

A French certification scheme for the evaluation of sensor systems dedicated to the ambient air quality monitoring

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maîtriser le risque pour un développement durable

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Overall context

- Strong development of low-cost sensors
- In addition to traditional measurements, growing needs for:
 - real-time measurements
 - better spatial representativeness
- Big data applications:
 - collaboration between scientists
 - collaboration between scientists and user communities (e.g. cities)
 - citizen sciences
- But today: no applicable regulation in Europe, only a CEN technical specification for gaseous sensors systems since January 2022

Sensor system: a set of integrated hardware that uses one or more sensors to detect and/or measure a chemical concentration or quantity and is able to provide real-time measurements

Sensor system as a black-box:

- sensitive element
- other components and functions such as:
 - active or passive sampling
 - power systems, including batteries
 - analogue to digital conversion
 - signal processing
 - Iocal data storage
 - data transmission

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CEN/TC264/WG42 group, european discussion on the design of an **evaluation protocol for air quality sensor system**:

- A first document published in **January 2022** for **gas sensor systems**
- **Discussions** on **PM sensor systems** starting over in **2022**

2008/50/CE Air Quality Directive Data Quality Objectives

	Sulphur dioxide, nitrogen dioxide and oxides of nitro- gen and carbon monoxide	Benzene	Particulate matter (PM ₁₀ /PM _{2,5}) and lead	Ozone and related NO and NO ₂
Fixed measurements (1)				
Uncertainty	15%	25 %	25 %	15%
Minimum data capture	90 %	90 %	90 %	90 % during summer 75 % during win- ter
Minimum time coverage:				
— urban background and traffic	_	35 % (2)	_	_
— industrial sites	—	90 %	—	—
Indicative measurements				
Uncertainty	25 %	30 %	50 %	30 %
Minimum data capture	90 %	90 %	90 %	90 %
Minimum time coverage	14 % (4)	14% (3)	14 % (4)	> 10 % during summer
Modelling uncertainty:				
Hourly	50 %	_	_	50 %
Eight-hour averages	50 %	_	_	50 %
Daily averages	50 %	_	not yet defined	_
Annual averages	30 %	50 %	50 %	_
Objective estimation Uncertainty	75%	100 %	100 %	75%

French certification process INERIS - LNE

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Specific case of NO₂



French performance ratings

Assignment of a performance rating based on the results of laboratory and field tests as well as on the results of manufacturing audits.

The performance rating is based on the use of the system:

Category of data quality objectives defined in **the evaluation protocol MO-1347** and **Division A** compliant with the data quality objectives (uncertainty, minimum data capture) of **Indicative Measurement** as described in the Directive 2008/50/EC.

Category of data quality objectives defined in **the evaluation protocol MO-1347** and **Division B** compliant with the data quality objectives (uncertainty, minimum data capture) of **Objective Estimation** as described in the Directive 2008/50/EC.

Division C Category of data quality objectives defined in **the evaluation protocol MO-1347** but that are out of the scope of the Directive 2008/50/EC. For this division, the level of requirements on terms of uncertainty is only sufficient for citizen science studies, educational action, etc., defined as **Awareness Studies**.

The systems will be evaluated for a use in **ambient air quality monitoring at fixed site**, i.e. measurements taken outdoors using a stationary sensor system. For **particulate matter (PM)**, as the type of aerosol may vary depending on the measurement site typology, this certification covers **background site type**.





French certification



Area of validity:

- NO₂ and PM_{2.5} sensor systems
- sensor system dedicated to the measurement of ambient air quality
- at a fixed point
- entire sensor system as a **black-box**
- as commercially available

General principles:

- voluntary approach for manufacturers and retailers of sensor systems
- validation of the metrological performances of sensor systems
- classification of the performances of sensor systems





Laboratory evaluation facility

ΝΑΤΙΟΝΑΙ

DE MÉTROLOGIE ET D'ESSAIS



Laboratory evaluation criteria

			NO2	
		Division A	Division B	Division C
LABORATORY	Accuracy (slope)	0.7 ≤ p ≤ 1.3	0.5 ≤ p < 0.7 or 1.3 < p ≤ 1.5	p < 0.5 or p > 1.5
	Linearity (from 0 to 300 µg/m³)	R ² ≥ 0.75	$0.5 \le R^2 < 0.75$	R ² < 0.5
	Limit of detection	$LD \le 19 \ \mu g/m^3$	19 μg/m³ < LD ≤ 29 μg/m³	LD > 29 μg/m³
	Repeatability at 200 μg/m³	$r \le 7.6 \mu g/m^3$	7.6 μg/m³ < r ≤ 11.5 μg/m³	r > 11.5 μg/m³
	Influence of relative humidity (15% and 80%) at 200 µg/m ³	<i>Deviation</i> ≤ 20 μg/m³	20 µg/m ³ < <i>Deviation</i> ≤ 40 µg/m ³	<i>Deviation</i> > 40 μg/m ³
	Influence of ozone at 200 μg/m ³	Deviation ≤ 20 $\mu g/m^3$	20 μg/m ³ < <i>Deviation</i> ≤ 40 μg/m³	<i>Deviation</i> > 40 μg/m ³
	Drift at zero within 3 weeks	d _{zero} ≤ 20 μg/m³	20 μg/m³ < d _{zero} ≤ 30 μg/m³	d _{zero} > 30 μg/m ³
	Drift at span (PE) within 3 weeks at 200 µg/m ³	d _{pE} ≤ 10 %	10% < d _{pE} ≤ 15 %	d _{PE} > 15 %



d _{PE} > 15 %	PM _{2.5}		
	Division A	Division B	Division C
Accuracy (slope)	0.7 ≤ p ≤ 1.3	0.5 ≤ p < 0.7 or 1.3 < p ≤ 1.5	p < 0.5 or p > 1.5
Linearity (from 0 to 120 µg/m³)	R ² ≥ 0.75	$0.5 \le R^2 < 0.75$	R ² < 0.5
Limit of detection	LD ≤ 5 µg/m³	5 μg/m ³ < LD ≤ 10 μg/m ³	LD > 10 μg/m ³
Repeatability at 80 μg/m ³	r ≤ 5 μg/m³	5 μg/m³ < r ≤ 10 μg/m³	r > 10 μg/m³
Influence of relative humidity (15% and 80%) at 80 µg/m ³	Deviation \leq 10 µg/m ³	10 μg/m³ < <i>Deviation</i> ≤ 15 μg/m³	<i>Deviation</i> > 15 μg/m ³
Drift at zero within 3 weeks	d _{zero} ≤ 5 μg/m³	5 μg/m³ < d _{zero} ≤ 10 μg/m³	d _{zero} > 10 μg/m³
Drift at span (PE) within 3 weeks at 80 µg/m ³	d _{pE} ≤ 10 %	10% < d _{pE} ≤ 15 %	d _{pE} > 15 %



Field evaluation facility



- On request up to 2 weeks of acclimatisation / stabilisation
- 2 weeks of ambient air monitoring (gas and PM) with both sensor systems and reference measurement
- 1 week of gaseous enhanced matrix including the pollutant of interest (NO₂) and the main interferent (O₃)
- 1 week of PM enhanced matrix using nebulised salty water as PM source

INERIS

Field evaluation criteria

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		NO ₂		
		Division A	Division B	Division C
FIELD	Reproducibility (u(bs,s))	u(bs,s) < 7.6 µg/m³	u(bs,s) < 15 μg/m³	u(bs,s) < 31 µg/m³
	Slope	0.7 ≤ p ≤ 1.3	0.5 ≤ p < 0.7 or 1.3 < p ≤ 1.5	p < 0.5 or p > 1.5
	Linearity	R ² ≥ 0.75	$0.5 \le R^2 < 0.75$	R ² < 0.5
	MAPE	< 50%	from 50% to 100%	> 100%
DIR 2008/50/EC	Minimum data capture	≥ 90 %	from 14% to 90%	< 14%
	Field uncertainty (DQO@ 200µg/m³)	U ≤ 25 % (U ≤ 50µg/m³)	25% < U ≤ 75 % (50 < U ≤ 150μg/m³)	75% < U ≤ 200% (150 < U ≤ 400μg/m³)

		PM _{2.5}		
		Division A	Division B	Division C
FIELD	Reproducibility (u(bs,s))	u(bs,s) < 7.5 μg/m³	u(bs,s) < 15 μg/m³	u(bs,s) < 30 µg/m³
	Slope	0.7 ≤ p ≤ 1.3	0.5 ≤ p < 0.7 or 1.3 < p ≤ 1.5	p < 0.5 or p > 1.5
	Linearity	R ² ≥ 0.75	0.5 ≤ R ² < 0.75	R ² < 0.5
	MAPE	< 50%	from 50% to 100%	> 100%
DIR 2008/50/EC	Minimum data capture	≥ 90 %	from 14% to 90%	< 14%
	Field uncertainty (DQO@ 50µg/m³)	U ≤ 50% (U ≤ 25µg/m³)	50 < U ≤ 100% (25 < U ≤ 50μg/m³)	100 < U ≤ 200% (50 < U ≤ 100μg/m³)



French certification

Notation scheme, from single evaluation to a group notation by type of tests







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/3 rule

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- 1st certification which exists and which allows performance to be assessed against the data quality objectives of the EU Directive
- Evaluation by independent and impartial laboratories according to a validated protocol
- Supplementary argument to be used in the framework of calls for tenders
- Audit-based production monitoring that guarantees the repeatability of a production and the quality of the device over time







A first certification protocol for the evaluation of sensor systems dedicated to the ambient air quality monitoring

Thank you

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