CIM2021 - Green deal challenges for Chemistry

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

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IN MEASUREMENT WE TRUST

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 regulations nor regulatory evaluation scheme

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
  - ❖ local 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 to be published at the **end of 2021** for **gas sensor systems**
- **Discussions** on **PM sensor systems** starting over in **2021/2022**

2008/50/CE Air Quality Directive Data Quality Objectives

	Sulphur dioxide, nitrogen dioxide and oxides of nitrogen 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 winter
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 context: to a volunteer certification process

Specific case of NO_2

		EU - NO_2	CEN
Fixed measurement	Uncertainty	15%	
	Data capture	90%	
	Minimum time coverage	-	
Indicative measurement	Uncertainty	30%	Class 1
	Data capture	90%	
	Minimum time coverage	10%	
Objective estimation	Uncertainty	75%	Class 2
Informative measurement	Uncertainty	200% CEN	Class 3
Outside EU AQD and CEN	Uncertainty	> 200%	No Class

French certification process INERIS - LNE

INERIS LNE

Division A

Division B

Division C

No certificat

AiR QUALITY SENSOR

French certification: 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:

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

- NO_2 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:

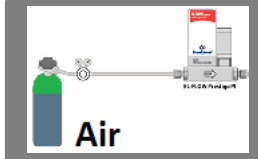
- voluntary approach for manufacturers and retailers of sensor systems
- validation of the metrological performances of sensor systems
- classification of the performances of sensor systems

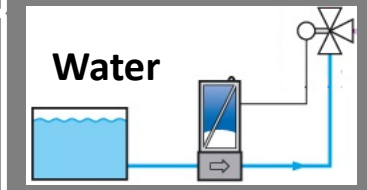
French certification: Laboratory evaluation facility

Generation

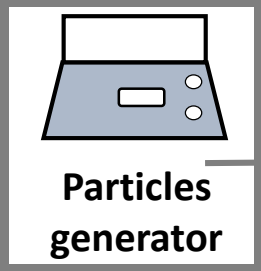
Gas mixtures

Dilution air controled in relative humidity





PM



Exposure chamber with low cost sensors

Reference measurements

Analysers gas & PM

- ✓ Accuracy (Slope)
- ✓ Linearity (R^2)
- ✓ Repeatability
- ✓ Limit of detection (LD)
- ✓ Pseudo long term drift (between 3 weeks and 1 month)
- ✓ Ozone influence in the case of NO_2
- ✓ Relative humidity interference

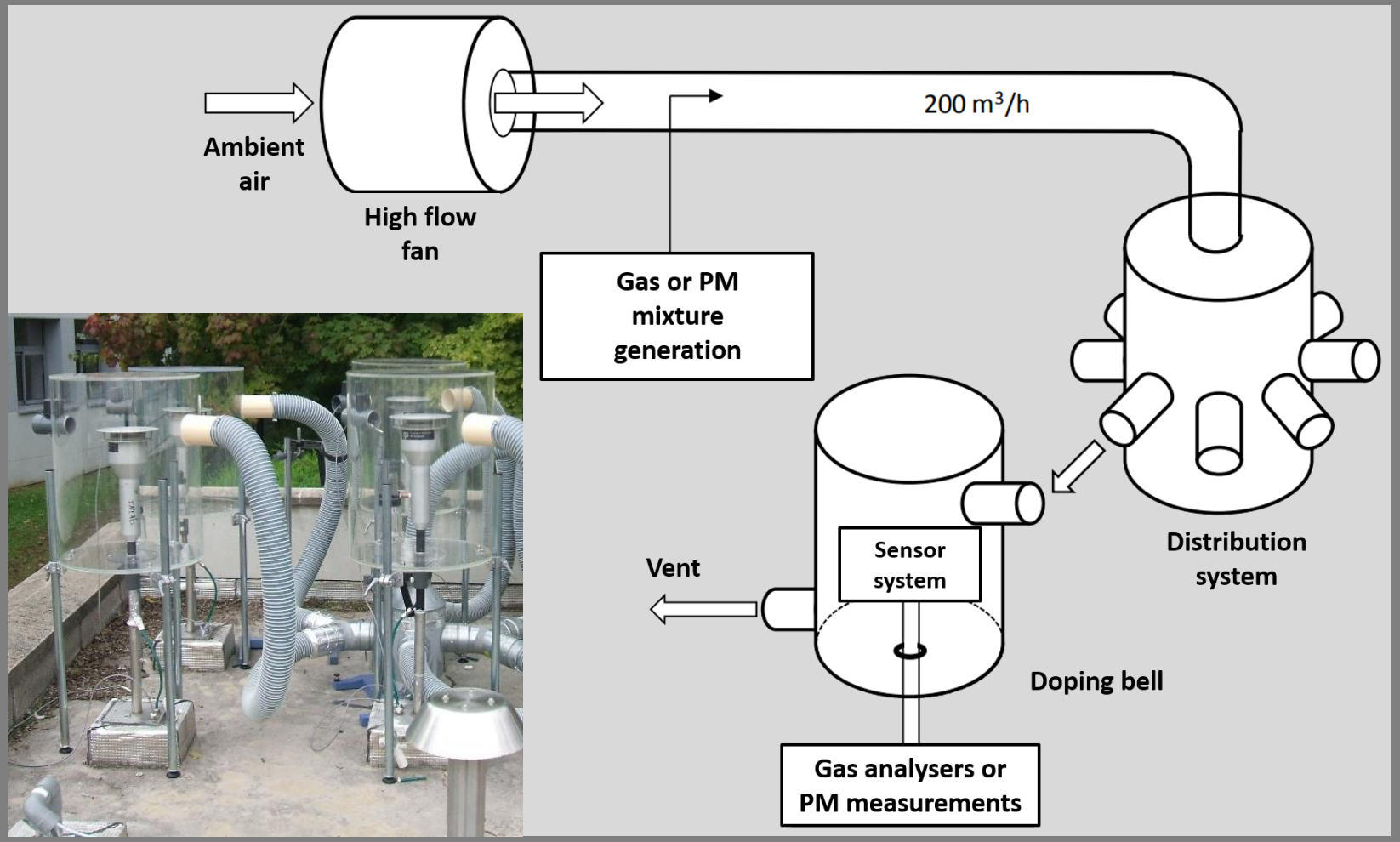
The results of this assessment carried out by the manufacturer or another laboratory commissioned by the manufacturer can be taken into account after evaluation *cf §6.3 PR-1053*

French certification: Laboratory evaluation facility

	NO_2		
	Division A	**Division B**	**Division C**
Accuracy (slope)	$0.7 \le p \le 1.3$	$0.5 \le p < 0.7$ or $1.3 < p \le 1.5$	$p < 0.5$ or $p > 1.5$
Linearity (from 0 to 300 µg/m³)	$R^2 \ge 0.75$	$0.5 \le R^2 < 0.75$	$R^2 < 0.5$
Limit of detection	$LD \le 19$ µg/m³	19 µg/m³ $< LD \le 29$ µg/m³	$LD > 29$ µg/m³
Repeatability at 200 µg/m³	$r \le 7.6$ µg/m³	7.6 µg/m³ $< r \le 11.5$ µg/m³	$r > 11.5$ µg/m³
Influence of relative humidity (15% and 80%) at 200 µg/m³	*Dev.* ≤ 20 µg/m³	20 µg/m³ < *Dev.* ≤ 40 µg/m³	*Dev.* > 40 µg/m³
Influence of ozone at 200 µg/m³	*Dev.* ≤ 20 µg/m³	20 µg/m³ < *Dev.* ≤ 40 µg/m³	*Dev.* > 40 µg/m³
Drift at zero within 3 weeks	$d_{zero} \le 20$ µg/m³	20 µg/m³ $< d_{zero} \le 30$ µg/m³	$d_{zero} > 30$ µg/m³
Drift at span (PE) within 3 weeks at 200 µg/m³	$d_{PE} \le 10$ %	10% $< d_{PE} \le 15$ %	$d_{PE} > 15$ %

	$PM_{2.5}$		
	Division A	**Division B**	**Division C**
Accuracy (slope)	$0.7 \le p \le 1.3$	$0.5 \le p < 0.7$ or $1.3 < p \le 1.5$	$p < 0.5$ or $p > 1.5$
Linearity (from 0 to 120 µg/m³)	$R^2 \ge 0.75$	$0.5 \le R^2 < 0.75$	$R^2 < 0.5$
Limit of detection	$LD \le 5$ µg/m³	5 µg/m³ $< LD \le 10$ µg/m³	$LD > 10$ µg/m³
Repeatability at 80 µg/m³	$r \le 5$ µg/m³	5 µg/m³ $< r \le 10$ µg/m³	$r > 10$ µg/m³
Influence of relative humidity (15% and 80%) at 80 µg/m³	*Dev.* ≤ 10 µg/m³	10 µg/m³ < *Dev.* ≤ 15 µg/m³	*Dev.* > 15 µg/m³
Drift at zero within 3 weeks	$d_{zero} \le 5$ µg/m³	5 µg/m³ $< d_{zero} \le 10$ µg/m³	$d_{zero} > 10$ µg/m³
Drift at span (PE) within 3 weeks at 80 µg/m³	$d_{PE} \le 10$ %	10% $< d_{PE} \le 15$ %	$d_{PE} > 15$ %

French certification: 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 (NO_2) and the main interferent (O_3)
- ✓ 1 week of PM enhanced matrix using nebulised salty water as PM source

French certification: Field evaluation facility

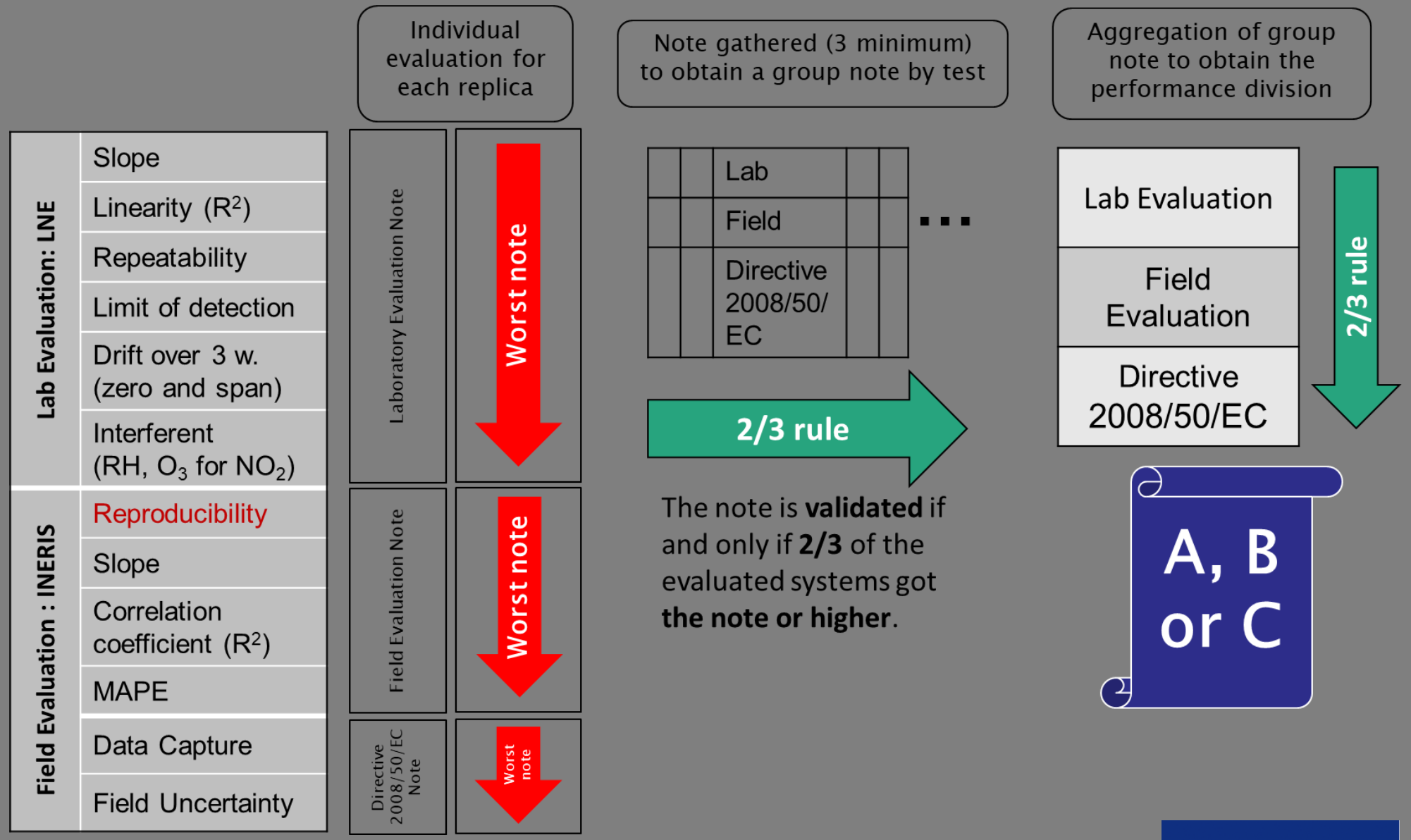
		NO_2		
		Division A	**Division B**	**Division C**
FIELD	**Reproducibility (u(bs,s))**	u(bs,s) < 7.6 µg/m³	u(bs,s) < 15 µg/m³	u(bs,s) < 31 µg/m³
	Slope	0.7 ≤ p ≤ 1.3	0.5 ≤ p < 0.7 or 1.3 < p ≤ 1.5	p < 0.5 or p > 1.5
	Linearity	R^2 ≥ 0.75	0.5 ≤ R^2 < 0.75	R^2 < 0.5
	MAPE	< 50%	from 50% to 100%	> 100%
DIR 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)

INERIS

French certification: notation scheme

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



Benefits of certification for manufacturers and users

- ✓ 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.
- ✓ Pedagogical support and guidance in the selection of sensor systems.

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Thank you

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