



The road to developing performance standards for low cost sensors in Europe

Part2: application to the CEN TC 264 WG 42 protocol for low cost sensors

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Workshop Deliberating Performance Targets for Air Quality 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 O₃, NO₂ and NO, CO, SO₂, benzene and CO₂.
- Part 2:** Particulate matter in ambient air (NWI proposal should be prepared) for PM10 and PM2.5.

Technologies considered in the protocol

- PM₁₀ and PM_{2.5}**: Laser based particle counter and nephelometer.
- O₃, NO₂, NO, CO and SO₂**: electrochemical sensors (potentiometric and amperometric), metal oxide sensors (SnO₂, WO₃ ...).
- CO and CO₂**: Infra-red cells.
- Benzene and other VOCs**: MOx, FID, mini GCs.

CEN WG 42 Technical Specification

3 sensor categories

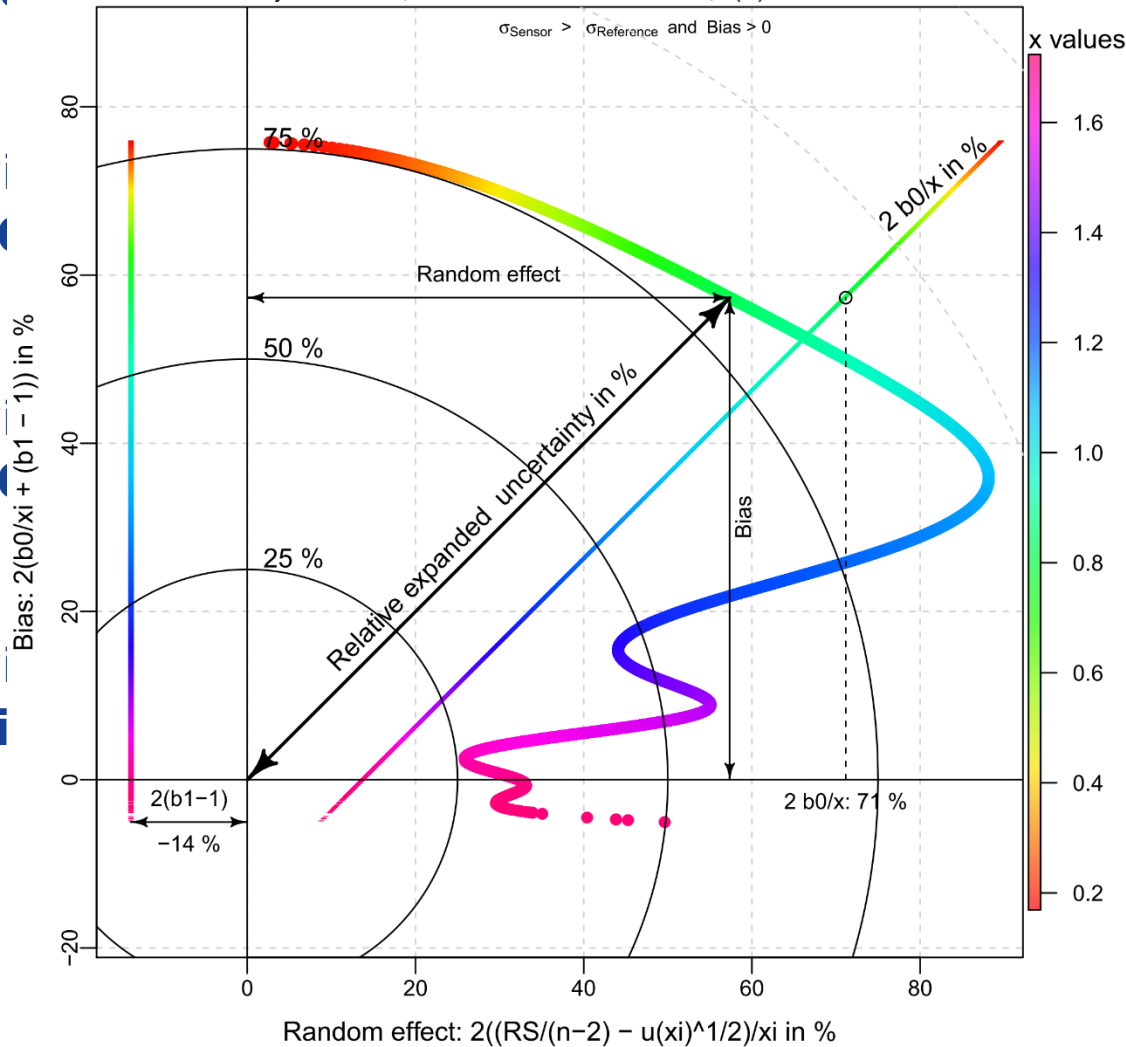
Class 1 sensor
measuring device
Data Quality (DQ)

Class 2 sensor
measuring device
Data Quality (DQ)

Class 3 sensor
measuring device
associated with

COA4 – Target Diagram – Relative expanded uncertainty

$y = b_0 + b_1 x$, with $b_0 = 0.076$ and $b_1 = 0.93$, $u(x_i) = 0.050$



Quality Directive

Compliant with the AQD

Compliant with the AQD

Highly accurate

Technical Specification for sensors - method

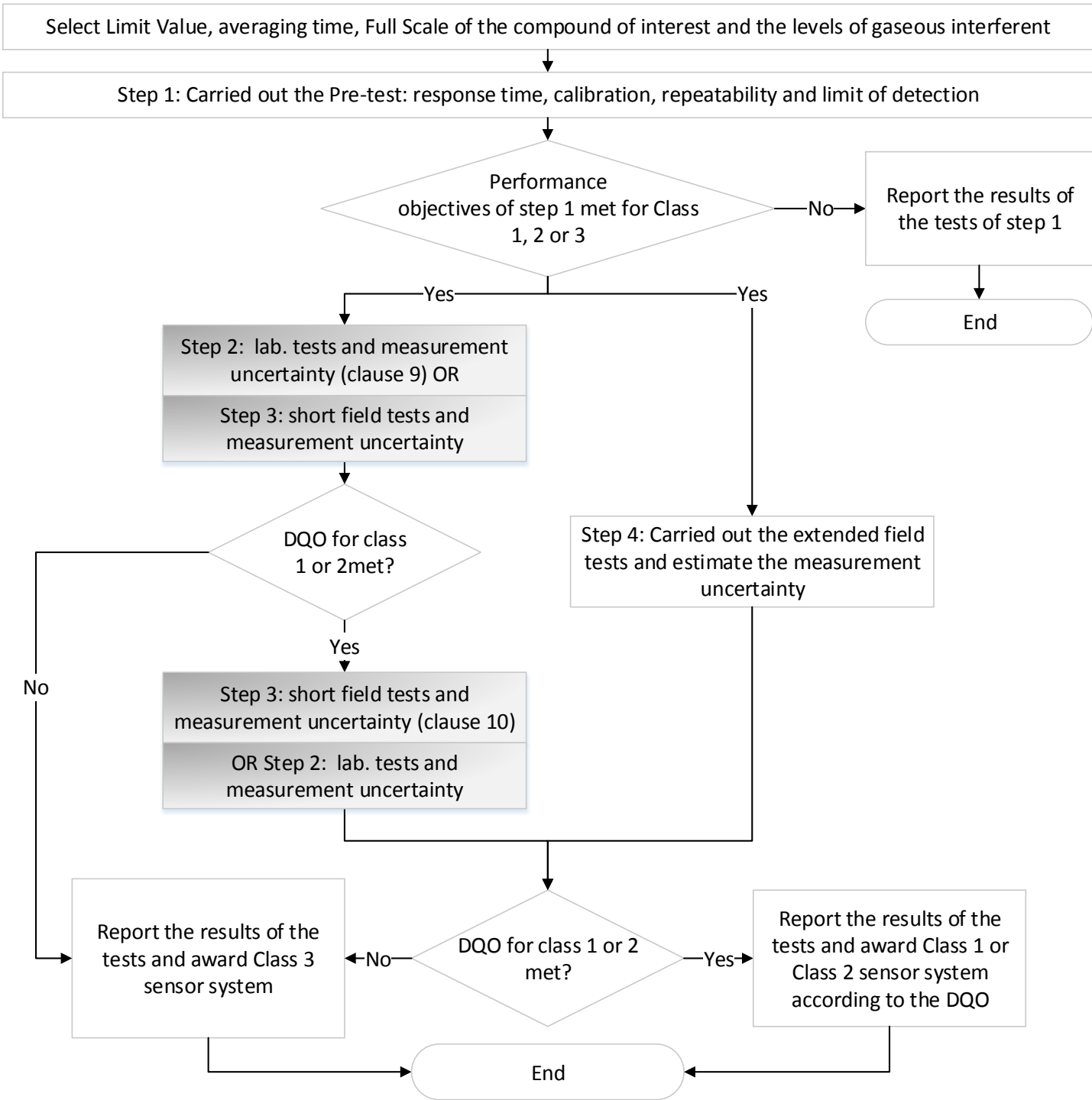
Gas sensors:

- 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.



Data Quality Objective – Air Quality Direct.

	Averaging time	LV	DQO of Class 1 sensor system	DQO of Class 2 sensor system
	(h / year)	($\mu\text{g}/\text{m}^3$)		
SO₂	1 h	350	87.5 (25 %)	262.5 (75 %)
SO₂	24 h	125	31.3 (25 %)	93.8 (75 %)
NO₂	1 h	200	50 (25 %)	150 (75 %)
NO₂	1year	40	10 (25 %)	30 (75 %)
NO_x	1year			
CO (mg/m^3)	8 h	10	2.5 (25 %)	7.5 (75 %)
O₃	8 h	120*	36 (30 %)	90 (75 %)
O₃	1 h			
Benzene	1 year	5	1.5 (30 %)	5 (100 %)

Tests to be performed for the evaluation of 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. or Field	Lab. or Field	
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 change of humidity (chemical sensors only)	Field	Field	
2: Wind velocity effect (informative)	Lab.	Lab.	
2: Pressure effect. This test is mandatory for sensor based on IR (informative)	Lab.	Lab.	
2: Electromagnetic fields (informative)	Field	Field	
2: Power supply (informative)	Lab.	Lab.	
3 and 4: short or extended field	Lab. or field	Lab. or field	Lab. or field

Examples of performance requirements

Steps		Class 1 sensor systems	Class 2 sensor systems	Class 3 sensor systems
1	Response time	$t_{90} < 1/10$ of averaging time (generally 1h) at traffic site or $t_{90} < 1/3$ of averaging time (generally 1h) at background sites	$t_{90} < 1/4$ of averaging time (generally 1h) at background sites	$t_{90} < 1/4$ of averaging time (generally 1h) at background sites
1	Calibration	U(lof) < 8 %	U(lof) < 12 %	U(lof) < 12 %
1	Repeatability (r), limit of detection (LOD)	O ₃ , NO, ... $r \leq 8.0$, LOD ≤ 20 $\mu\text{g}/\text{m}^3$ $r \leq 5.0$, LOD ≤ 12.5 $\mu\text{g}/\text{m}^3$...	$r \leq 12$, LOD ≤ 30 $\mu\text{g}/\text{m}^3$ $r \leq 7.5$, LOD ≤ 18.7 $\mu\text{g}/\text{m}^3$...	$r \leq 12$, LOD ≤ 30 $\mu\text{g}/\text{m}^3$ $r \leq 7.5$, LOD ≤ 18.7 $\mu\text{g}/\text{m}^3$...

Data Quality Objective – Air Quality Direct.

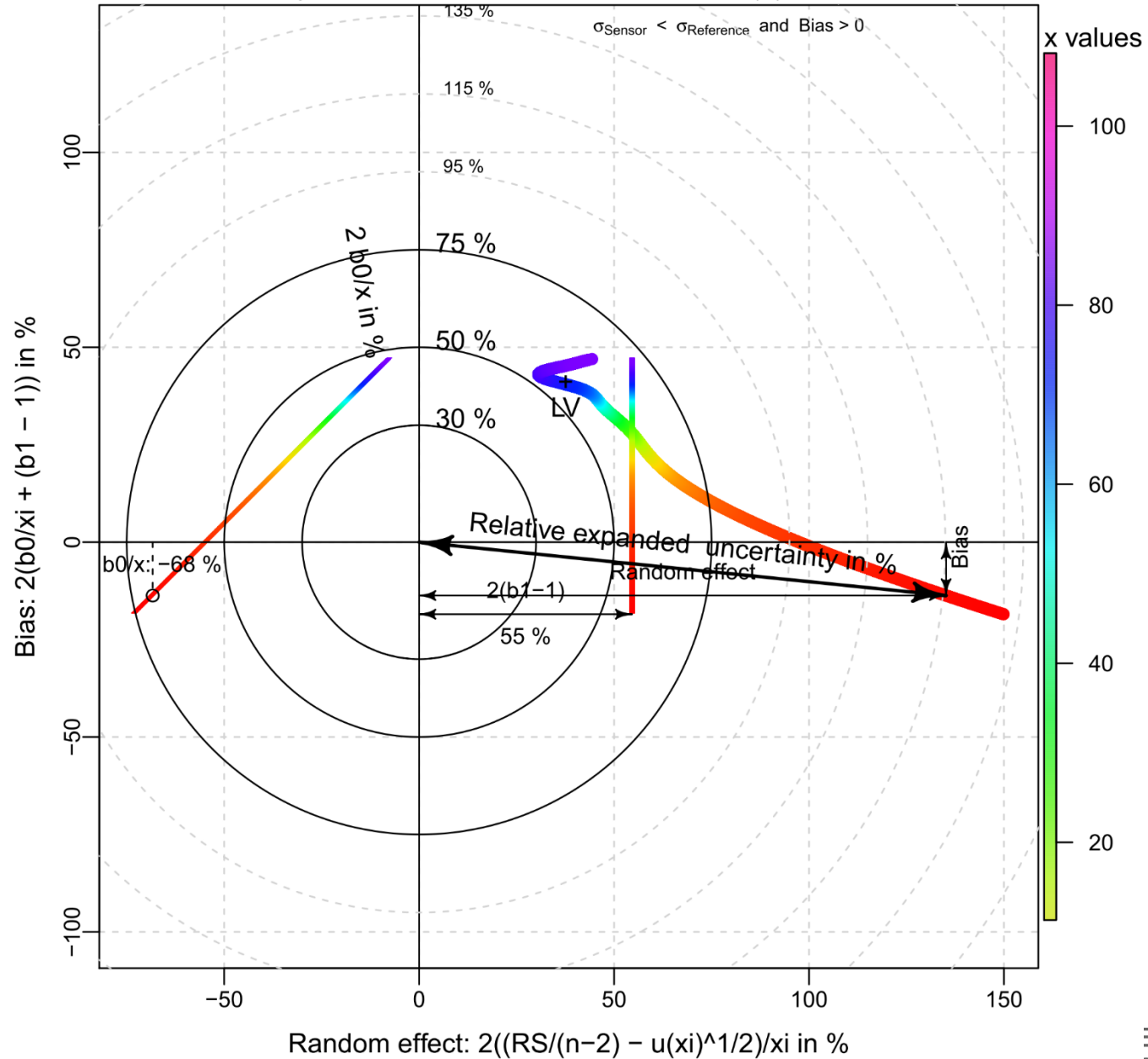
Averaging time	
Parameters	Standard uncertainties
lack of fit of calibration function	$u(\text{lof})$
Long term drift	$u(D_{LD})$
Temperature effect	$u(X_T)$
Humidity Effect	$u(X_{RH})$
Cross sensitivities from gaseous interferents	$u(\text{int})$
Hysteresis of the test gas	$u(h_X)$
Hysteresis of humidity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

Number of field sites

Compound	Areas				Sit		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	

O3_M5 – Target Diagram – Relative expanded uncertainty

$y = b_0 + b_1 x$, with $b_0 = -4.1$ and $b_1 = 1.27$, $u(x_i) = 0.0$



Unresolved issues

- Difficult to find an agreement/equilibria between the costs of testing and the need of sensor evaluation reflecting all gas composition and meteo conditions found in EU.
- Number of field extended tests when the full list of laboratory tests is not performed: current proposal is 12 sites for class 1 and 6 sites for class 2 gas sensors. The WG is looking for possibility to decrease these numbers.
- For PM sensors: difficult to implement the flow stability, leak test, temperature and power supply drift tests with low-cost PM sensors.
- It seems contradictory to require more tests for PM low-cost sensors than for AMS as requested in EN 16450

Unresolved issue

- Results of evaluation studies are needed for drafting the TS, avoiding setting unrealistic test conditions and performance criteria for O₃, NO₂, NO, CO, CO₂, SO₂ and PM sensors

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