PERFORMANCE EVALUATION OF SENSORS FOR GASEOUS POLLUTANTS AND PARTICULATE MATTER MONITORING IN AMBIENT AIR

CEN TC 264 WG 42 protocol for sensors

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Technical Specification for Sensors

-**Main question**: can low-cost sensors meet prescribed data quality objectives of the European Air Quality Directive

-**Expected result**: a protocol describing specific performance requirements and test methods under prescribed laboratory and field conditions

Technical Specification for Sensors

The TS on air quality sensors is split into two parts "Air quality – Performance evaluation of air quality sensors":

-**Part 1**: Gaseous pollutants in ambient air for O_3, NO_2 and NO, CO, SO_2, benzene and CO_2.

-**Part 2**: Particulate matter in ambient air (NWI proposal should be prepared) for PM10 and PM2.5.

Technologies considered in the protocol

-**PM_{10} and $PM_{2.5}$**: Laser based particle counters and nephelometers.

-**O_3, NO_2, NO, CO and SO_2**: electrochemical sensors (potentiometric and amperometric), metal oxide sensors (SnO2, WO3 …).

-**CO and CO_2**: Infra-red cells.

-**Benzene and other VOCs**: MOx, FID, mini GCs.

CEN WG 42 Technical Specification

3 sensor categories, class 1 and 2 are linked with the Air Quality Directive (AQD)

Class 1 sensor system
measuring device delivering measurements that are consistent with the **Data Quality Objectives of indicative methods** set in the AQD

Class 2 sensor system
measuring device delivering measurements that are consistent with the **Data Quality Objectives of objective estimations** set in the AQD

Class 3 sensor system
measuring device delivering measurements that are **not formally associated with any mandatory target measurement uncertainty**

Technical Specification for sensors - method

Gas sensors:

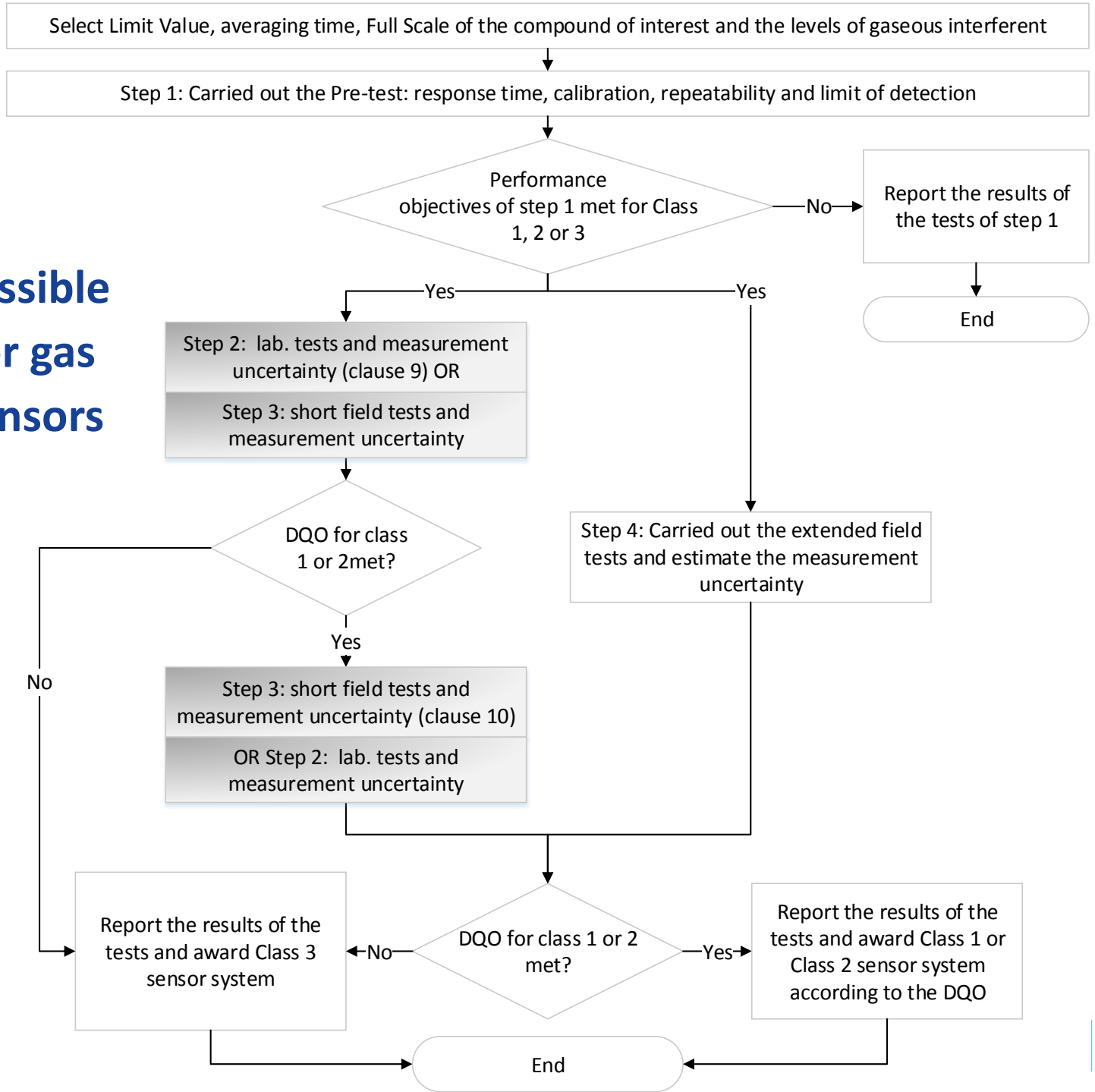
- A lab. pre-test is required to check linearity, response time and limit of detection
- Two routes are feasible for the classification of sensors:
  - perform a list of laboratory tests in exposure chamber using synthetic gas mixture plus a short field test programme
  - or only perform an extended field test programme

PM sensors:

- Check flow rate, effect of temperature and power supply in lab.
- Perform an extended field test programme.

The field tests of gas and PM sensors are evaluated with the method of the "Guide for the Demonstration of Equivalence". More stringent performance criteria for the best class.

Possible for gas sensors



Data Quality Objective – Air Quality Direct.

	Averaging time	LV	DQO of Class 1 sensor system	DQO of Class 2 sensor system
	h / year	µg/m³	µg/m³ (%)	µg/m³ (%)
PM_{10}	24 h	50	25 (50%)	50 (100 %)
$PM_{2.5}$	24 h	30	15 (50 %)	30 (100 %)
NO_2	1 h	200	50 (25 %)	150 (75 %)
O_3	8 h	120	36 (30 %)	90 (75 %)
CO (mg/m³)	8 h	10	2.5 (25 %)	7.5 (75 %)
SO_2	1 h	350	87.5 (25 %)	262.5 (75 %)
SO_2	24 h	125	31.3 (25 %)	93.8 (75 %)
Benzene	1 year	5	1.5 (30 %)	5 (100 %)

Tests to be performed for the evaluation of gas sensors in laboratory or at field sites	Class 1	Class 2	Class 3
1: Response time	Lab.	Lab.	Lab.
1: Calibration	Lab.	Lab.	Lab.
1: Repeatability, limit of detection	Lab.	Lab.	Lab.
2: Short and long term drifts	Lab	Lab.	
2: Cross sensitivities by gaseous interfering compounds	Lab.	Lab.	
2: Humidity effect	Lab.	Lab.	
2: Temperature effect	Lab.	Lab.	
2: Hysteresis of sensor for the main pollutant	Lab.	Lab.	
2: Hysteresis effect when changing the level of temperature and humidity	Lab.	Lab.	
2: Transient effects of rapid changes of humidity (chemical sensors only)	*Field*	*Field*	
2: Wind velocity effect (**Not mandatory**)	Lab.	Lab.	
2: Pressure effect on sensor based on IR (**Not mandatory**)	Lab.	Lab.	
2: Electromagnetic fields (**Not mandatory**)	Field	Field	
2: Power supply (**Not mandatory**)	Lab.	Lab.	
3 and 4: short or extended field	Field	Field	Field

Examples of performance requirements

			Class 1 sensor systems	Class 2 sensor systems	Class 3 sensor systems
1	Response time		*background site*: t_{90}< 1/3 of averaging time *traffic site*: t_{90} < 1/10 of averaging time (generally 1h)	*background site*: t_{90}< 1/4 of averaging time	*background site*: t_{90}< 1/4 of averaging time
1	Calibration		U(lof) < 8 %	U(lof) < 12 %	U(lof) < 12 %
1	Repeatability (r) µg/m³ , limit of detection (LOD) µg/m³	O3, NO, …	r ≤ 8.0, LOD ≤ 20 r ≤ 5.0, LOD ≤ 12.5 …	r ≤ 12, LOD ≤ 30 r ≤ 7.5, LOD ≤ 18.7 …	r ≤ 12, LOD ≤ 30 r ≤ 7.5, LOD ≤ 18.7 …

Data Quality Objective – Air Quality Direct.

	Averaging time
Parameters	Standard uncertainties
lack of fit of calibration function	u(lof)
Long term drift	$u(D_{LD})$
Temperature effect	$u(X_T)$
Humidity Effect	$u(X_{RH})$
Cross sensitivities from gaseous interferents	u(int)
Hysteresis of the test gas	$u(h_X)$
Hysteresis of humidity	$u(h_{XRH})$
Hysteresis of temperature	$u(h_{XT})$

Optional tests: wind velocity, pressure, electromagnetic fields and power supply effects

Number of field sites

Compound	Areas			Site		Short field test	Extended field test
	Urban	Suburban	Rural	Traffic	Background	Total number of sites	Total number of sites
NO2	+	+		+	+	4	8
NO	+	+		+	+	4	8
O3	+		+		+	2	4
CO	+			+	+	2	4
SO2	+				+	1	2
Benzene	+			+		1	2
CO2			+		+	1	2

Unresolved issues

- Difficult agreement between the costs of testing and sensor evaluation reflecting all gas composition and meteo conditions found in EU
- Current proposal for the number of gas sensors field tests:
  - up to 4 if the full laboratory tests is performed
  - up to 8 without performing the full laboratory tests

  We are looking for possibility to decrease these numbers
- For PM sensors: difficult to check flow stability, leaks, temperature and power supply drift -> no pneumatic system
- It seems contradictory to require more tests for PM low- cost sensors than for AMS as in EN 16450
- More evaluation studies are needed for avoiding setting unrealistic test conditions and performance criteria