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Micro-sensors: a solution for the future?

AIRPARIF

EDITORIAL SUMMARY

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Micro-sensors: a solution for the future?

This dossier, entitled "Micro-sensors: a solution for the future?", seeks to shed light on an emerging trend. But, what are micro-sensors? The concept is elucidated through a conceptual scheme before presenting a comprehensive exploration of their wide-ranging applications across various contexts. Given their significant number and diverse applications, performance evaluation projects are being carried out in France, the United States, and Ghana for these instruments. Focusing on developing countries, the scientist Dr. Subramanian provides insights into how a country's climate and economic situation are factors to consider when using micro-sensors for outdoor air.

Additionally, an AIRLAB project highlights another application area for micro-sensors: indoor air quality (IAQ) measurement. The medical biologist Dr. Squinazi further elucidates the significance of micro-sensors in IAQ monitoring. Another use of micro-sensors is raising public awareness of air pollution. In the field, Guillaume Salque-Moreton presents the captothèque project (a sensor library) deployed by the Atmo Auvergne-Rhône-Alpes observatory.

Awareness can also be raised by using micro-sensors as alarms in the case of fire event.

Finally, the French Agency for Food, Environmental and Occupational Health and Safety (Anses) reveals the relevance of using micro-sensors to assess individual exposure to various pollution sources.

Nevertheless, the diverse uses of micro-sensors come with costs for acquisition, operation, and environmental impacts. Therefore, is it an inexpensive tool? Despite its generally affordable purchase price, micro-sensors require various expertise to obtain reliable and usable data. With rare earth electronic components, metal extraction, and limited lifespan, the question of their environmental impact arises.

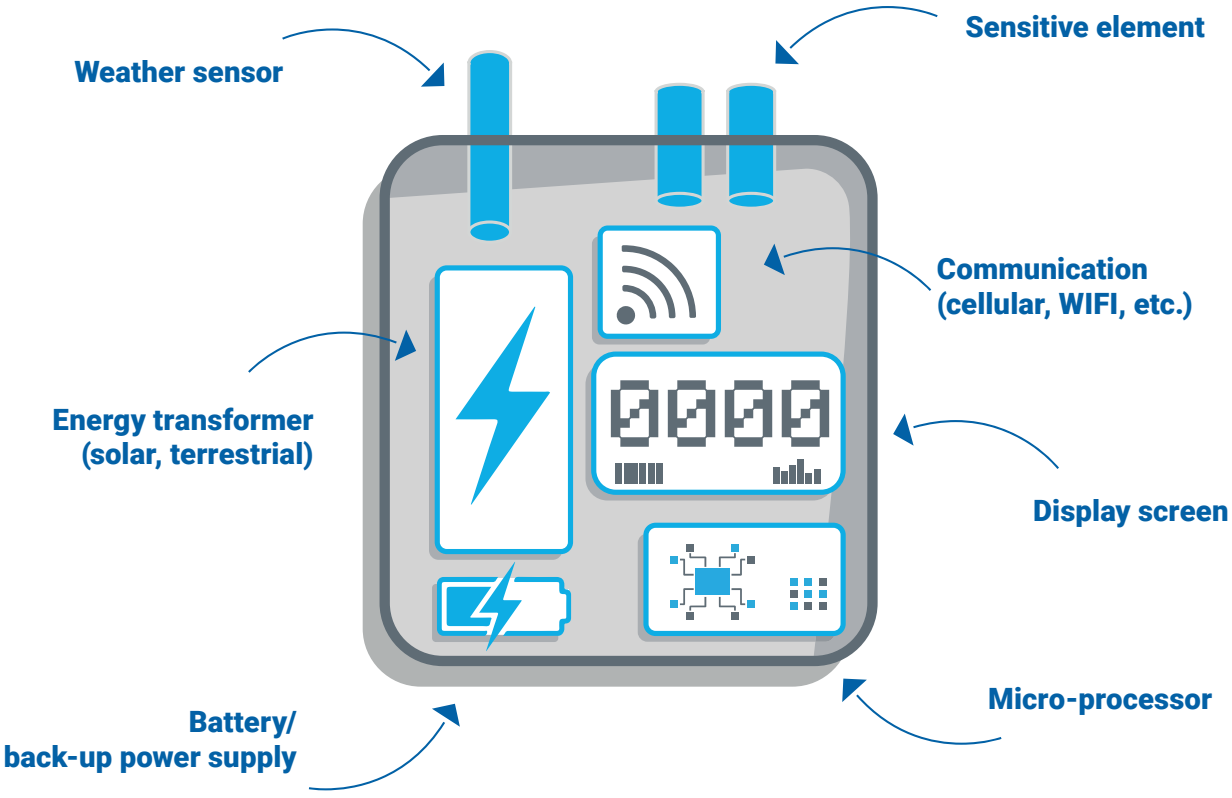
In conclusion, this dossier summarises the advantages and limitations of using micro-sensors.

Anatomy of a micro-sensor

Due to its small size and low cost, micro-sensor differs from reference devices in the field of air quality measurement. These characteristics make it a relatively simple instrument to carry for monitoring air pollutants.

The micro-sensor, also called sensor system as the official term used by the French Association for Standardisation (Afnor) and the World Meteorological Organisation (WMO), encompasses a variety of components. It consists of a combination of at least one sensor and a global electronic system. The sensor consists of a sensitive element dedicated to a specific pollutant and software through which the measured data are converted into an indication of the concentration of the respective pollutant. Each sensor measures one or more components, including particulate matter, nitrogen dioxide, volatile organic compounds, and carbon dioxide.

Typical components of an air quality micro-sensor



Regulatory monitoring in France and Europe

In France, air quality monitoring is entrusted by law to accredited and independent associations like Airparif. The monitoring relies on a system of complementary measurement tools, including permanent and temporary stations, as well as modelling, to ensure spatial and temporal multi-pollutant coverage, ensuring the reliability of air quality measurements. These tools and data quality meet regulatory requirements, which is not the case for micro-sensors.

Monitoring stations

These stations can measure one or several pollutants, either continuously or periodically, using real time measurements or sampling for a posteriori laboratory analysis. Fixed stations are essential to ensure a comparable quality of measurement across regions and countries. There are two types of stations: background stations, located far away from pollution sources, especially roads, and stations located close to traffic or industrial areas. This classification is applied throughout the European Union.

Atmospheric Model

This mathematical technique makes it possible to estimate pollutant concentrations at any point within a given area for past, present, or future periods, thanks to meteorological and topographical parameters, and information on emission sources. Atmospheric modelling is inseparable from measurements taken at the stations.

EXPERT'S PERSPECTIVE

In the future, what role will micro-sensors have in regulatory texts?

MICHEL GERBOLES, HEAD OF THE LABORATORY FOR THE EVALUATION OF MICRO-SENSORS FOR AIR QUALITY MONITORING AT THE EUROPEAN COMMISSION'S JOINT RESEARCH CENTRE (JRC), SHEDS SOME LIGHT ON THE SUBJECT.

“In accordance with the Ambient Air Quality Directives, Member States are required to assess ambient air quality. They may use different methods namely fixed measurements, modelling, objective estimation, and indicative measurements. In the future selected sensor systems are expected to meet the data quality objectives of indicative measurements that are set out in the Ambient Air Quality Directive. Currently, a CEN working group is dealing with technical specifications for the classification of gas and particulate matter sensors in line with the required data quality objectives. The European Commission is planning to encourage the standardisation efforts of CEN in the future, for example by supporting validation studies or procedures to ensure data quality over the lifetime of a sensor.”

Diverse uses for varied situations

As a miniature connected electronic measuring device, the micro-sensor delivers real-time information through a built-in display screen or a smartphone. Its small size and relatively light weight make it suitable for use in various situations. Whether for professionals, researchers, or private individuals, using a micro-sensor offers the opportunity to increase the number of air quality monitoring sites in ambient and indoor air. It can also be used for public awareness campaigns regarding air quality issues.

However, it is important to consider not only the characteristics of the micro-sensor itself but also the situation and environment in which it is used. A given micro-sensor may yield different results in indoor or outdoor air, or in a country with a temperate or humid climate, for example. From their appearance to practical uses, micro-sensors are versatile but should be used with caution, however.

Uses and categories

OUTDOOR AIR
- Monitoring

INDOOR AIR
- Monitoring
- Regulating air within a building (aeration, ventilation…)

RAISING AWARENESS
- Informing through participatory science
- Promoting behavioural change

INDIVIDUAL EXPOSURE
- Understanding exposure to pollutants by activity

Outdoor air: A variety of uses for micro-sensors

Every day, the average person breathes in around 15,000 litres of air. The air that surrounds us in the streets, parks and gardens, schoolyards, and countryside contains pollutants that affect our health. Nitrogen oxides, ozone, particulate matter, volatile organic compounds, sulphur dioxide, ammonia and benzene are the main pollutants in outdoor air, also known as ambient air. Whether from human origin (heating, transportation, industry, agriculture, etc.) or naturally occurring (sandstorms, volcanic eruptions, etc.), the sources of these pollutants are numerous.

This raises several key issues: primarily health-related, with 4.2 million premature deaths per year worldwide caused by ambient air pollution (source: WHO), but also economic issues, as air pollution costs €101 billion each year in France (source: Sénat). To address these challenges, monitoring, informing, raising awareness, and reducing emissions are necessary. In this regard, can micro-sensors be part of the solution?

ONGOING EVALUATION NECESSARY

In this rapidly expanding market, there is a significant number of devices in circulation, and they are not subject to any regulations. Therefore, their evaluation in terms of performance becomes necessary to best analyse their relevance depending on the intended objective and to provide potential users with valuable insights.

Evaluation programmes are being conducted in France, the United States and Ghana in particular.

Among the pioneers, California's AQ-Spec

In California, the South Coast Air Quality Management District was one of the first to establish a long-term evaluation programme for micro-sensors, including a protocol at a dedicated site. The evaluation is carried out continuously upon receiving a new device, lasting for 30 to 60 days. This raises the question of the comparability of evaluation results conducted over different periods. For some sensors of interest, an evaluation in an exposure chamber with humidity and temperature control is carried out after the initial tests.

In France, the AIRLAB Challenge

Beyond solely assessing metrological quality, the AIRLAB Challenge also considers the utility, ergonomics, and operational cost of the use of micro-sensors. This unique aspect of the challenge aligns with its goal which is to analyse the best response provided by a sensor for a given use. The specificity of the challenge also lies in its format: all the micro-sensors sent in by the manufacturers are evaluated together over a period of 3 to 4 months.

For its 4th edition, the AIRLAB Challenge is expanding internationally, with evaluations taking place in France, in Paris and Lille, with the support of Atmo Hauts-de-France, and in Thailand, in Bangkok, with the assistance of the Asian Institute of Technology, the Alliance Française, the Bangkok Metropolitan Administration, and the National Institute of Metrology Thailand. This dual evaluation aims to assess disparities in micro-sensor performances related to different climates as well as the different sources and pollution levels.

Afri-SET in Ghana

Following the AQ-Spec model, the Afri-SET programme is unique in that it evaluates micro-sensors over 12 weeks during both dry and wet seasons in West Africa. Experimental tests are conducted in Accra, Ghana, and propose calibration models for both seasons, unlike the other American and French evaluation projects. It is the most recent micro-sensor evaluation programme, but its results have not yet been published.

EXPERT'S PERSPECTIVE

“ Micro-sensors are an additional tool for air quality monitoring ”

ACCORDING TO **DR SUBRAMANIAN**, HEAD OF THE AIR QUALITY SECTOR AT THE CENTRE FOR THE STUDY OF SCIENCE, TECHNOLOGY, AND POLICY (CSTEP) IN INDIA, MICRO-SENSORS REPRESENT A VIABLE ALTERNATIVE, ALBEIT WITH CHALLENGES, FOR COUNTRIES IN THE GLOBAL SOUTH WITH LIMITED RESOURCES TO ACQUIRE REFERENCE EQUIPMENT. TO INCREASE THE USE OF THESE ESSENTIAL INFRASTRUCTURES, HE ADVOCATES FOR GREATER SUPPORT FROM PHILANTHROPIC ORGANISATIONS AND DEVELOPMENT AGENCIES.

In the course of your career, which has taken you to several countries and continents, what challenges have you come up against when using micro-sensors outdoors? Low-cost sensors data quality is best verified by collocation with a reference monitor, but many cities lack these reference monitors.

Power outages or cloud/rainy days in the case of solar-powered sensors can result in data loss. PM sensors and wireless communication modules consume the most power.

WiFi is not always available. Internet of Things (IoT) SIM cards are expensive. Devices developed and tested in EU/US may not work in African or Asian countries.

Some sensor companies charge substantial annual fees, so each additional year of service costs the same as buying new sensors.

Duties and taxes on sensor imports cause shipping delays and increased cost.

Have you seen these questions and issues evolve over the course of your professional experience? We at AfriqAir (partly supported by the ANR Make Our Planet Great Again program) have installed reference-grade monitors in many African cities.

Rwanda exempts universities from import taxes on air quality monitors including microsensors.

Long-range IoT networks are in development, but the French SigFox filed for bankruptcy in 2022.

AirQo (Uganda) and Sensors Africa sensors are affordable alternatives to expensive US/EU products.

What are your recommendations for the future use of microsensors? The obstacles to be overcome, the limits to be respected, the best practices to be promoted. Microsensors as part of a hybrid monitoring network can identify hot spots, determine the spatial and temporal impacts of large point sources, and reduce the overall cost of air quality monitoring. With current sensing technology, they are not a substitute for reference monitors but are an important supplementary air monitoring tool. Microsensors need to be carefully calibrated against reference monitors before deployment, and periodically checked (e.g. annually) to verify their continuing performance.

The lack of reference monitors for ensuring data quality of micro-sensor networks is an infrastructure challenge that needs to be addressed by the international community. European countries could deploy reference monitors at their embassies worldwide to support microsensor deployments as a global public service. Philanthropies and development agencies should support such essential infrastructure across the Global South.

Using micro-sensors inside

On average, we spend 80% of our time in enclosed spaces. Indoor air quality is therefore just as important as outdoor air quality. From the many, sometimes unexpected, origins of indoor pollution to the transfer of outdoor pollution, indoor air is influenced by many factors. It has rightly become a source of growing concern for building occupants, especially following the emphasis placed on room ventilation during the Covid-19 pandemic and the need to improve the energy efficiency of buildings.

To ensure good indoor air quality, there are two main principles:

- limiting the emission of pollutants
- ensuring efficient air renewal, and in some cases, air treatment

Micro-sensors can therefore play an essential role in managing indoor air.

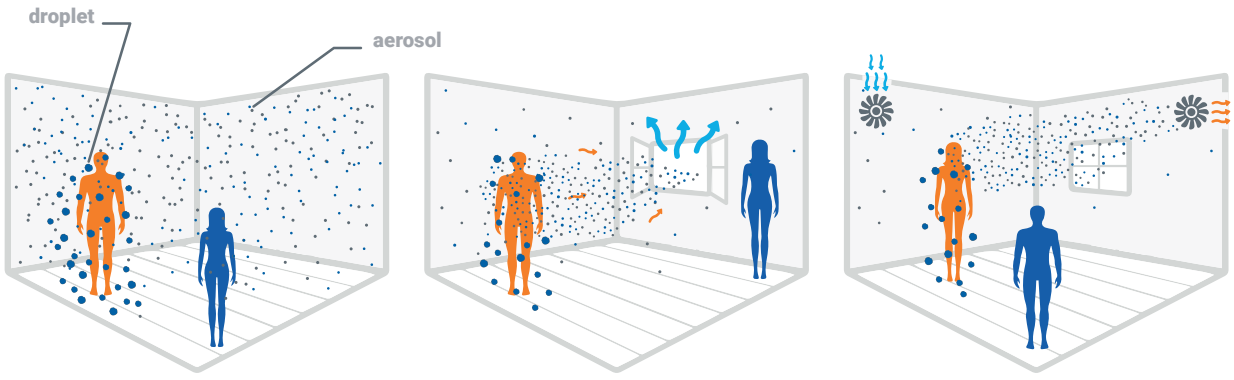
A BREATH OF FRESH AIR IN BUILDINGS

In 2018, as part of AIRLAB, Airparif's innovation laboratory, Icade and Veolia experimented real-time indoor air quality monitoring using micro-sensors.

The insights gained from this project highlighted the importance of continuously monitoring key indicators of indoor air quality: CO2, fine particulate matter, volatile organic compounds, temperature, and humidity. These monitoring efforts ensure the efficiency of filtration and ventilation systems, the proper air renewal rate, and the detection of new sources of indoor pollution.

The project also emphasised the importance of involving building occupants in actions related to indoor air quality, as they often lack control or sufficient knowledge in this regard. It became apparent that data on indoor comfort and air quality needed to be made accessible and understandable, while being mindful of the numerous factors that can influence occupants' experiences: health, well-being, satisfaction at work, the building's location, among others.

Aerosols dispersion in an enclosed spaced



From Morawska and al. (2020), graphic adaptation Airparif

EXPERT'S PERSPECTIVE

The usefulness of micro-sensors indoors

MEDICAL BIOLOGIST **DR FABIEN SQUINAZI**, FORMER DIRECTOR OF THE HYGIENE LABORATORY OF THE CITY OF PARIS AND CHAIRMAN OF THE "ENVIRONMENTAL RISKS" COMMISSION OF THE FRENCH HIGH COUNCIL FOR PUBLIC HEALTH, EXPLAINS THE BENEFITS OF USING MICRO-SENSORS TO MONITOR INDOOR AIR QUALITY (IAQ).

What can the use of micro-sensors bring to indoor air quality monitoring? Air sampling campaigns, using passive samplers or active pumping, within homogeneous sections of the building, followed by laboratory analyses, result in integrated average values for volatile organic compounds, nitrogen dioxide, particulate matter, or bacterial and fungal flora. These averages are then compared to reference values. Micro-sensors, on the other hand, track concentrations over time, identifying variations and trends. While certain parameters such as temperature, humidity, carbon dioxide, carbon monoxide, and particulate matter, and occasionally formaldehyde, are compared to target values, for volatile organic compounds (VOCs), these are considered "indicative" measurements of specific VOCs rather than total VOCs. The challenge for micro-sensors lies in finding a balance between the representativeness of the areas studied, the number of sensors, and the quantity of raw data to be processed and analysed. The choice of measurement time intervals will also affect measurement accuracy, data processing, and interpretation. Micro-sensors require initial calibration followed by regular calibration. However, it is difficult to provide general guidelines for IAQ monitoring, as each building and each micro-sensor is a unique case.

Can micro-sensors be used to support action for indoor air quality improvement? By monitoring indicators of indoor air quality, micro-sensors provide information on occupants' exposure levels, emitting activities, and ventilation system practices. They also assist in managing ventilation and air treatment. The information they provide raises occupants' awareness to improve their behaviours. For air renewal in indoor spaces, direct carbon dioxide measurement enables occupants to respond in real-time by opening windows and establishing an optimal ventilation schedule in terms of frequency and duration of window opening. In ventilated rooms, this monitoring verifies the ventilation's compatibility with room occupancy. Particulate matter counting detects pollution events, such as outdoor air pollution transfer or indoor emission sources. VOCs indicate occasional emissions or ventilation efficiency, but this indicator is limited to the molecules detected by the micro-sensor.

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HENRY BURRIDGE, PHD AND SENIOR LECTURER IN ENVIRONMENTAL FLUID MECHANICS AT IMPERIAL COLLEGE, LONDON, LOOKS BACK AT HIS EXPERIENCE WITH MICRO-SENSORS, FOCUSING ON MONITORING AIR QUALITY IN SCHOOLS.

“My experience with low-cost ‘micro-sensors’ centres around monitoring air quality in schools. So far, we have deployed more than a thousand air quality monitors containing these sensors. Deployment has taken a number of forms from installation by a trained researcher or third-party, by school site management staff, or by school teaching staff; the first method being of higher cost, and the latter two methods requiring preparation of adequate supporting materials but still being of higher risk and uncertainty. Deployment by teaching staff offers the greatest potential for changing IAQ related behaviours but this requires further investigation and the evidence to assess whether any benefit is significant, or not, is lacking. Data acquisition has been either through dedicated gateway hubs which use mobile data or by connection to the school WiFi; again, the former is more expensive and incurs ongoing costs, but it mitigates issues associated with the schools’ firewalls and other connectivity issues. The benefits from this monitoring are that we now have ongoing data collection from over 500 classrooms in the UK, some of which is ongoing since Mar/2021, that provide indications as to the relative ventilation levels within these classrooms. Moreover, we have used these sensors as part of the evidence to establish the impact on classroom IAQ and school illness-related absence of adding standalone HEPA filter devices [editor’s note, high-efficiency particulate air filter] to classrooms.”

RAISING AWARENESS

Understanding for better action

Everyone, at their own level, has an impact on air quality. However, understanding the underlying phenomena, such as atmospheric chemistry, pollution transfer, and weather conditions, can be challenging for a novice. Nevertheless, air quality remains a significant health concern. So, how can we bridge the gap between science and citizens for an effective understanding of this subject?

The micro-sensor then enters in its role of raising awareness. In a playful and educational manner, the Atmo Hauts-de-France observatory is engaged with families and children to create awareness about air quality issues by providing them with micro-sensors for use at home, outdoor itineraries, and production workshops.

Research supported by Ademe, the French ecological transition agency, also shows that micro-sensors play a key role in the behaviour change process, debunking misconceptions and enabling the adoption of new and sustainable practices, provided there is support for getting started and collective facilitation.

FOCUS

WILDFIRES: MICRO-SENSORS FOR SUPPORT

In the United States, in response to the increasing incidence of wildfires, the Environmental Protection Agency (EPA) and the US Forest Service have developed a system to inform the public about the occurrence and progression of fires. This system relies on satellite images, regulatory air quality monitoring stations, as well as micro-sensors. Deployed by individuals, associations, or local agencies, they generate data that requires adjustments by the US EPA and cannot be used for regulatory purposes. However, the use of these micro-sensors enables more extensive monitoring coverage across the country, particularly on the West Coast and in California, to track fires and alert the public.

For some countries with fewer reference stations, micro-sensors prove to be even more valuable in addressing similar risks.

In Thailand, a particular project has been implemented in this regard.

ADISORN LERTSINSRUBTAVEE, RESEARCHER, AND **KANCHANA KANCHANASUT**, RESEARCH PROFESSOR AT THE INTERNET EDUCATION AND RESEARCH LABORATORY FOR THE ASIAN INSTITUTE OF TECHNOLOGY (INTERLAB AIT), GIVE THEIR POINT OF VIEW ON MICRO-SENSORS.

“Local populace of $PM_{2.5}$ affected areas remains largely uninformed about the hazardous levels of dust they are inhaling. The figures provided by authorities may stem from expensive, distant monitoring stations. Consequently, the utilization of compact, cost-effective microsensors capable of measuring particulate matter in various locales and issuing timely warnings could prove invaluable. The severity of the fine particulate matter issue in the northern region escalates with the occurrence of burning activities or forest fires, which are primary sources of smoke and $PM_{2.5}$. Recognizing this, researchers from our lab, the Interlab AIT, in collaboration with the Pierre et Marie Curie University in France, initiated the Hazemon project. Funded by the STIC-ASIE grant from the French government in 2016, the group designed and developed an Internet of Things (IoT) platform known as Canarin for air quality monitoring. The aspiration was to utilize real-time data to aid in forest fire detection. This endeavor expanded with support from other funding sources, leading to the deployment of approximately 200 microsensors across various countries in Southeast Asia. Our team achieved success in real-time forest fire detection in Lamphun province, in 2022. Our system analyzes data and identifies conditions indicative of forest fires, referencing patterns learned from historical data. This enables precise fire warnings to be issued to communities in affected areas.”

EXPERT'S PERSPECTIVE

“ The *captothèque* project: a citizen's air quality measurement system ”

THE AWARENESS-RAISING ASPECT ATTRIBUTED TO MICRO-SENSORS HAS BEEN PARTICULARLY HIGHLIGHTED BY THE ATMO AUVERGNE-RHÔNE-ALPES OBSERVATORY THROUGH THE CREATION OF A *CAPTOTHÈQUE*. **GUILLAUME SALQUE-MORETON**, PROJECT MANAGER, EXPLAINS WHAT HE MEANS.

Can you tell us about the *captothèque* project being rolled out in the Auvergne-Rhône-Alpes region? The *captothèque* is the Atmo Auvergne-Rhône-Alpes' citizen air quality monitoring system. It enables everyone to freely explore air quality and engage in discussions on the subject by borrowing a fine particulate matter micro-sensor for the region.

Mobile micro-sensors can be used to explore sources, while fixed micro-sensors provide citizen observatories for understanding changes over time. Beyond experimenters borrowing a sensor, the *captothèque* offers all citizens the opportunity to observe the collected data and discuss measurements by simply registering on the platform www.captotheque.fr.

What is the benefit of lending micro-sensors to individuals? Micro-sensors allow citizens to explore the air around them, pollution sources, and phenomena on their own.

What are the limitations of this use? Micro-sensors provide indicative information on concentration levels and for understanding atmospheric phenomena. However, monitoring only one pollutant (in the *captothèque*, only particulate matter sensors are offered as sufficiently reliable) can lead to misunderstandings, and the guidance of an expert in understanding the results is essential to provide context.

INDIVIDUAL EXPOSURE

Individual exposure to pollutants: how to use micro-sensors?

The air in every living environment contains varying amounts of pollutants. Throughout the day, an individual moves through different environments and is thus exposed to the air pollutants they contain. On average, a human inhales 6 litres of air per minute; 3 times more when walking and 10 times more when running. Whether at home, school, work, travelling, or leisure activities, individual exposure to air pollution is permanent, and questions about exposure throughout the day are real, with the challenge of grasping significant and rapid variations, especially in mobility.

EXPERT'S PERSPECTIVE

“Information provided by micro-sensors regarding health risks should be considered cautiously”

In its latest report on the use of micro-sensors for air quality monitoring, the French National Agency for Food, Environmental and Occupational Health and Safety (Anses) assess the benefits and limitations of micro-sensors used by the general public to monitor their exposure to air pollution.

EMMANUELLE DURAND AND **AMANDINE PAILLAT**, FROM THE AIR-RELATED RISK ASSESSMENT UNIT AT ANSES, AND COORDINATORS OF THE REPORT, EXPLAIN ITS KEY FINDINGS:

Is the use of micro-sensors relevant for assessing individual exposure? Portable micro-sensors provide data in the immediate environment of the individual, taking into account each person's unique exposure conditions and the various places they visit during the day. Therefore, they are particularly useful for assessing individual exposure to certain pollutants. However, they still have limitations, with the main one being their lower metrological quality compared to regulatory monitoring systems.

More generally, what are the preferred and avoided uses for micro-sensors? Micro-sensors are valuable for evaluating short-term exposure to certain air pollutants. They are not suitable for evaluating individuals' long-term exposure to air pollution but can be used to enhance large-scale maps and models. These devices are thus complementary to other exposure assessment methods.

For personal use, micro-sensors allow individuals to obtain qualitative information about their exposure, such as identifying sources or temporal variations, but they should never be used to estimate individual health risks. Guidance to understand the information provided is essential, and the visual information provided by micro-sensors on pollution level gradations or health risks should be considered with great caution.

Low-cost sensors: a deserved name?

The cost of micro-sensors is an often highlighted advantage, leading to their characterisation as "low-cost sensors". This characteristic primarily hinges on their initial purchase cost. Some are indeed sold for less than 50 euros online. But what can really be said about the actual cost of these devices, namely their overall cost, per use?

Over four editions, the AIRLAB micro-sensor Challenge has identified usage costs ranging from 108 euros to 17,280 euros. Calculated over three years, the cost of using each micro-sensor considers the purchase or rental (the cheaper option is retained), data access, and device maintenance. Among the 167 micro-sensors evaluated in the 2018, 2019, 2021, and 2023 editions, the average three-year usage cost is 3,550 euros, which equates to over 1,000 euros per year. No changes in these costs were noted between 2018 and 2023. It is also worth noting that while some micro-sensors may have attractive purchase or rental costs, data access can be expensive, along with maintenance and the replacement of essential components for proper functioning.

While the costs of micro-sensors over three years appear, on average, significantly lower than the prices of regulatory reference analysers for the main air pollutants, they are often used as a pretext for large-scale deployment (the installation of over a hundred sensors in an urban area) without any real documented added value.

An environmental cost not to be neglected

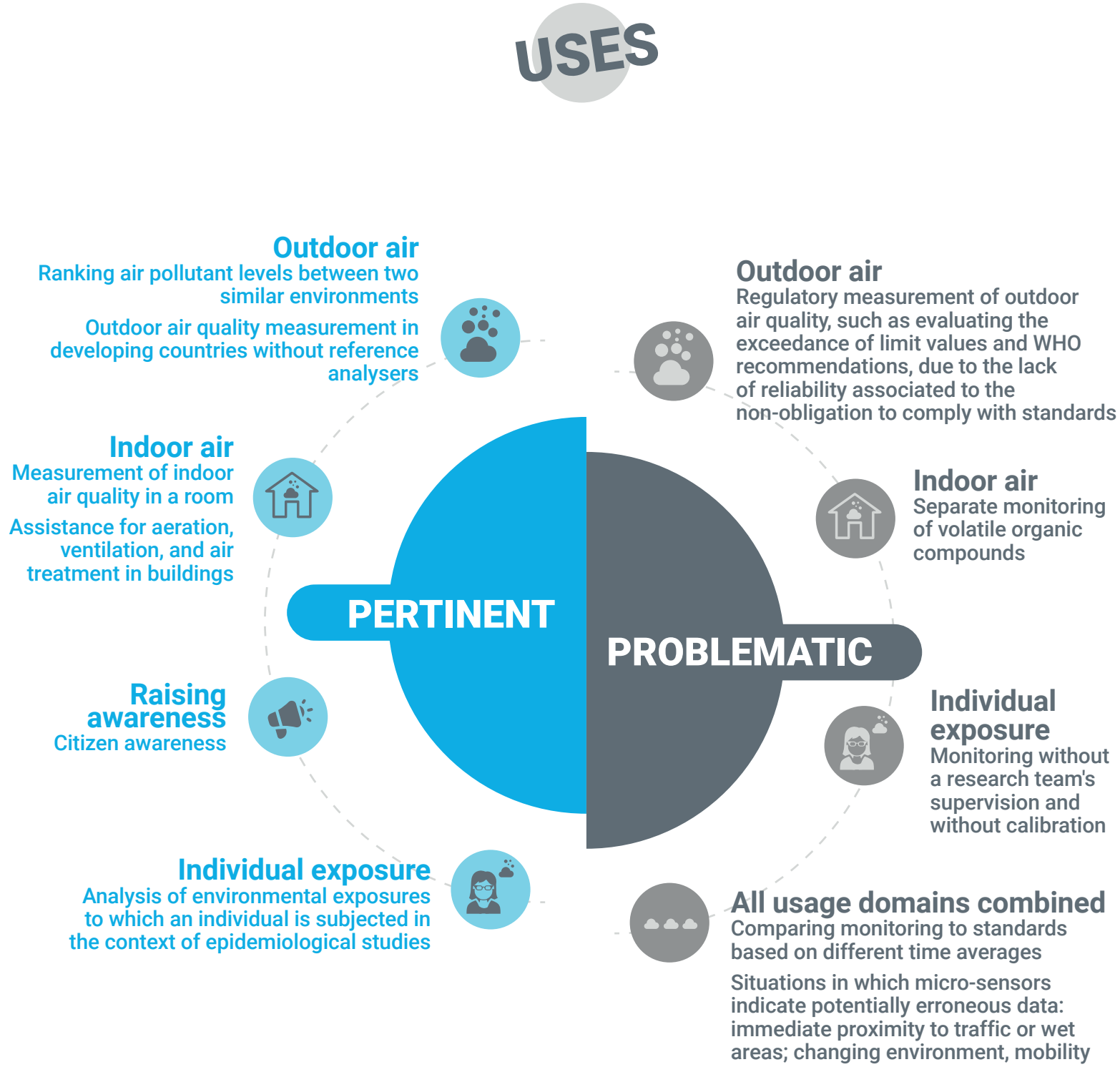
Lastly, micro-sensors are connected devices with limited use period and lifespan. The question of the environmental cost of these objects, particularly concerning data sharing, processing, and analysis, which are not accounted for and require specific expertise, represents a significant concern for the industry. In this context, life cycle analysis (LCA) approaches should be implemented. The 2023 edition of the AIRLAB Challenge addressed this issue by asking candidates to complete a questionnaire on the environmental footprint of their proposed sensor. Multiple elements must be considered in an LCA study of micro-sensors: device composition (metal, plastic, electronic components, battery), the number of suppliers, the distance between the supplier and distributor, recyclability, packaging weight, and more. These criteria vary from one country to another and from one continent to another. For example, the energy mix differs between France and Thailand. Nevertheless, an LCA would remain a necessary tool for comparison.

For a proper use of micro-sensors

ADVANTAGES	LIMITATIONS
Reduced bulk and size	Unreliable and inaccurate monitoring
Potentially modest cost	High sensitivity to variations in terms of temperature and humidity
Multiple uses (fixed, mobile, indoor/outdoor)	Rapid component aging, regular replacement required
Easy-to-read	Risk of misinterpreting data in the absence of guidance and regular calibration with a reference station
	For particulate matter sensors, inability to observe the finest particles (<300 nm) including ultra-fine particles

THE ADVANTAGES AND LIMITATIONS, AS WELL AS THE RELEVANT AND PROBLEMATIC USES OF

Sources: WMO, Anses, AIRLAB, LCSQA, Atmo France



MICRO-SENSORS, CAN BE DIFFERENTIATED ACCORDING TO THE MEASURED POLLUTANTS AND THEIR USE.

TO FIND OUT MORE

AIRPARIF

Airparif dossier #01 : Participatory projects
september 2020

Looking back on an experiment in citizen participation in monitoring and understanding air quality using micro-sensors

Airparif dossiers #02 : Particulate matter
april 2021
and
Airparif dossiers #06 : Ozone
july 2022

Explaining two main air pollutants

Airparif Dossier #05 : Health issues related to air pollution
march 2022

Deciphering the various health effect of air pollution

• **Micro-sensor comparison tool** based on the results of the AIRLAB Challenges www.airlab.solutions

From other institutions

• **An update on low-cost sensors for the measurement of atmospheric composition,** World Meteorological Organisation, December, 2020

• **AQ-SPEC,** air quality sensor performance evaluation center, South Coast Air Quality Management District, United States

• **Afri-SET,** air quality sensor evaluation and training centre for West Africa, Ghana

• **Captothèque,** Atmo Auvergne-Rhône-Alpes observatory

• **Atmo Hauts-de-France** observatory

• **Research Letter n°44,** ADEME, September 2023

• **Smoke and fire maps,** AirNow, US Environmental Protection Agency

• **Hazemon Project,** Thailand

• **1st national suitability test of micro-sensors (EAµC) for air quality monitoring: results summary,** *Laboratoire central de surveillance de la qualité de l'air*, November 2018

• **Using micro-sensors for monitoring indoor and outdoor air quality,** Anses, Mai 2022

“TAKING ACTION FOR CLEAN AIR IN A MORE SUSTAINABLE WORLD”

AIRPARIF