloting (IA-P)": **The E 4000NG sensor marketed by NanoSense (France)**
• In the category «Indoor Air - Monitoring (IA-M)": **The E 5000RE sensor also marketed by NanoSense (France)**
• For all «Indoor Air» categories, whether it is monitoring, awareness or piloting: **AIRVISUAL PRO+ sensors marketed by IQAIR (Switzerland) and LASER EGG marketed by KAITERRA (China)**

An improvement of the proposed solutions compared to the 2018 edition

Overall, the results of the challenge reflect the differences in market maturity with fairly similar performances according to the categories of use, but with offers whose quality has increased in one year. As in 2018, the evaluation of these sensors shows that the best performing currently available solutions are for fixed indoor air sensors: both for air quality awareness uses, and for piloting and managing air



quality inside a building, and this category, to which the winners of 2018 already belonged, has further progressed with the laureates getting 4.5 stars, compared to 4 stars in 2018.
Similarly, solutions intended for measuring for regulatory oversight, personal exposure assessment, or in mobility, have also improved in terms of measurement quality and the number of pollutants, but remain one level lower.

The 34 sensors tested during this second edition all have a satisfactory level of ergonomics and improved by more than 10% compared to the 2018 edition. Although the quality of the measurements varies from excellent (for carbon dioxide in indoor air) to unsatisfactory, with differences depending on the pollutants for the same sensor, a clear improvement has been observed in the accuracy which has increased on average by more than 30% on the 2019 edition. In addition, the jury points out that they have not observed a solution in major dysfunction this year, unlike the previous edition.

Possible improvements on measurement accuracy and the actual cost of solutions

While the technological maturity of these sensors works well in indoor air, developments are encouraging in outdoor air, but the technology is not yet ready to meet regulatory requirements. The solutions intended to measure for the purpose of regulatory monitoring of personal exposure assessment, or in mobility, remain indeed to be improved, notably on the quality of measurements and the number of pollutants monitored. The conclusions of the challenge, on this point, are in line with the work of the World Meteorological Organization, the World Health Organization and the United Nations Environment Program, for whom low-cost sensors are not a direct substitute for reference measurements, especially for regulatory issues, but they represent a complementary source of information, provided that an appropriate device is used[1].

Moreover, regarding the cost and contrary to expectations, the calculation of the overall cost (purchase and operation) over three years shows that all these solutions are not always «low cost» products with an amount ranging from nearly 200 euros to more than 17,000 euros. And there is also the question of their environmental impact, which has not been evaluated in the context of the challenge, given their lifespan (typically 1 year to 18 months).

In addition, these results are representative of the sensors tested but cannot necessarily be extrapolated to other batches, for which performance can differ. Similarly, apart from the laboratory assessment, these results were obtained with pollution levels which are those of a large European capital and the weather conditions of Île-de-France. In outdoor air, differences from these results may be observed in other areas of the globe with higher levels of pollution and higher temperature and humidity conditions. Before any installation of a device of this type, verification of proper operation comprising metrological tests is recommended.

Is the metrological criterion the only parameter to take into account when setting up a project based on these measurement devices? Experiments, of more or less large-scale, are developing in France and abroad and are presented within the framework of a workshop organized by the AFD and Airparif before the results of the Challenge. Beyond the individual metrological performance of

the sensors (as assessed in the challenge for a given batch), these feedbacks point to other questions. The experimentation of Urban Lab, Paris&Co and the City of Paris, in partnership with AIRLAB, ADEME and the Caisse des Dépôts[2] highlights in particular the importance of «an evaluation of the effectiveness and sustainability of proposed solutions to move towards a responsible and sustainable purchase» and recommends arbitration according to an overall cost / benefit approach.

The evaluations freely available on www.airlab.solutions

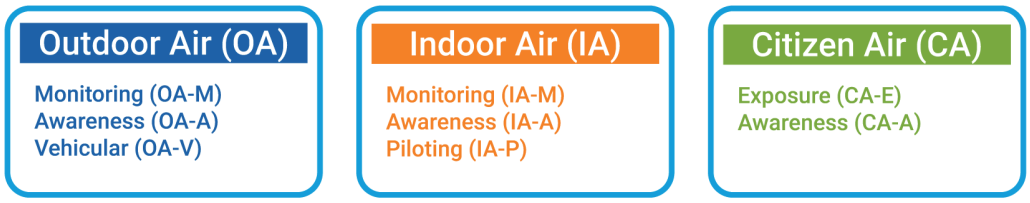
All the sensor results are freely available on the AIRLAB website (www.airlab.solutions) in accordance with the Challenge rules so that each sensor potential user can clarify his choice according to the expected use of these technologies. These evaluations are available in English and French.

[1] Source: Low cost sensors for the measurement of atmospheric composition: overview of topic and future applications - World Meteorological Organization (WMO), World Health Organization (WHO), United Nations Environment Program (UNEP) - International Global Atmospheric Chemistry (IGAC), EMEP - May 2018.

[2] Program aimed at experimenting with the implementation of concrete projects to improve the quality of outdoor and indoor air, which are innovative and economically viable, mainly involving measurement with microsensors, and remediation. Results available online: https://www.parisandco.paris/Sitepage/Synthese-de-l-evaluation-Qualite-de-l-air - October 2019.

Results by category of use

The Challenge rules provided for 8 categories of use. The supply and maturity of sensors available on the market vary widely. The sensors registered for the challenge reflect this variety. Therefore, the categories with most candidate solutions are:



The 8 categories of use grouped into 3 classes as a function of the application environment

- OA-M : Outdoor Air – Monitoring
- OA-A : Outdoor Air – Awareness raising
- IA-M : Indoor Air – Monitoring
- IA-A : Indoor Air – Awareness raising
- IA-P : Indoor Air – Piloting and managing air inside buildings

The sensor results for these categories are presented in the summary tables below.

Outdoor Air – Monitoring (OA-M)

brand	name	star-score
• 42 Factory	ATMOTRACK	★★★☆☆
• LoThoSoft	AVC2	★★★☆☆
• RUBIX S&I	WT1	★★★☆☆
• SIM Engineering	SIM-MONI	★★★☆☆
• ADDAIR	AQMesh	★★★½☆
• AGRISCOPE	PM-SCOPE	★★★½☆
• Airlabs	AIRNODE	★★★½☆
• Decentlab GmbH	Air Quality Station	★★★½☆
• Kunak Technologies	KUNAK AIR A-10	★★★½☆
• Pollutrack	Pollutrack	★★★½☆
• VAISALA SAS	AQT410	★★★½☆
• Airly	Airly	★★★★☆
• Clarity Movement Co.	Node-S	★★★★☆
• ECOMESURE	ECOMSMART	★★★★☆
• HabitatMap	AirBeam2	★★★★☆
• NanoSense	QAA-RE	★★★★☆

Outdoor Air – Awareness raising (OA-A)

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brand	name	star-score
• Azimut-Monitoring	Greenbee Secteur	★★★☆☆
• Azimut-Monitoring	Greenbee Solaire	★★★½☆
• Clarity Movement Co.	Node-S	★★★½☆
• Decentlab GmbH	Air Quality Station	★★★½☆
• Pollutrack	Pollutrack	★★★½☆
• VAISALA SAS	AQT410	★★★½☆
• Airly	Airly	★★★★☆
• HabitatMap	AirBeam2	★★★★☆
• NanoSense	QAA-RE	★★★★☆

Indoor Air – Monitoring (IA-M)

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brand	name	star-score
• ethera	NEMo XT	★★★½☆
• airthinx	airthinx IAQ	★★★½☆
• Decentlab GmbH	Indoor Ambiance Monitor	★★★★☆
• ECOMESURE	ECOMZEN	★★★★☆
• ethera	NEMo	★★★★☆
• HabitatMap	AirBeam2	★★★★☆
• inBiot Monitoring	MICA	★★★★☆
• meo air analytics	meo	★★★★☆
• NanoSense	E4000NG	★★★★☆
• RUBIX S&I	Rubix POD	★★★★☆
• IQAir	AirVisual Pro+	★★★★½
• kaiterra	Laser Egg	★★★★½
• NanoSense	EP5000RE	★★★★½

Indoor Air – Awareness raising (IA-A)

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brand	name	star-score
• ZAACK	ZAACK QAI	★★★☆☆
• Azimut-Monitoring	Fireflies	★★★½☆
• Decentlab GmbH	Indoor Ambiance Monitor	★★★★☆
• HabitatMap	AirBeam2	★★★★☆
• inBiot Monitoring	MICA	★★★★☆
• meo air analytics	meo	★★★★☆
• NanoSense	E4000NG	★★★★☆
• NanoSense	EP5000RE	★★★★☆
• IQAir	AirVisual Pro+	★★★★½
• kaiterra	Laser Egg	★★★★½

Indoor Air – Piloting and managing air inside buildings (IA-P)

brand	name	star-score
• Azimut-Monitoring	Fireflies	★★★½☆
• ZAACK	ZAACK QAI	★★★½☆
• Decentlab GmbH	Indoor Ambiance Monitor	★★★★☆
• HabitatMap	AirBeam2	★★★★☆
• inBiot Monitoring	MICA	★★★★☆
• meo air analytics	meo	★★★★☆
• NanoSense	EP5000RE	★★★★☆
• IQAir	AirVisual Pro+	★★★★½
• kaiterra	Laser Egg	★★★★½
• NanoSense	E4000NG_P	★★★★½

Although the performance has improved for all categories of use, the difference remains important between sensors operating in indoor versus outdoor air. An essential reason for this difference lies in the higher complexity of the outdoor environment in terms of the variability of influencing parameters (temperature, humidity) and for particle measurements in terms of chemical composition and their structure.

Some solutions were evaluated on the categories: measuring the quality of outdoor air in mobility (with a vehicle), documenting personal exposure to pollution for the purposes of sanitary interpretations or raising awareness of the air quality encountered during your daily activities, for which the number of participants is much lower. The results are thus presented directly in the sensor evaluation sheets.

Results by pollutant

The Challenge tested around fifteen pollutants. The availability and maturity of these measures vary widely. For example, NO2 and PM2.5 are often included in microsensors intended for outdoor use, however the NO2 technology generally performs considerably better compared to that used for PM measurements (PM1, PM2.5, and PM10) for this type of environment. Ozone measurements, although generally using the same type of technology as for NO2 offers less consistent results, with some microsensors attaining similar performance as for NO2, while others greatly underperforming.

For indoor air, CO2 and PM2.5 are the most commonly targeted pollutants, with VOCs gaining more popularity this year. In terms of performance, the technologies for CO2 and PM measurements (PM1, PM2.5, and PM10) are very mature for the indoor settings, while VOC technology needs significant further improvement. This technological immaturity is an even more significant issue for the less commonly available formaldehyde measurements.

The most relevant and best-in-class pollutants, with only the ratings greater than 7 out of 10 are presented below:

In outdoor air (OA)

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>> PM2.5

brand	name	score
• ADDAIR	AQMesh	7.8
• Airly	Airly	7.7
• Clarity Movement Co.	Node-S	7.2
• NanoSense	QAA-RE	7.2
• Pollutrack	Pollutrack	7.1
• 42 Factory	ATMOTRACK	7.1
• AGRISCOPE	PM-SCOPE	7

>> PM10

brand	name	score
• ADDAIR	AQMesh	7.9
• AGRISCOPE	PM-SCOPE	7.2
• Airly	Airly	7.1

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MICROSENSORS CHALLENGE

2019

AIRLY AIRLY

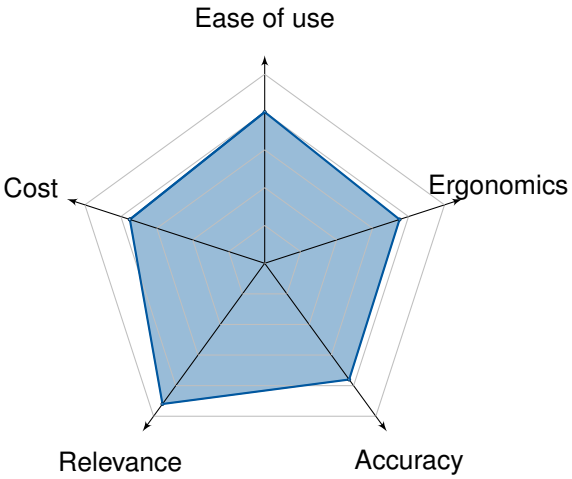
Use for which the evaluation was the best : Monitoring and awareness in outdoor air

Jury's opinion

With a very clean, robust, and discrete design, the Airly sensor targets both monitoring and awareness raising for outdoor air quality, and its relatively small price allows access to both markets. The performance of its particulate matter measurements is good for PM_{10} and $PM_{2.5}$ and very good for PM_1, being the best performing PM sensor for outdoor air this year. Gas sensing is also possible through an add-on module, however this was not available for testing in this edition.

OA ★★★★☆

Evaluation



Evaluated uses :
- outdoor air
- indoor air
- mobility

Measured pollutants

- ◯ CH_2O
- ◯ CO
- ◯ CO_2
- ◯ VOC
- ◯ H_2S
- ◯ NH_3
- ◯ NO
- ◯ NO_2 (NO_x)
- ◯ O_3
- ☑ PM_1
- ☑ $PM_{2,5}$
- ☑ PM_{10}
- ◯ SO_2
- ◯ Particle number (concentration)

Other measurements

- ☑ Temperature
- ☑ Humidity
- ◯ Odours
- ◯ GPS
- ☑ Atmospheric pressure
- ◯ Luminosity
- ◯ Acoustic comfort
- ◯ Anemometer

Data storage location : Europe

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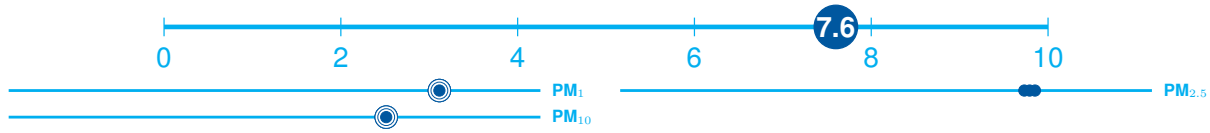
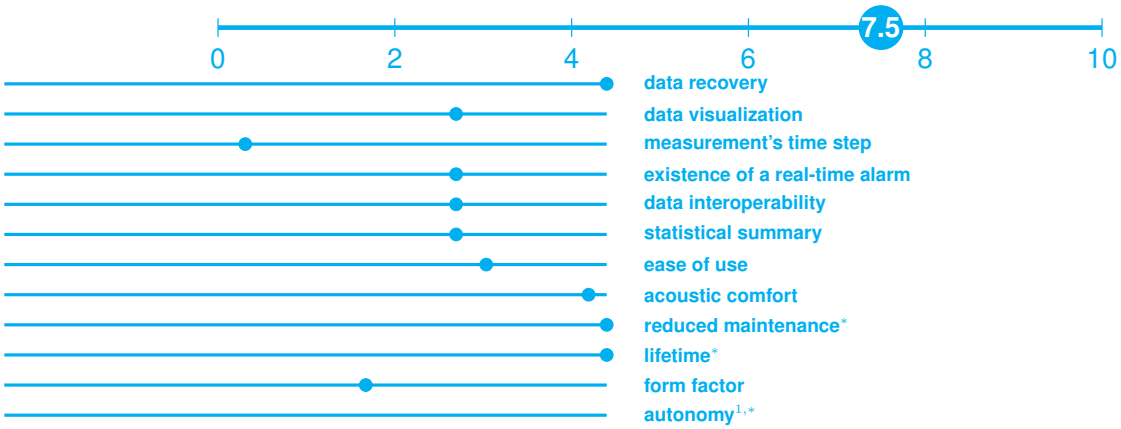
Detailed test results

Evaluated uses :
- outdoor air
- indoor air
- mobility
- all uses

ACCURACY on 3 microsensors based on the SET method (Fishbain & al. 2017)

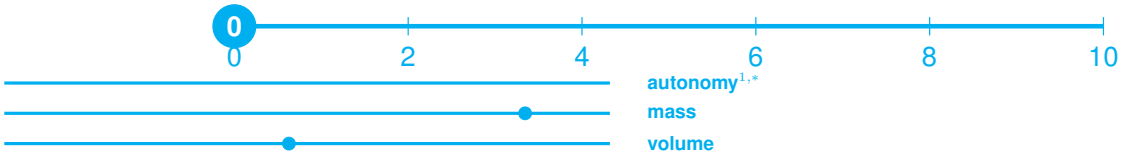


ERGONOMICS based on several sub-criteria (data vizualisation, ease of use, autonomy, ...)



RELEVANCE of the measured pollutants : number and stake of the sensor's measured pollutants in view of its competing categories (OA-M and **OA-A**)[2]

PORTABILITY[1,*]



COST investment and running costs over 3 years

[1] Regarding mains-operated sensors, autonomy is **only** taken into account for portability
[2] The values on the graph correspond to the categories marked in bold
* This parameter was not directly evaluated : it was graded based on the manufacturer declaration

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