Workshop on Implementation of BAT Conclusions for Waste Incineration

Puzzle piece 4: measurement uncertainty

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Summary

- Where it started
- Twofold strategy
  - Data collection
  - INERIS report
- Compliance rules
- Current developments at EU level

A journey of discovery

Suitable equipment → Correctly set-up → Ongoing check of correct functioning

Quality Assurance Level 1 – QAL1 → Quality Assurance Level 2 – QAL2 → Quality Assurance Level 3 – QAL3

Quality Assurance Level 2 – QAL2 → Annual Surveillance Test - AST

A journey of discovery – QAL2

- QAL2 calibration function established from the results of a number of parallel measurements performed with a SRM.
- This involves minimum 15 valid measurements (see 6.3 of EN 14181).
- It is **not sufficient to use the measurement of reference materials** (e.g. gases of known composition = "span gases") to obtain the calibration function: potentially interfering flue gas components and the representativeness of sampling points cannot be assessed appropriately by using reference materials alone.
- It is important that the **concentrations during calibration are as close as possible to the expected concentrations**.
- Note that as described for QAL1, **EN 14181 refers to ELVs**.
- Variability calculated as the standard deviation of the differences between each concentration value obtained by the AMS and corresponding values obtained by the SRM measured in parallel.

A journey of discovery – QAL2

EN 14181 states that the AMS passes the variability test if:

$$S_D \leq \sigma_0 \cdot k_v$$

$$\sigma_0 = \frac{p \cdot ELV}{1.96}$$

- s_D is the standard deviation of the differences between AMS readings and corresponding SRM readings in parallel measurements;
- k_V test value for variability, for 15 parallel measurements is 0.976;
- σ_0 is the standard deviation associated with the uncertainty laid down by the authorities. In this case, the uncertainty in the IED is defined as a fixed percentage *p* of the ELV as half length of a 95% confidence interval (see IED, Annex VI Part 6).

The variability test gives the green light for the AMS. And it depends on the uncertainty defined by the authorities, which means a % of the ELV.

A journey of discovery – QAL2

June 2013

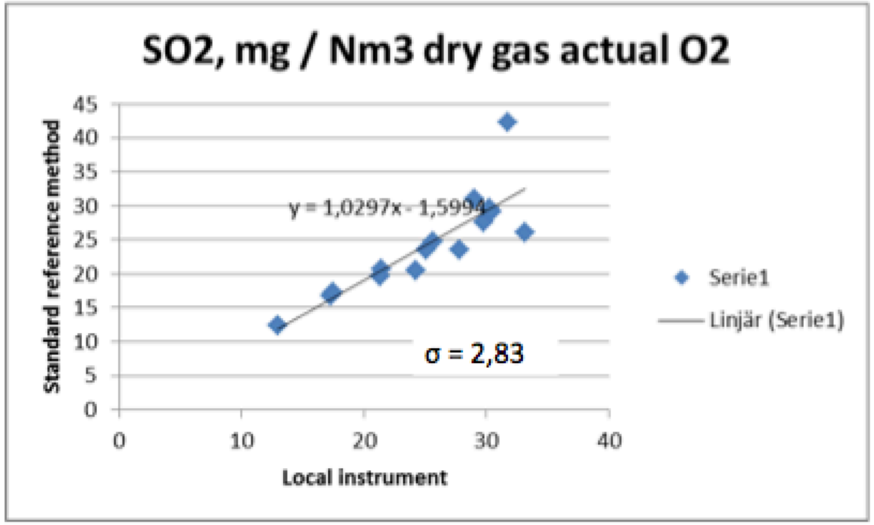
Tekniska verken

Spread is inevitable – what is the limit?

$ELV_{min} = 1{,}96 * \sigma / P$

ELV_{min} = 27,8 mg / normal m3, 11 % O2

A lower ELV than this would have caused this calibration to fail!



A journey of discovery – QAL2

Twofold strategy

For BREF data collection

Request that the parameters from QAL2 be included in the questionnaire.

To assess correlation between ELV and uncertainty

Study commissioned to INERIS.

BREF data collection

Structure of the questionnaire

The annex questionnaire is divided into 3 main sheets; the first one is a very short recap of a few plant characteristics and other information having particular relevance for the data structure of this annex questionnaire; the other two are intended for entering the 2014 values of AMS monitoring data, in the form of 10 minutes averages for CO and of 1/2 hourly averages for the other pollutants covered. All concentration data shall be reported at the reference temperature of 273,15 K, pressure of 101,3 kPa, after correcting for the water vapour content of the waste gases (dry basis), and standardised at 11 % reference oxygen level in the waste gas without subtraction of the confidence interval. AMS data shall be reported as calibrated according to standard EN14181.

- *General information and layout*
- *Half-hourly averages of emissions of pollutants to air*
- *10-minute averages of CO emissions to air*

Reasoning: collecting data before the subtraction assuming that this makes them comparable with regards to uncertainty (or that a same large uncertainty covering all cases will be applied afterwards)

Does it? In-situ calibration greatly influences the readings of the AMS. No QAL2 parameter was collected…

Instrument readings vs. true value - impact of uncertainty

- Current situation:
  - Very low emissions
  - High uncertainties
  - There is a margin to the ELV
- Future situation:
  - Very low emissions
  - High uncertainties
  - **<u>But NO MARGIN to the ELV</u>**

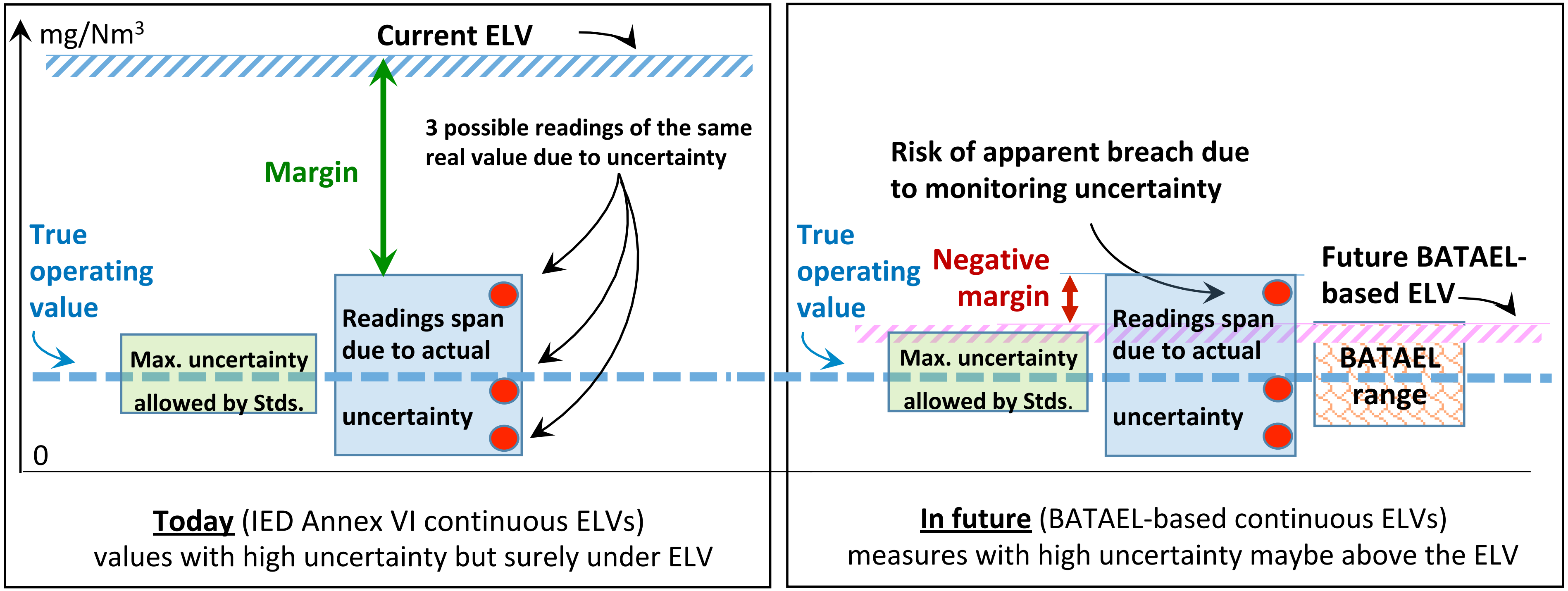


Figure 2: Schematic diagram. The Y-axis shows emission concentration. The height of the green boxes shows the uncertainty requested by the monitoring standards that should be complied with according to both IED Annex VI and the WI BAT conclusions. The real uncertainties as reported by INERIS correspond to the height of the blue boxes. The blue dashed line represent the true value (which in real life is neither known nor a constant). The red dots show 3 readings in the real uncertainty range. With the current IED Annex VI ELV, thanks to the margin between the ELV and the operating value, the operator and the regulator are certain that the values – even though not exact – are below the ELV (as shown on the left hand drawing). On the right hand side, it can be seen (e.g. with dot n° 3) that it might not be possible to ensure that the real value (although well below the ELV in the example) as read by the monitoring system is actually below the BATAEL-based ELV..

Correlation ELV-uncertainty

INERIS to investigate firstly the relation between required uncertainty and consequent ELV and more in general uncertainty and concentration.

Question: Is it possible with the monitoring systems available today or soon

- to comply with the requirements on uncertainties of
  - the IED
  - the EN standards (required by IED and BAT conclusions)
- at the level of ELVs set at the level of BATAELs?

Study commissioned by CEWEP, ESWET&FEAD during the review to start the discussion from a scientifically sound basis and involve monitoring experts

The aim was to find the minimum ELVs allowing to comply with the requirements of the standards in respect of uncertainty or to provide an estimation of the uncertainty associated to BATAEL ranges that would be available for permitting authorities.

INERIS Report on uncertainty

Starting points:

- Measurement **uncertainty** is a parameter associated with the measurement **result**, which characterizes the **dispersion** of values that may be attributed to the **measurand** (quantity to be measured: concentration, flow, etc.).
- To determine this uncertainty, a precise definition of the measurand is necessary, as well as the knowledge of all parameters that can influence.
- This parameter characterizes the quality of the measuring system implemented to determine the measurand.

INERIS Report on uncertainty

To **guarantee this quality**:

- the European Commission has fixed **maximum uncertainties** for emission values measured by plants to control and monitor their emissions and has **mandated CEN** to define the necessary quality assurance levels (QAL1, **QAL2, QAL3 and AST** of EN 14181).
- each **SRM** (Standard Reference Method) used for periodic measurements or calibration of online instruments, AMS (Automated Measuring Systems), has **to meet a fixed maximum uncertainty objective set in the relevant standard.**"

"The compliance with these objectives must be demonstrated at the lowest emission limit value which applies to the plant where the characterization takes place." (i.e. daily ELV for WI plants) (see INERIS report, § 2.1)

INERIS Report on uncertainty

Possible methods to assess uncertainty:

- GUM (Guidance on Uncertainty of Measurements): wider range of variations // Only addresses a part of the chain, the online instrument (AMS*)
  → **very low uncertainties**
  This is the method referred to by the EIPPCB

- ILC (Inter-Laboratory Comparison): Addresses most parts of the measuring chain (SRM, AMS, DAHS, human factors) // Real life
  → **Much higher uncertainties**
  Relevant method to cover all uncertainty sources

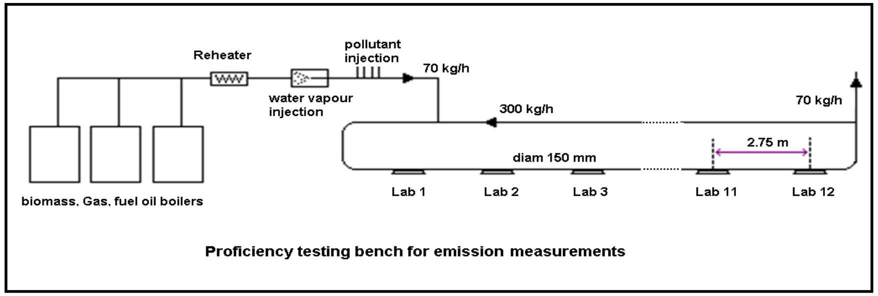
	GUM	ILC
Applies to	One measuring system at a time, fulfiling the requirement of uncertainty of the standard reference methods (SRMs) or to be used for self-monitoring (AMSs) Applies to any concentration	Several measuring systems fulfiling requirements of uncertainty for standard reference methods (SRMs), implemented in parallel by several control laboratories. Could be applied as well to AMS, even if not done up to now because not required by the standard and difficult to implement. Applies to any concentration
Method	'Quadratic Sum' of a list of standard uncertainties (equal to the sum of variances) corresponding to standardized ranges of variation of several factors (voltage, …) See EN 15267-3 and EN ISO14956	Dispersion of measured values obtained by different measuring systems and accredited teams on a same flue gas. See ISO 5725
Completeness	**Does not include uncertainties due to sampling, DAHS (Data Acquisition and Handling System), nor the ones due to human factors. For AMS it also does not include the uncertainty of the SRM which is used for the calibration of the AMS.**	**Includes all sources of uncertainties but does not cover the full ranges of variation of the factors covered in GUM.**
Pros	Possibility to see the relative influence of the different components of standardised uncertainty components.	**Provides an overview of the overall uncertainties.** **Considers the influence of human factors, of using different equipment and of DAHS (Data Acquisition and Handling System).**
Cons	**Does not consider the uncertainties due to human factor, variability of equipment and DAHS (Data Acquisition and Handling System), nor, for AMS, the uncertainty of the SRM used to calibrate the AMS.** Need to model the measurement to identify influence parameters of measurement and relationship between these parameters and the measurand. Necessity to be able to quantify the performance characteristics, including the effect of influencing quantities.	Availability of ILCs on representative matrices on all parameters. (a real matrix with hot and wet conditions is highly recommended). No possibility to quantify the individual contribution of each influence parameter or metrological performance.
Findings	**Shows often low uncertainty values compared to the ILCs approach**	**Shows significant higher uncertainty values (when ILCs are carried out on actual flue gases)**

INERIS Report on uncertainty

Data on actual uncertainty of SRMs provided by Inter-Laboratory Comparisons during laboratories accreditation (ISO CEI 17043)

INERIS Test facility:

Inter-laboratory comparison on real gas



- The bench is designed to generate gaseous effluents of identical composition for each of the **12 sampling ports**. Prior to their introduction in the loop, **the gases provided by combustion** in one of the three boilers fueled with gas, light fuel oil or biomass **can be**, if necessary, **heated, moistened and enriched by some pollutants injected** through a generation system with mass-flow controllers (CO, NO, SO_2, HCl, HF, CH_4, C_3H_8, etc.) or liquid (specific VOC, Hg) **to simulate gas matrices very similar to those of industrial facilities burning fuels or waste**.
- The concentration levels generated are **monitored by a FTIR which allows to adjust the level of concentrations**. The generated gases enter in a loop made of steel, internally protected by a PFA coating, where a 400 kg/h flow-rate circulates. This loop is maintained in temperature by electric tracing . The inside diameter of the duct is 150 mm.

- *FTIR: Fourier Transform InfraRed spectrometer*

INERIS is accredited by COFRAC (n° 1-2291) for the organization of **inter-laboratory campaigns** according to ISO CEI 17043

INERIS Report on uncertainty

Question: do we always know the uncertainty associated to a single measurement?

No. However, the investigation provided in the INERIS report clearly shows that there is a wide distance between the level of uncertainty that is supposed to be met by monitoring instruments and the level that is actually achieved. Why is this happening?

Let's have a look at on-site calibrations…

INERIS Report on uncertainty

In order to have a good calibration, many conditions have to be fulfilled. Among them:

1. The uncertainty of Standard Reference Method, U_{SRM}, is significantly lower than the one of the Automated Measuring System, U_{AMS}, i.e.

$$U_{SRM} << U_{AMS}$$

2. The calibration function can be approximately represented by a linear equation, i.e.

$$x = y$$

Where x is the reading of the AMS and y the reading of the SRM, the latest being assumed to be closer to the true value

Is condition 1 fulfilled? Is $U_{SRM} << U_{AMS}$?

According to SRM standards, SRMs are not even required to achieve the downgraded goal to have **$U_{SRM} \leq 0,5\ U_{maxAMS}$**

	$U_{max\ IED}$	U_{maxAMS} (= 0,75 Umax IED)	U_{SRM} (requested by SRM standards)
CO	10%	7,5%	6% (EN 15058)
SO_2	20%	15%	20% (EN 14791)
NO_x	20%	15%	10% (EN 14792)
Dust	30%	22,5%	20% (rev pr EN 13284-1)
TOC, CH_4	30%	22,5%	15% (XP X 43-554)
HF, NH_3(France)	40%	30%	-
HCl	40%	30%	30% (EN 1911)
Water vapour	-	-	20% (EN 14790)
O_2	-	-	6% (EN 14789)

➔ This is an uncomfortable situation to calibrate an AMS against SRMs.

- **U_{SRM}**: Uncertainty requested for the SRMs by SRMs standards. (Latter called $U_{th\ SRM}$)
- **$U_{max\ IED}$**: equals IED Annex VI 95%CI
- **$U_{max\ AMS}$**: AMS' share of IED Annex VI 95%CI. It is 75% of the 95%CI since 25% of the 95%CI is allocated to peripheral instruments (P, T, O_2, H_2O) in accordance with §14, EN 15267-3.

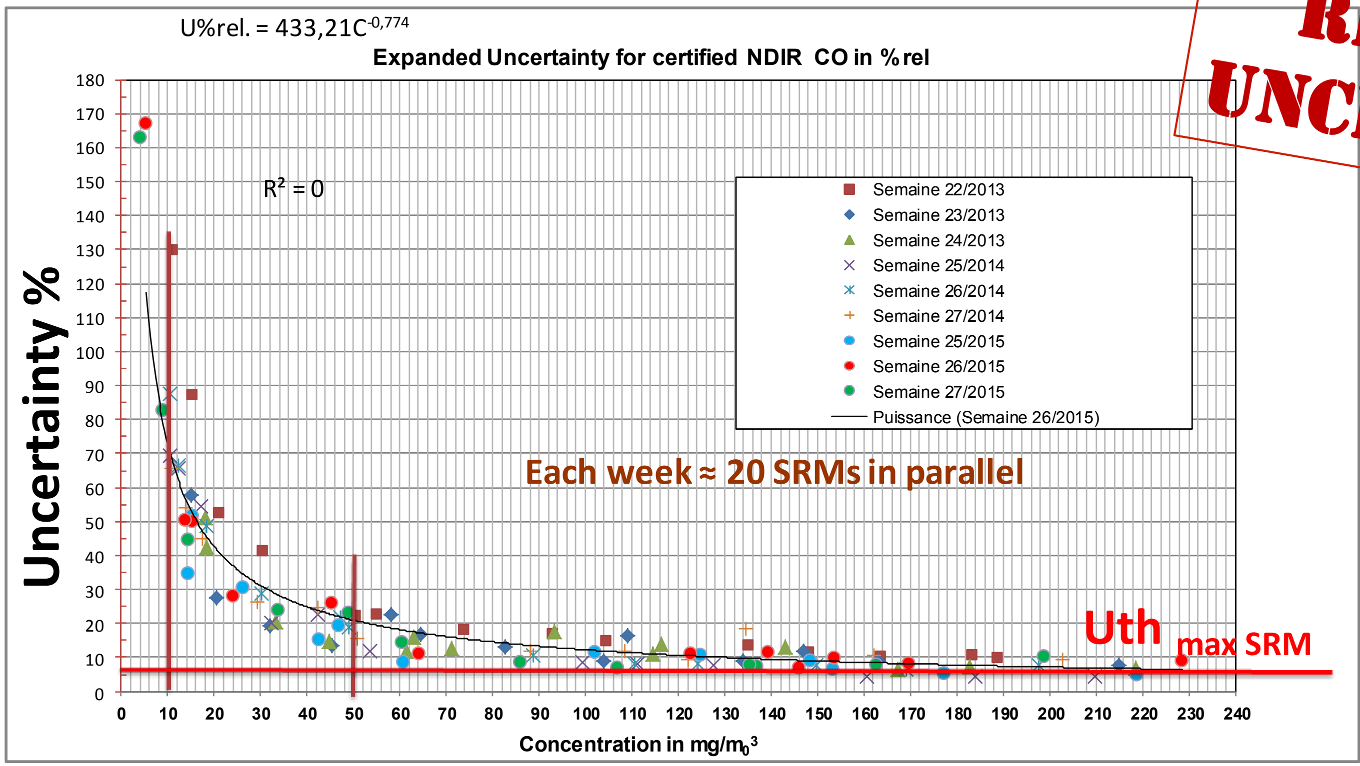
Is condition 1 fulfilled? Is $U_{SRM} << U_{AMS}$?

Actual performances – Inter-Laboratories Comparisons (ILCs) findings for **CO**

- **Required** by EN 15058 at daily ELV: **$U_{th\ SRM}$ < 6 %** (checked with a GUM approach)
- **Observed** during ILCs: **U_{SRM}: 10-22% at 50 mg/Nm^3** (= IED Anx. VI daily ELV)

U_{SRM}: 75% at 10 mg/Nm^3

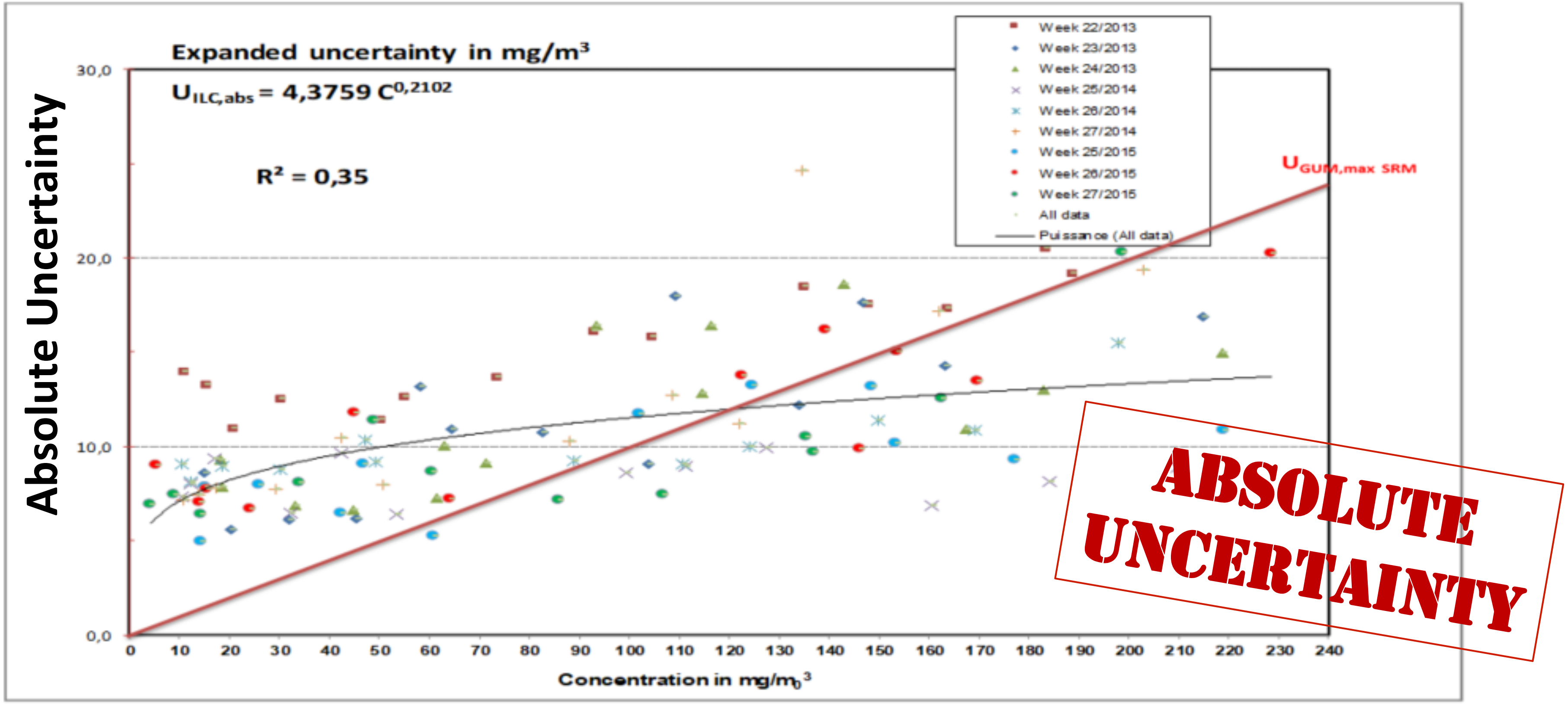
RELATIVE UNCERTAINTY



Is condition 1 fulfilled? Is $U_{SRM} << U_{AMS}$?

Comparison between actual performances – ILCs findings for **CO**

Absolute uncertainty is slightly decreasing while concentration decreases



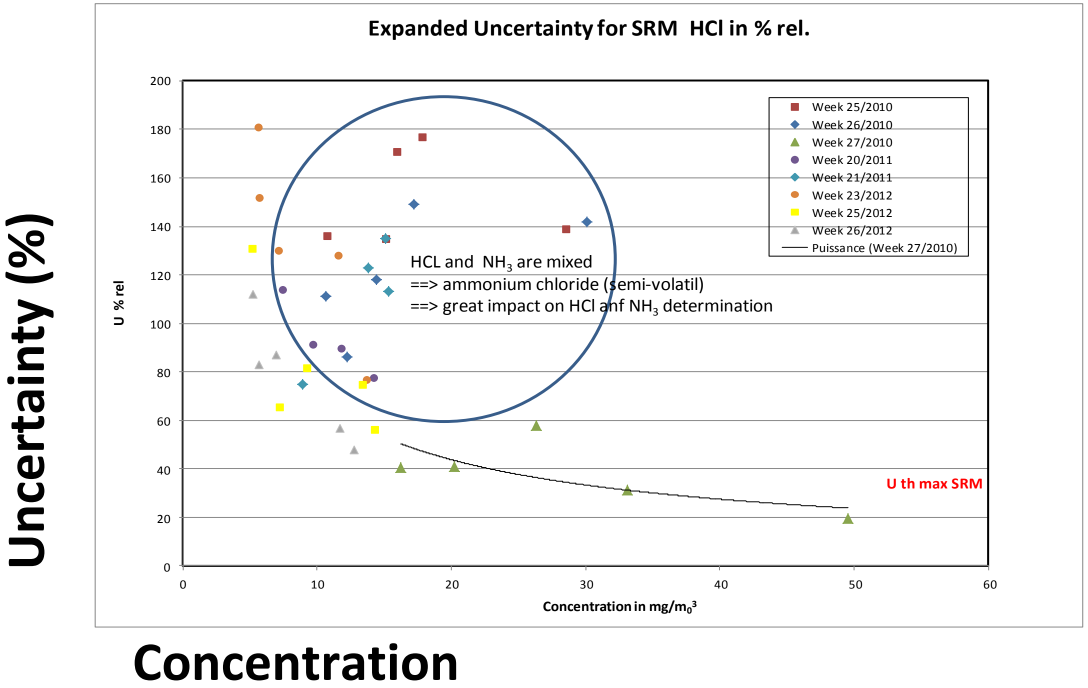
Concentration

Is condition 1 fulfilled? Is $U_{SRM} << U_{AMS}$?

Actual performances – Inter-Laboratories Comparisons (ILCs) findings for **HCl**

- **Required** by EN 15058 at daily ELV: $\mathbf{U_{thSRM} < 30\ \%}$ (checked with a GUM approach)

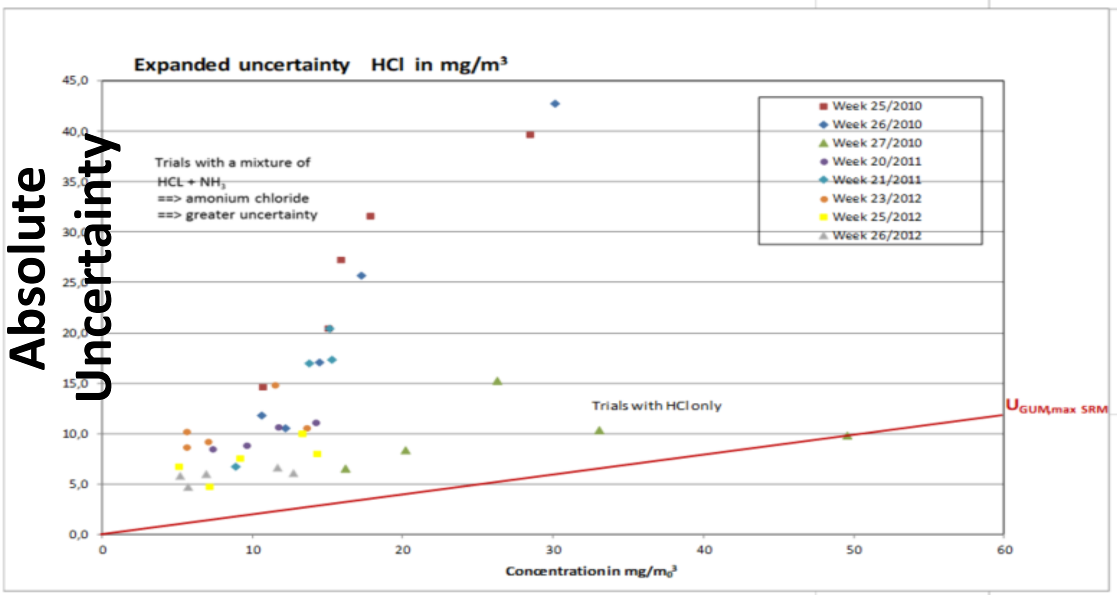
- **Observed** during ILCs: $\mathbf{U_{SRM}}$**: 45% at 20 mg/Nm³** when HCl alone (black curve)
  $\mathbf{U_{SRM}}$**: 50-180% at 5-20 mg/Nm³ when NH_3 interferes**



RELATIVE UNCERTAINTY

Is condition 1 fulfilled? Is $U_{SRM} << U_{AMS}$?

Comparison between actual performances – ILCs findings for HCl
Absolute uncertainty is slightly decreasing while concentration decreasesAbsolute uncertainty very high in presence of NH3: 5 to 15 mg/Nm3 at 10 mg/Nm3



Concentration

ABSOLUTE UNCERTAINTY

INERIS Report on uncertainty

In order to have a good calibration, many conditions have to be fulfilled. Among them:

1. The uncertainty of Standard Reference Method, U_{SRM}, is significantly lower than the one of the Automated Measuring System, U_{AMS}, i.e.

$$U_{SRM} << U_{AMS}$$

Is it respected? No.

INERIS Report on uncertainty

In order to have a good calibration, many conditions have to be fulfilled. Among them:

1. The uncertainty of Standard Reference Method, U_{SRM}, is significantly lower than the one of the Automated Measuring System, U_{AMS}, i.e.

$$U_{SRM} << U_{AMS}$$

2. The calibration function can be approximately represented by a linear equation, i.e.

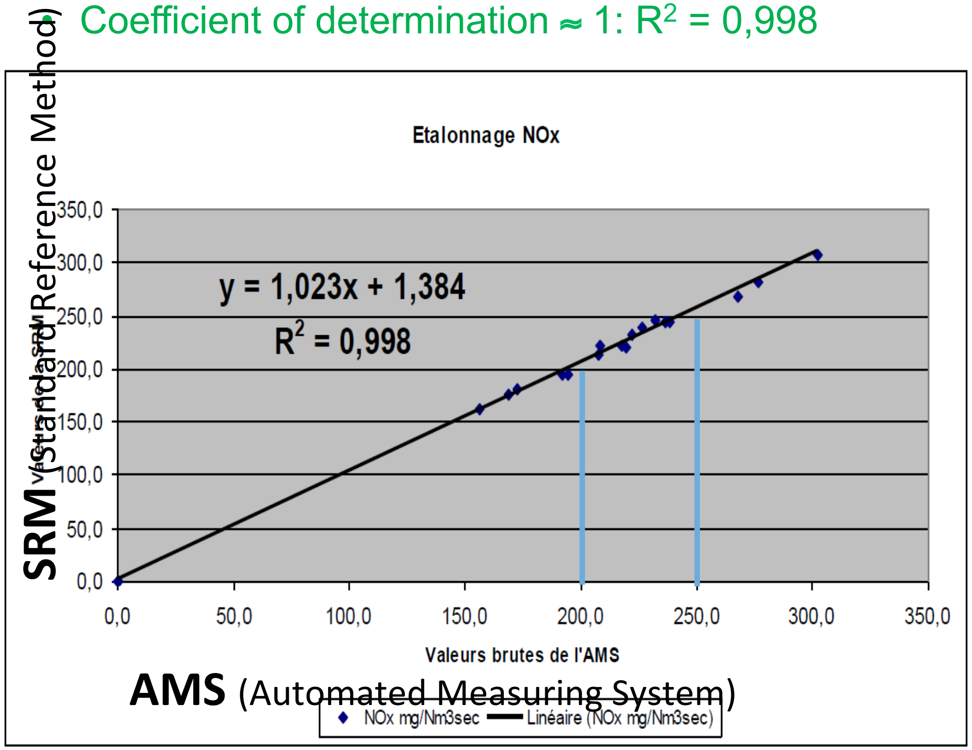
$$x = y$$

Where x is the reading of the AMS and y the reading of the SRM, the latest being assumed to be closer to the true value

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instrument vs. SRM (QAL2) - NOx

- Very good calibration function:
  - Slope ≈ 1
  - Small y-intercept (1,384) vs. ELV (200 mg/Nm³)
  - Coefficient of determination ≈ 1: $R^2 = 0{,}998$



Why?

- Rather high concentrations compared to the LoQ of measuring systems
- Possibility to make variations in concentrations during QAL 2

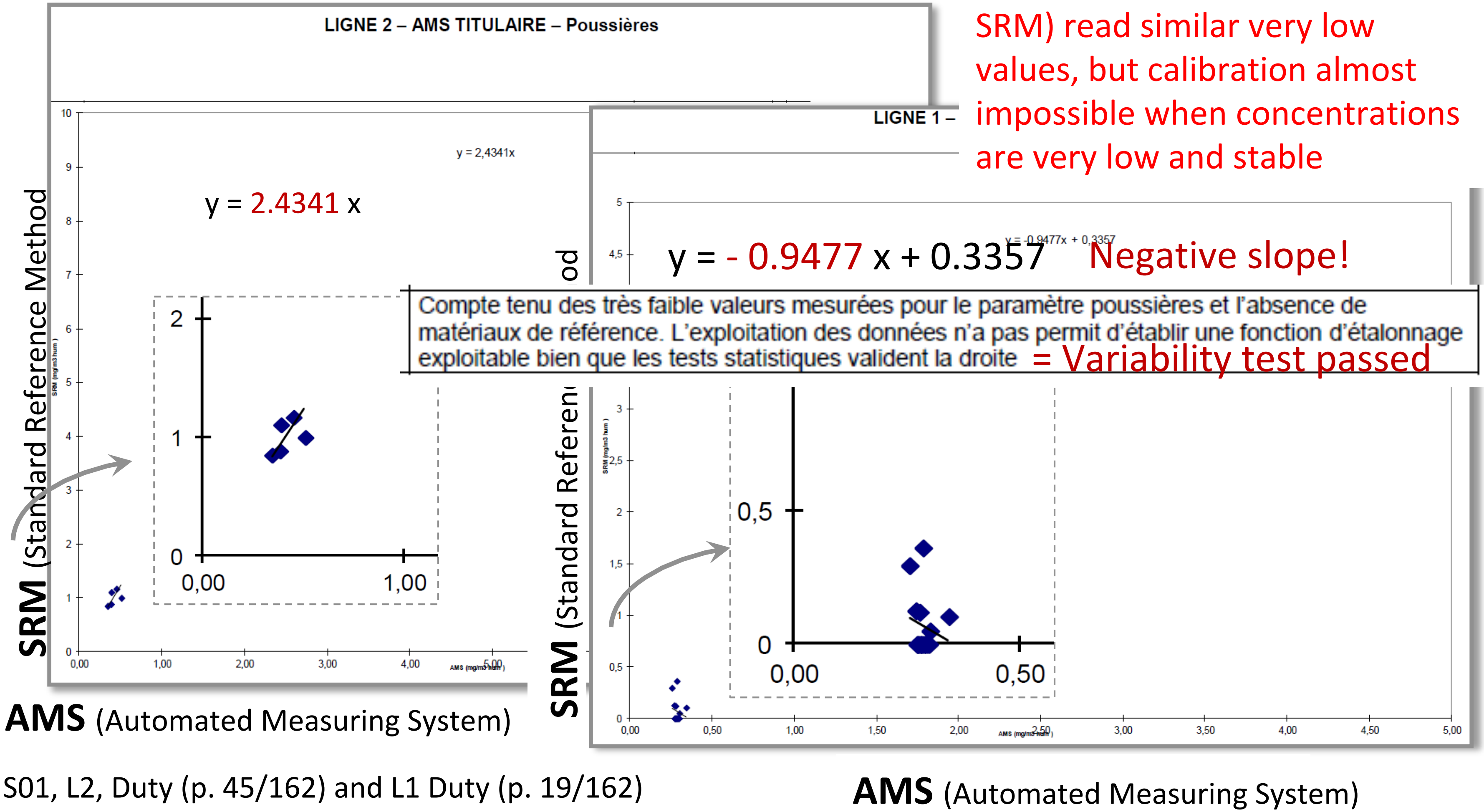
➔ suitable regression line : x ≈ y

plant S03, L2, Duty (p.69/115)

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (AST) - Dust

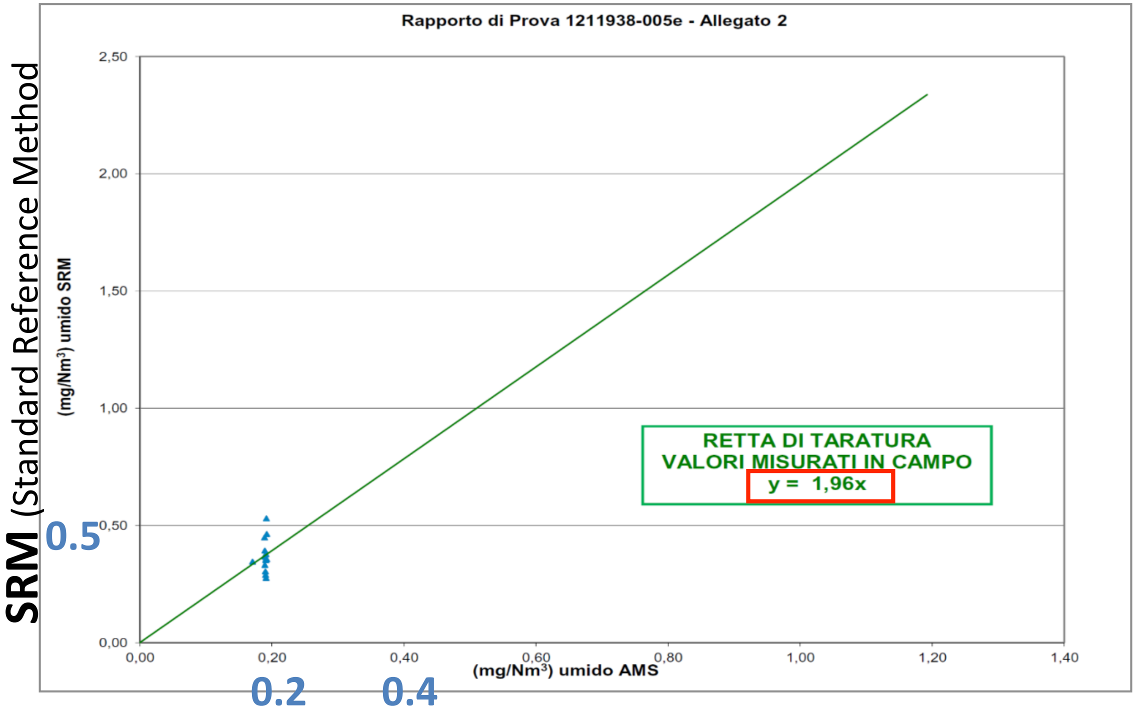
Both instruments (AMS and SRM) read similar very low values, but calibration almost impossible when concentrations are very low and stable



Plant S01, L2, Duty (p. 45/162) and L1 Duty (p. 19/162)

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2) - Dust



AMS (Automated Measuring System)

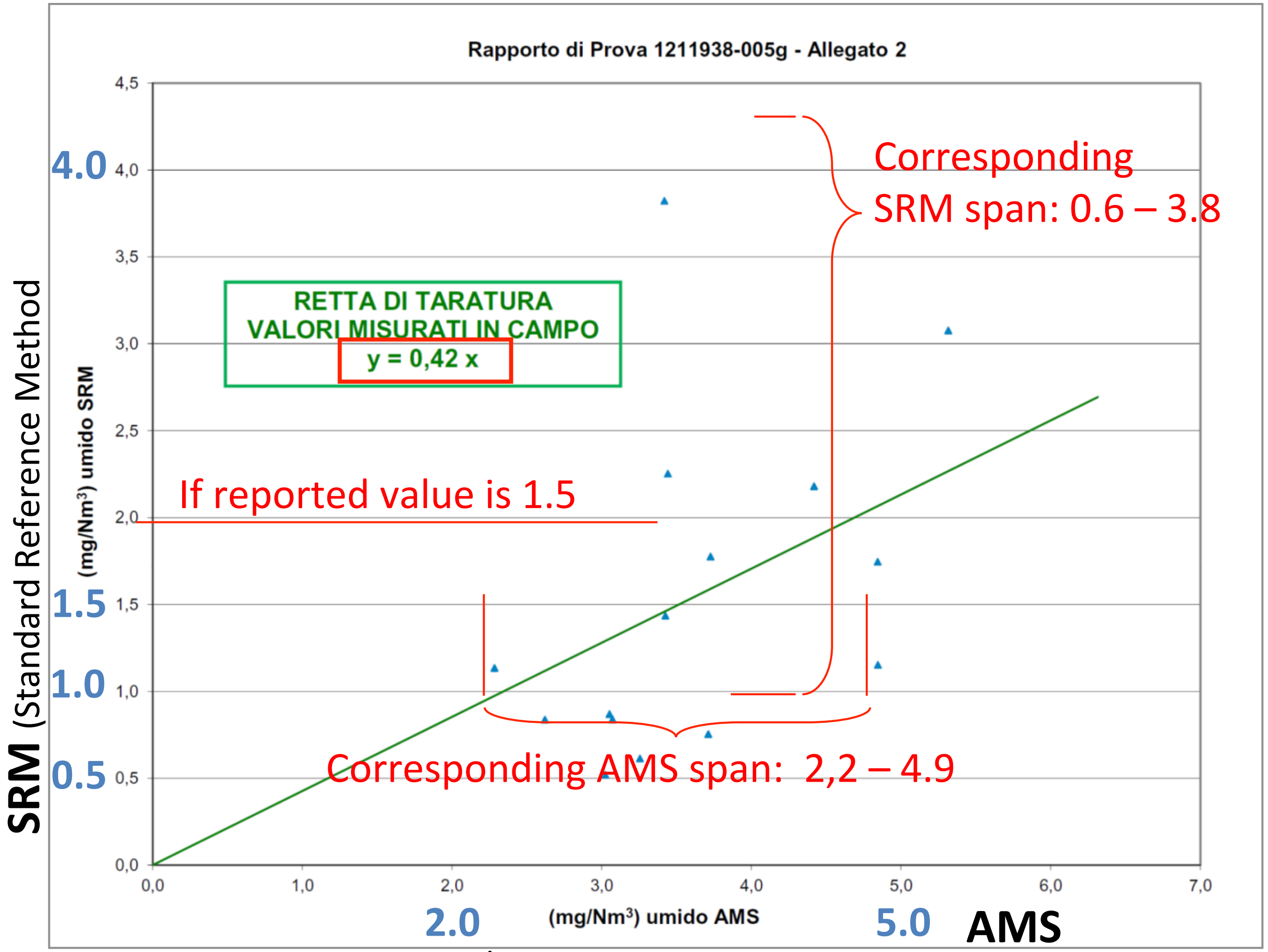
Plant I-P, L1, Duty, p. 41/69

- Values were so low that the AMS reading was constant (LoQ?)
- It is thanks to a zero measurement that the slope is at 1.2
- Most of the data reported by this plant will read 0.4 mg/ Nm^3
- What could be the robustness of data reported by this instrument ?

- ***LOQ:** Limit of Quantification*

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2) – SO_2



Plant I01, L1, Stand-by, p. 69/69

- Both AMS and SRM show low readings in respect of the daily ELV (50 mg/Nm^3).
- In order to get a plausible regression line, it has been forced to zero
- However if the reported value is 1.5 mg/Nm^3, the AMS may have read a value between 2.2 and 4.9 mg/Nm^{3}whilst the SRM was reading a value between 0.6 and 3.8 mg/Nm^3.

➔ poor accuracy

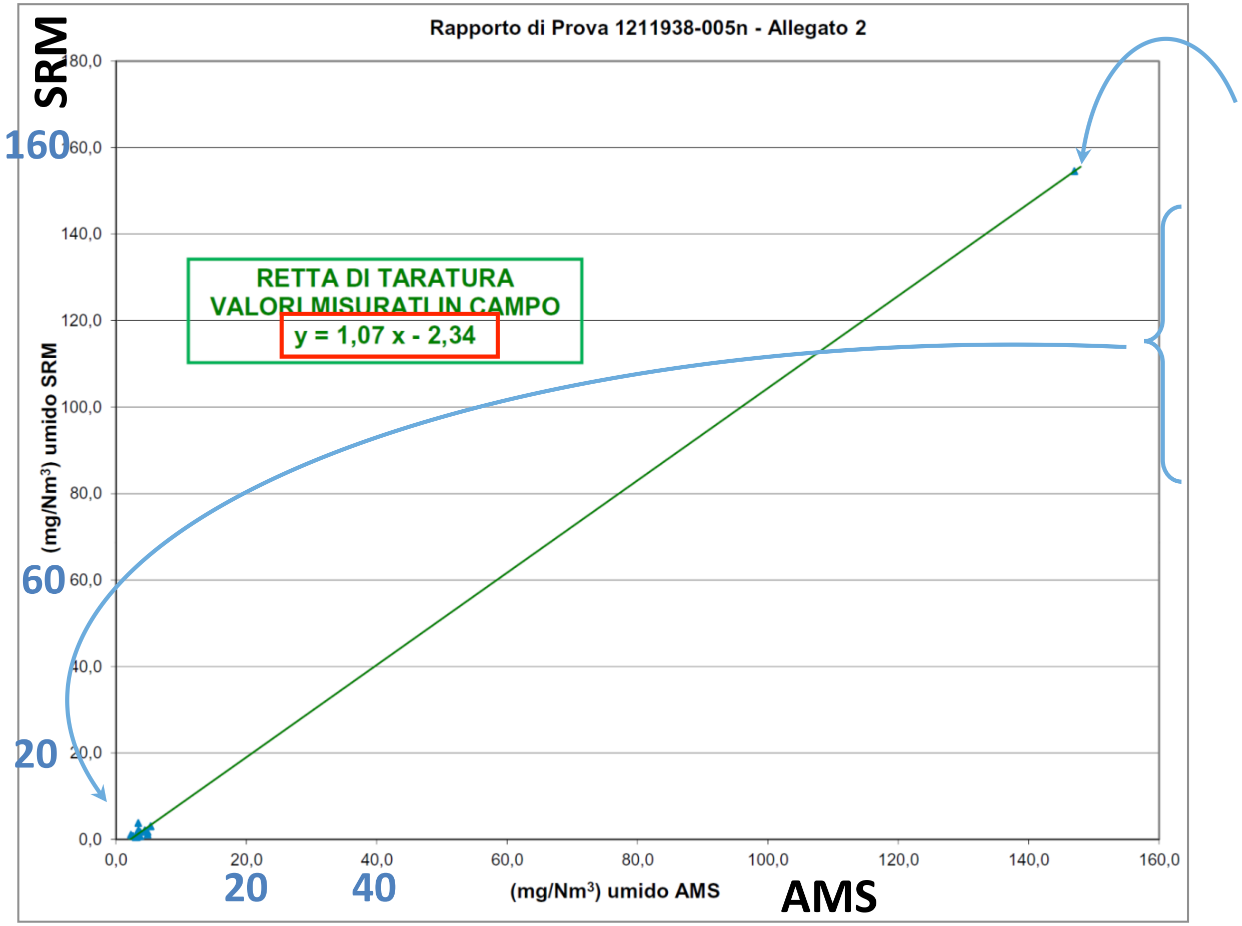
- Once again the relative uncertainty is very high even if the absolute uncertainty remains reasonable in respect of the daily ELV
- Fortunately, the level of concentration is much lower than the ELV ➔ the conformity of the plant should be respected.
- If ELVs are lowered; risk of mistakes in declaration of compliance

For HCl and HF, variability of the measurements are worse…

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2) – SO_2

Same line as in previous graph. Accuracy may be good at 150 mg/Nm³ but from 1 to 5 mg/Nm³??



Plant I01, L1, Stand-by, p. 69/69

- The use of a calibration span gas provides a good accuracy at 150 mg/Nm³
- It is therefore possible to draw a line between this point and the observed cloud of points at very low concentration
- **Its accuracy is probably pretty good at high concentrations** (150 mg/Nm³ and below)
- **But the accuracy remains as poor as in the previous slide at very low levels (around 5 mg/Nm³)**
- **Data provided by this instrument should not be used to set BATAELs (future ELVs) at the observed low concentrations**
- **NB 1: Span gas are not available at low concentrations with the required accuracy**
- **NB 2: According to the standard, values above the daily ELV (here 50 mg/Nm³) should be discarded, i.e. the point at 150 mg/Nm³ should not be taken into account.**

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2) – Dust

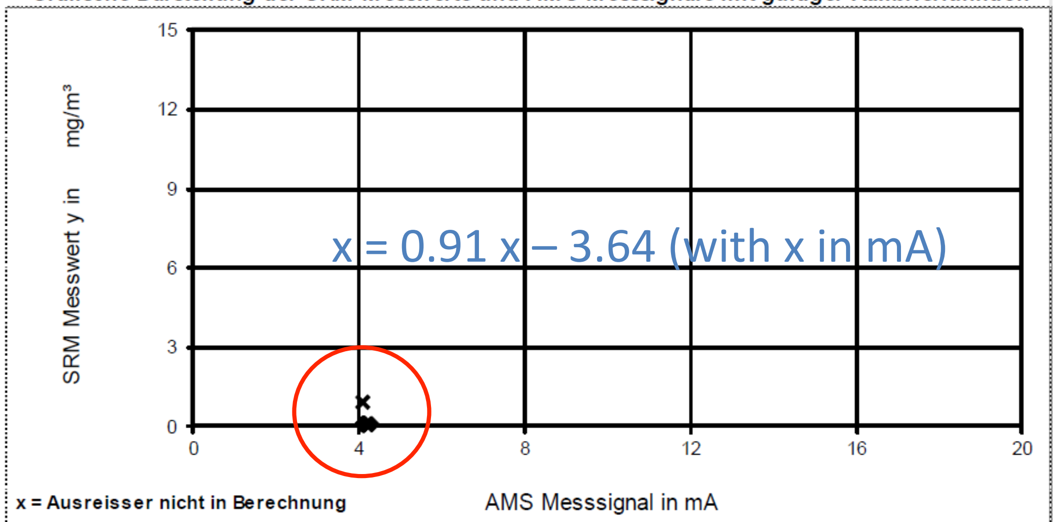
- All readings but one for AMS and one for SRM are the same: 0.1
- What is the actual accuracy of the readings?

Tabelle: Ergebnisse der Vergleichsmessungen vom 12.11.2013 bis 14.11.2013

Nr	Datum	Uhrzeit	AMS Messsignal x mA	AMS Messwert kalibriert $\hat{y}$ mg/m³	AMS Temperatur t °C	AMS Druck im Abgaskanal p hPa	AMS Feuchtegehalt h %	AMS Sauerstoff o %	AMS Messwert kalibriert Norm $\hat{y}_s$ mg/m³	SRM Messwert unter AMS Bed. y mg/m³	SRM Temperatur t °C	SRM Druck im Abgaskanal p hPa	SRM Feuchtegehalt h %	SRM Sauerstoff o %	SRM Messwert Norm y_s mg/m³
1	12.11.13	11:03 - 11:33	4,12	0,1	159	998	23,6	7,8	0,2	0,1	141	1014	22,6	7,9	0,1
2	12.11.13	12:10 - 12:40	4,1	0,1	160	998	24,1	8,2	0,2	0,1	143	1013	23,6	8,3	0,1
3	12.11.13	13:53 - 14:23	4,1	0,1	160	998	21,5	8	0,1	0,1	142	1012	19,6	8,1	0,1
4	12.11.13	15:18 - 15:48	4,29	0,3	159	998	22,8	9,3	0,5	0,1	141	1012	20,5	9,5	0,1
5	12.11.13	16:18 - 16:48	4,11	0,1	163	998	26,3	8,3	0,2	0,1	144	1012	23,5	8,4	0,1
6	12.11.13	17:18 - 17:48	4,11	0,1	160	998	22,4	8,4	0,2	0,1	142	1012	20,5	8,5	0,1
7	13.11.13	10:00 - 10:30	4,09	0,1	159	998	24	10	0,2	0,1	141	1018	22,3	9,6	0,2
8	13.11.13	11:00 - 11:30	4,09	0,1	159	998	23,9	9,1	0,1	0,1	142	1018	21,9	8,8	0,2
9	13.11.13	12:00 - 12:30	4,1	0,1	160	998	23,8	10	0,2	0,1	142	1018	22	9,7	0,2
10	13.11.13	13:34 - 14:04	4,11	0,1	159	998	23,7	8,2	0,2	0,1	142	1018	21,5	7,9	0,2
11	13.11.13	14:34 - 15:04	4,12	0,1	159	998	23,2	8,3	0,2	0,1	142	1018	21,1	8	0,2
12	13.11.13	15:34 - 16:04	4,08	0,1	161	998	24,9	8	0,1	0,1	143	1018	22,4	7,7	0,2
13	13.11.13	16:38 - 17:08	4,1	0,1	160	998	25,7	8	0,2	0,9	141	1018	23,2	7,7	1,3
14	14.11.13	10:05 - 10:35	4,1	0,1	158	998	23,3	8,2	0,1	0,1	140	1009	21,6	8,4	0,2
15	14.11.13	11:05 - 11:35	4,11	0,1	159	998	25	7,6	0,2	0,1	141	1009	23,4	7,7	0,2
16	14.11.13	12:05 - 12:35	4,07	0,1	158	998	22,7	8,6	0,1	0,1	140	1009	17	8,8	0,2
17	14.11.13	13:35 - 14:05	4,11	0,1	158	998	22	8,8	0,2	0,1	141	1008	20	9	0,2
18	14.11.13	14:35 - 15:05	4,08	0,1	158	998	23	8,6	0,1	0,1	140	1008	21,1	8,8	0,2
- Mittelwerte ohne AR =			4,11	0,1	159	998	23,5	8,6	0,2	0,1	142	1013	21,4	8,5	0,2
- MAX Werte ohne AR =			4,29	0,3	163	998	26,3	10	0,5	0,1	144	1018	23,6	9,7	0,2
- MIN Werte ohne AR =			4,07	0,1	158	998	21,5	7,6	0,1	0,1	140	1008	17	7,7	0,1

Plant G02, L4, Duty, p. 17, 18/31

- Grafische Darstellung der SRM-Messwerte und AMS-Messsignale mit gültiger Kalibrierfunktion



- Gültiger Messbereich für Normbedingungen

$\hat{y}_{s,UG}$	0	mg/m³	untere Grenze (UG) des gültigen Kalibrierbereichs
$\hat{y}_{s,OG}$	2,5	mg/m³	obere Grenze (OG) des gültigen Kalibrierbereichs
Anmerkung	Der gültige Messbereich wird gemäß behördlicher Absprache mit 50 % des Emissionsgrenzwertes angesetzt.		

- Ergebnisse der Variabilitätsprüfung

ELV	5	mg/m³	Emissionsgrenzwert
P	30	%	Anforderung an die Messunsicherheit in %
s_D	**0,1**	**mg/m³**	**Variabilität (ermittelte Standardabweichung)**
σ_0	0,77	mg/m³	Anforderung an die Messunsicherheit (als s_D)
k_v	0,9791	für N = 17	kv-Wert
$k_v\sigma_0$	0,75	mg/m³	
$s_D \leq k_v\ \sigma_0$	**ja**	**mg/m³**	**Variabilitätsprüfung bestanden**

Variability test OK

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2) – Hg

By two points, only passes one line. What does that mean when one of the points is 18 times the actual readings of SRM and AMS (0,0)?

Anlagenparameter:

- Bericht-Nr.	**13/96621-271**	- Anlage	**Linie 4**
- Firma	**MV Kiel**	- Quelle	**Reingas**

- Messobjekt	**Quecksilber (Hg)**	Messbereich: 0 bis 75 µg/m³
Normbedingungen ELV:	273,15 K, 1013 hPa, trockenes Abgas, 11 Vol.-% Sauerstoffbezug	
Messbedingungen AMS:	273,15 K, 1013 hPa, trockenes Abgas	
Messbedingungen SRM:	273,15 K, 1013 hPa, trockenes Abgas	

Tabelle: Ergebnisse der Vergleichsmessungen vom 12.11.2013 bis 14.11.2013

Nr	Datum	Uhrzeit	AMS Messsignal x mA	AMS Messwert kalibriert $\hat{y}$ µg/m³	AMS Sauerstoff o %	AMS Messwert kalibriert Bedingungen ELV $\hat{y}_s$ µg/m³	SRM Messwert unter AMS Bedingungen y µg/m³	SRM Sauerstoff o %	SRM Messwert Bedingungen ELV y_s µg/m³
1	12.11.13	11:03 - 11:33	3,95	0	7,8	0	0	7,9	0
2	12.11.13	12:10 - 12:40	3,95	0	8,2	0	0	8,3	0
3	12.11.13	13:53 - 14:23	3,95	0	8,0	0	0	8,1	0
4	12.11.13	15:18 - 15:48	3,95	0	9,3	0	0	9,5	0
5	12.11.13	16:18 - 16:48	3,95	0	8,3	0	0	8,4	0
6	12.11.13	17:18 - 17:48	3,96	0	8,4	0	0	8,5	0
7	13.11.13	10:00 - 10:30	3,95	0	10,0	0	0	9,6	0
8	13.11.13	11:00 - 11:30	3,95	0	9,1	0	0	8,8	0
9	13.11.13	12:00 - 12:30	3,96	0	10,0	0	0	9,7	0
10	13.11.13	13:34 - 14:04	3,95	0	8,2	0	0	7,9	0
11	13.11.13	14:34 - 15:04	3,95	0	8,3	0	0	8,0	0
12	13.11.13	15:34 - 16:04	3,95	0	8,0	0	0	7,7	0
13	13.11.13	16:38 - 17:08	3,95	0	8,0	0	0	7,7	0
14	14.11.13	10:05 - 10:35	3,95	0	8,2	0	0	8,4	0
15	14.11.13	11:05 - 11:35	3,95	0	7,6	0	0	7,7	0
16	14.11.13	12:05 - 12:35	3,95	0	8,6	0	0	8,8	0
17	14.11.13	13:35 - 14:05	3,95	0	8,8	0	0	9,0	0
18	14.11.13	14:35 - 15:05	3,95	0	8,6	0	0	8,8	0
19			14,54	49,8		49,8	49,8		49,8
- Mittelwerte =			4,51	2,6	8,5	2,6	2,6	8,5	2,6
- MAX Werte =			14,54	49,8	10,0	49,8	49,8	9,7	49,8
- MIN Werte =			3,95	0	7,6	0	0	7,7	0

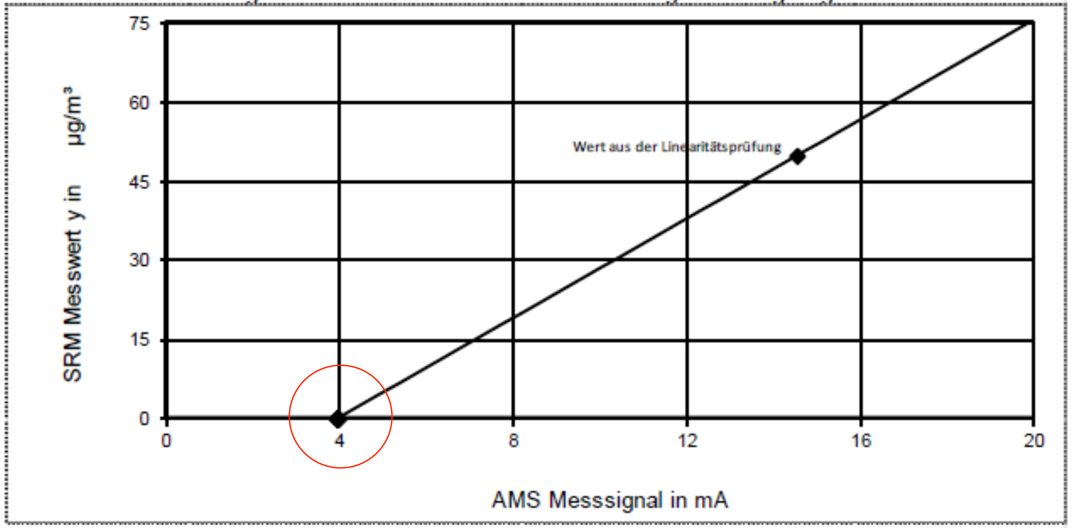
- Bemerkungen

Bedingungen ELV (Emissionsgrenzwert) = 273,15 K, 1013 hPa, trockenes Abgas, 11 Vol.-% Sauerstoffbezug

Zur Variabilitätsprüfung erfolgt, gemäß DIN, immer ein Sauerstoffbezug für den Messwert unter Bedingungen ELV.

Plant G02, L4, Duty, p. 18-19/21

- Grafische Darstellung der SRM-Messwerte und AMS-Messsignale mit gültiger Kalibrierfunktion



x = 4.703 x - 18.61 (with x in mA)

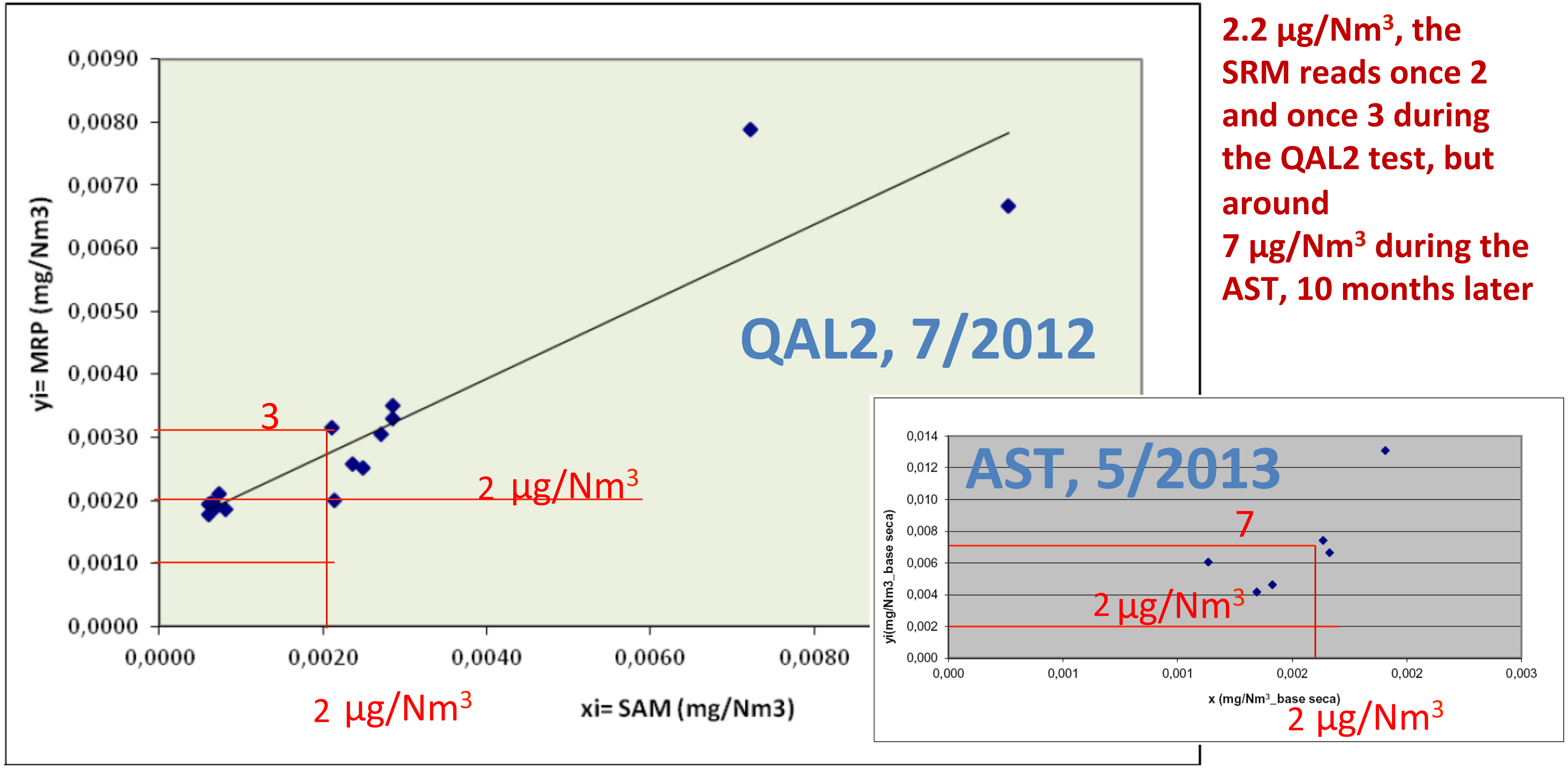
- Ergebnisse der Variabilitätsprüfung (ohne Referenzpunkt)

ELV	30	µg/m³	Emissionsgrenzwert
P	40	%	Anforderung an die Messunsicherheit in %
s_D	**0**	**µg/m³**	**Variabilität (ermittelte Standardabweichung)**
σ_0	6,12	µg/m³	Anforderung an die Messunsicherheit (als s_D)
k_v	0,9803	für N = 18	kv-Wert
$k_v \sigma_0$	6	µg/m³	
$s_D \leq k_v \sigma_0$	**ja**	**µg/m³**	**Variabilitätsprüfung bestanden**

Variability test OK

Is condition 2 fulfilled? Is x=y?

Calibration of AMS instruments vs. SRM (QAL2 & AST) – Hg



When the AMS reads 2.2 µg/Nm³, the SRM reads once 2 and once 3 during the QAL2 test, but around 7 µg/Nm³ during the AST, 10 months later

Plant E11, L1, Duty, p. 53/131 & p. 47/123

INERIS Report on uncertainty

In order to have a good calibration, many conditions have to be fulfilled. Among them:

1. The uncertainty of Standard Reference Method, U_{SRM}, is significantly lower than the one of the Automated Measuring System, U_{AMS}, i.e.

$$U_{SRM} << U_{AMS}$$

2. The calibration function can be approximately represented by a linear equation, i.e.

$$x = y$$

Where x is the reading of the AMS and y the reading of the SRM, the latest being assumed to be closer to the true value

Is it respected? In most cases, no.

INERIS Report – main outcomes

Substance	Current (IED) Daily ELV (1)	Min ELV (5 x LoQ) (5*LoQmin - 5*LoQmed) (4)	Target $U_{th,SRM}$ (5)	Target $U_{th,AMS}$ (6)	$U_{pr,SRM}$ at Current ELV (8)	$U_{pr,SRM}$ << $U_{certif,AMS}$ (9)	Min ELV to comply with $U_{th,SRM}$ (10)
CO	**50** mg/Nm³	0.35 - 4.0 mg/Nm³	6%	7.5%	12%	No	**120** mg/Nm³
NO_x	**200** $mgNO_2/Nm^3$	0.2 - 4.0 mg/Nm³	10%	15%	6%	Yes for C > 75 mg/Nm³	**75** mg/Nm³
TOC	**10** mgC/Nm³	0.065 - 0.2 mgC/Nm³	15%	23%	30%	No	**50** mgC/Nm³
Dust	**10** mg/Nm³	0.035 - 0.3 mg/Nm³	20%	23%	60%	No	**50** mg/Nm³
SO_2	**50** mg/Nm³	0.95 - 3.0 mg/Nm³	20%	15%	16%	No	**150** mg/Nm³
HCl	**10** mg/Nm³	0.095 - 0.9 mg/Nm³	30%	30%	100%	No	**50** mg/Nm³

(4): Minimum ELV for LoQmin and LoQmed, according to the EIPPCB's rule, that BATAEL should not be under 5 times the AMS's LoQ (cf. § 2.3.2).

(5): SRM's relative expanded uncertainty target, as defined in the Standard describing the SRM or in the draft revised Standard for Dust (cf. § 2.3.3), or desirable in the cases of HF and NH3, substances for which the measurement method Standard does not set a threshold.

(6): AMS's relative expanded uncertainty target from EN 15267 Standard, corresponding to 75% of the confidence interval set by the IED (cf. § 2.3.3).

8): Expanded uncertainty coming from ILCs (Inter-Laboratory Comparisons) organised by INERIS of for Standards validation (cf. summary sheets in Annex E and in § 4), therefore when various laboratories implement the method on site.

(9): Fulfilment of the condition that the SRM's uncertainty must be significantly lower than that of the AMS (cf. § 2.3.3).

(10): Minimum ELV fulfilling the SRM's uncertainty target set in the Standard describing the SRM.

INERIS study v.B, (11/2017), Table 1, 1/2

INERIS Report – main outcomes

Substance	Current (IED) Daily ELV (1)	Min ELV (5 x LoQ) (5*LoQmin - 5*LoQmed) (4)	Target $U_{th,SRM}$ (5)	Target $U_{th,AMS}$ (6)	$U_{pr,SRM}$ at Current ELV (8)	$U_{pr,SRM}$ << $U_{certif,AMS}$ (9)	Min ELV to comply with $U_{th,SRM}$ (10)
O_2	-	0.02 - 0.15 % vol	6%	-	2.3%		
HF	**1** mg/Nm³	0.125 - 0.48 mg/Nm³	20% desirable	30%	100%	No	=
NH_3	No IED ELV. **10** mg/Nm³ often found. In France: **30** mg/Nm³	0.185 - 1.05 mg/Nm³	20% desirable	30%	300%	No	**50** mg/Nm³
Hg	**50 µg/Nm³** (periodic)	0.5 - 0.7 µg/Nm³	-	-	50%	No	-

(4): Minimum ELV for LoQmin and LoQmed, according to the EIPPCB's rule, that BATAEL should not be under 5 times the AMS's LoQ (cf. § 2.3.2).

(5): SRM's relative expanded uncertainty target, as defined in the Standard describing the SRM or in the draft revised Standard for Dust (cf. § 2.3.3), or desirable in the cases of HF and NH3, substances for which the measurement method Standard does not set a threshold.

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(10): Minimum ELV fulfilling the SRM's uncertainty target set in the Standard describing the SRM.

INERIS study v.B, (11/2017), Table 1, 1/2

Other results on uncertainty from CEN test for validation of standards on metals (EN 14385)

Heavy metals (EN 14385) CEN

Com-pound	Concentra-tions in µg/m_0^3	U in %	Com-pound	Concentra-tions in µg/m_0^3	U in %
As	0,5-10	294	Ni	0,5-10	393
Cd	2-10	147	Pb	100-550	97
Co	0-5	253	Sb	1-25	122
Cr	1-100	447	Tl	0.05-60	385
Cu	10-100	106	V	0.01-7	270
Mn	1-20	155			

From these CEN data, INERIS calculated for the sums:

- Cd + Tl uncertainty is **245%** at 20 µg/Nm^3 **(= BATAEL upper end**)
- Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V uncertainty is **81%** at 340 µg/Nm^3 **(slightly above BATAEL upper end**)
    - Without Pb, the uncertainty is 86% at 60 µg/Nm^3

Other results on uncertainty from CEN tests for validation of standards on PCDD/F (EN 1948)

PCDD/F (EN 1948) CEN

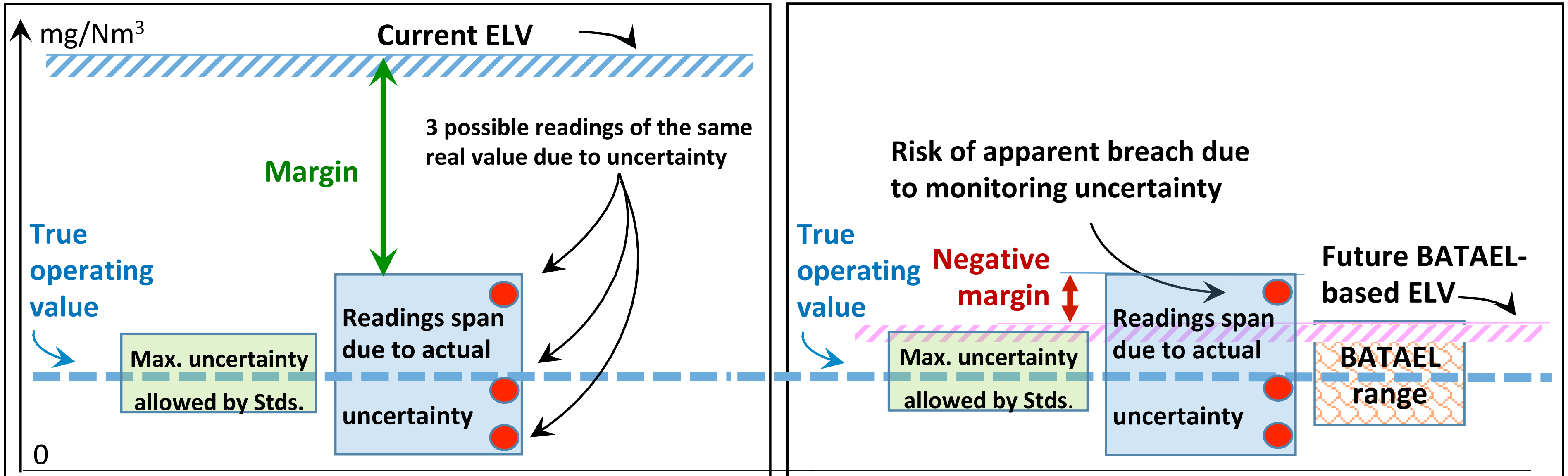
Concentrations in ng I-TEQ/m_0^3	U in %
0,035	140
12	36

CEN calculated from its test:

- for a PCDD/F concentration of **12 ng $_{\text{I-TEQ}}$/Nm³** of PCDD/F, which is very high, the uncertainty was **36%**;
- for a PCDD/F concentration of **0.035 ng $_{\text{I-TEQ}}$/Nm³** of PCDD/F, which is **around the middle of the BATAEL range** in long term sampling and **close to the upper end** of the range in short term sampling, the uncertainty reported by CEN is **140%**.

INERIS Report – consequences

By concentrating on assessing the real performance of SRMs in parallels through ILCs, **the study shows that due to the weaknesses of calibrations, in many cases there is a strong risks leading of biased ELV compliance/non-compliance declarations**, due to the uncertainty of measurements.



Today (IED Annex VI continuous ELVs)
values with high uncertainty but surely under ELV

In future (BATAEL-based continuous ELVs)
measures with high uncertainty maybe above the ELV

INERIS Report – consequences

1. On BATAEL derivation: operational data collected to set BATAELs were not accurate enough to set BATAEL values
2. On implementation of BATAELs to set ELVs taking into account the mandatory monitoring aspects

However, no mention of the INERIS report in the WI BAT conclusions. The report is referenced to in the EIPPCB Reference Report on Monitoring (ROM).

Conditions to express and use BATAELs (IED Ch. 1 & 2 and WI BAT-c)

- On one hand, for emissions to air BATAELs have been derived and are expressed:
  1) in NOC (Normal Operating Conditions) (See IED Article 3.13)
  2) in standard conditions, P, T, 11%O_2, dry (see BAT conclusions General considerations)
  - **Without reference to an uncertainty**
  - **Without indications on how to calculate average, data validity,…**
- On the other hand, conditions for ELVs implementation and compliance are
  1) In NOC (Normal Operating Conditions) (See IED Article 15,3)
  2) In standard conditions (P, T, 11%O_2, dry)
  3) **In compliance with EN standards** (listed in BAT-c 4), which themselves set conditions on uncertainty.
  4) Other implementation and compliance **conditions that should be determined by Member States**

Conditions for compliance with IED Anx. VI ELVs to air

IED, Annex VI, Part 6, §1.2 – *Sampling and analysis of all polluting substances including dioxins and furans as well as* ***the quality assurance of automated measuring systems and the reference measurement methods to calibrate them shall be carried out according to CEN-standards****. If CEN standards are not available, ISO, national or other international standards which ensure the provision of data of an equivalent scientific quality shall apply. Automated measuring systems shall be subject to control by means of parallel measurements with the reference methods at least once per year.*

IED, Annex VI, Part 6, §1.3 - *At the* ***daily emission limit value level****, the values of the* ***95 % confidence intervals*** *of a single measured result shall not exceed the following percentages of the emission limit values:*

Carbon monoxide	10%
…	…
Hydrogen fluoride	40%

IED, Annex VI, Part 8, §1.2 - *The half-hourly average values and the 10-minute averages shall be determined […]* ***from the measured values after having subtracted the value of the confidence interval*** *specified in point 1.3 of Part 6.* ***The daily average values shall be determined from those validated average values****.*

Why is it a problem that BATAELs in WI BAT Conclusions are not expressed together with an associated uncertainty?

First reason: science.

But forget about the scientists…. What about legal certainty?

By using BATAELs as basis for new ELVs without accounting for the higher uncertainty we are endangering legal certainty for emission compliance.

How to proceed with uncertainties in BAT conclusions?

According to the EIPPCB:

- The compliance rules for BATAEL-based ELVS are **not necessarily the same** as the current ones (the ones given in IED Annex VI)
- Monitoring requirements and uncertainties is an implementation issue for Member States **to define** and achieve

However, since BATAEL will be the basis to set new ELVs in permits, **when checking compliance** with these ELVs:

- **It should be possible, with the physical constraints on monitoring and measurement techniques/systems available today,** to comply with the requirements of the IED, the EN standards
- Or **new monitoring rules** must be tailor-made in order to be implementable when assessing compliance with BATAELs-based ELVs

This will help ensuring a **level playing field** and avoid that permitting authorities and operators are left in **discussions on a very complicated issue** and to have an even more fragmented picture of requirements

How to proceed with uncertainties in BAT conclusions?

Chapter 7

For emissions to air of dust, HCl, HF, CO, TVOC, SO_2, metals and metalloids including mercury, NH_3, as well as PCDD/F and dioxin-like PCBs, the TWG highlighted the potential difficulty, at the time when the Waste Incineration BREF was under review, of assessing compliance with emission limit values when these are set around the lower end of the BAT-AEL ranges, due to the likely increase of the relative measurement uncertainty (i.e. the uncertainty expressed as a percentage of the measured value) with decreasing emission levels.

Best compromise achieved during the Final Meeting of the Review

PRO	CON
There is an official acknowledgment of the problem.	The paragraph is not in the BAT Conclusions

The challenge ahead…

- Is mainly not in abating techniques but in monitoring the extremely low emission values
- Monitoring techniques available today or in a close future are not able to comply with the requirements on uncertainty of CEN standards

…and this is an extremely complicated topic tackled by a niche of technical experts

The challenge ahead…

Implementation support project started by the European Commission in 2018 (Terms of Reference Ref. Ares(2018)1267609 - 07/03/2018)

As a result of the feedback and comments so far, a number of topics have already been identified that may cause problems for Member States' competent authorities regarding the implementation of IED. These include:

- interpretation of BAT conclusions and transposing them into permitting;
- granting derogations (IED Article 15(4));
- compliance assessment;
- reporting and effective monitoring to ensure compliance;
- relation between horizontal and vertical BREFs and using them in permitting;
- taking account of trans-frontier pollution;
- use of stricter Emission Limit Values (ELVs) to comply with environmentally quality standards (EQS) (IED Article 18);
- setting ELVs for indirect releases and use of IED Article 18 in case of breaching of water environmental quality standards (EQS);
- public participation such as improving web access to permits, decision documents and inspection reports and the challenges identified in EEB's "Burning: the evidence" report;
- site closure / baseline reports;
- practice on addressing measurement uncertainty;
- permit reconsiderations in cases of significant pollution or after the publication of BAT conclusions / use of general binding rules.

The challenge ahead…

Implementation support project started by the European Commission in 2018

It may be the case that certain Member States have developed interesting approaches to address specific difficulties and gaps. These might be considered as best solutions or good practices that could be followed by other Member States. It is therefore desirable to find ways of gathering and sharing such ideas. This might be carried out along the lines of the recent assessment of the implementation of IED article 15(4)[6].

Identification and exploration of these problems and concerns as well as the challenges and pressures of a political nature per country could contribute to a better understanding of issues regarding the implementation of IED. A number of approaches can be considered to support Member State implementation. For example, the identification of best practices and solutions, the establishment of a platform for sharing implementation information and workshops with selected or all Member States could help support effective Member State implementation of specific IED provisions. The overall approach needs to respond to Member State needs and remain flexible depending on agreement on the most important topics to address through this contract.

Member States to follow the best?

CEN role

- INERIS report on AMS/SRM vs ELVs presented at CEN TFE (Task Force Emissions) meeting, on 10-11/1/2018
  - TFE decided to investigate performances of SRMs at BATAELs levels where they identified p

TFE recommended that all future validation activities and standards take account of lower ELV in BREF documents and specify the performance of the method also at the lower validation range.

TFE agreed to prepare a list of BAT-AEL values and to compare these values with validation data. This should take also into account current research activities. Rod Robinson agreed to prepare the conclusions within the next 6 months.

TFE identified potential performance problems for some SRM at the lower measurement range. Therefore, the current methods should be checked regarding the application at lower concentrations. TFE agreed to prepare a position paper identifying critical SRM with respect to lowered BAT-AEL and the applicability of the existing measurement methods as well as the need for new validation and new measurement methods.

TFE discussed other ways of monitoring in case of lowered ELV to avoid that monitoring costs are increased without benefit for the environment.

TFE discussed the preparation of an internal table of standards, which provides information on the field of application of the SRM (measurement range, uncertainty, interferences etc.). A similar table already exists for CEN and ISO standards which will be updated on a regular basis by Rudolf Neuroth and Rolf Kordecki. TFE agreed to use this table as a basis, to amend the

Secretariat to CEN/TC 264/Task Force Emissions

our date 2018-01-11
our reference Ko/pe

CEN/TC 264/TFE N **84**

Decisions

1st meeting of CEN/TC 264/Task Force Emissions
10/11 January 2018
Düsseldorf (Germany)

Decision 1:
TFE accepts the draft agenda (N 77).

Decision 2:
TFE accepts the decision drafting committee consisting of Rolf Kordecki.

Decision 3:
TFE agrees to prepare a table of CEN, ISO and national standards on stationary source emissions providing information on the field of application of the methods (measurement range, validation range, uncertainty, interferences, etc) and to review and update this table at least once a year.

Decision 4:
TFE agrees to keep the document "Recommendation on the handling and reporting of concentrations below Limit of Detection or Limit of Quantification" in its present state with some editorial corrections.

Decision 5:
TFE recommends that all future validation activities and standards take account of lower ELV in BREF documents and specify the performance of the method also at the lower validation range.

Decision 6:
TFE agrees to prepare a list of BAT-AEL.

Decision 7:
TFE agrees to prepare a position paper identifying critical SRM with respect to lowered BAT-AEL and the applicability of the existing measurement methods as well as the need for new validation and new measurement methods.

Decision 8:
TFE recommends to prepare a guidance document describing the elements of emission standards for manual and automated method on the basis of CEN/TS 15674 with the aim to withdraw the TS after the finalization of the guidance document.

Secretariat to CEN/TC 264/Task Force Emission
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Secretariat to CEN/TC 264/Task Force Emissions

our date 2018-01-22
our reference Ko/pe

CEN/TC 264/TFE N **85**

Draft minutes

1st meeting of CEN/TC 264/Task Force Emissions
10/11 January 2018
Düsseldorf (Germany)

Participants

Wim Burgers, Netherlands
Domenico Cipriano, Italy
Marc Coleman, United Kingdom
Christian Ehrlich, Germany
Lars Gram, Denmark
Rolf Kordecki, Germany
Jean Poulleau, France
Rod Robinson, United Kingdom

1 Opening the meeting

The meeting was opened by Christian Ehrlich, convenor of TFE.

Christian Ehrlich explained the establishment of TFE in 2010 and the activities during the last years. The main task of TFE is giving recommendations to TC 264 and the European Commission (EC) in the field of emissions. The TFE is similar to AQUILA which gives recommendations to the EC in the field of ambient air quality. The meeting was arranged based on a request by TC 264 to discuss relevant issues in a physical meeting.

2 Roll call of delegates

The participants in the meeting signed the list of assignees.

TFE identified that the most relevant emission working groups of CEN/TC 264 are represented in the TFE. However, especially the convenors of working groups not represented in the TFE should be asked at the next TC plenary meeting if they have interest in participation in the TFE.

3 Appointment of the decision committee

Rolf Kordecki volunteered for the decisions' committee.

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CEN role

Development of a new EN standard to measure gaseous hydrogen chloride (HCl) concentration in waste gases by an automated method.

- Validation tests finalized and existing technical specification revised.
- The work will be an input for the development of the New Standard Reference Method and recommendations for further improvements of the measurement devices.

DG ENV is in the process of drafting a further standardization request to CEN for three emissions monitoring standards for:

- long-term sampling for PCDD/F and dioxin-like PCBs,
- a sorbent trap method for quantitative total gaseous mercury measurements, with low limits of detection

DG ENV plans to include the revision of periodic measurement of total mercury (EN 13211) with projects for revision of existing measurement standards for other pollutants for standardization for 2020.

Key Messages

- The fact that the WtE sector improved continuously its emissions performances has taken the issue of uncertainty of measurement very high in the priority list.
- BATAELs are provided without any associated uncertainty.
- Uncertainty can be estimated either via GUM or via ILC and the two methods provide very different values.
- INERIS study shows how the uncertainty changes in relation with the concentration by applying ILCs.
- Why is the uncertainty higher than expected? Remember $U_{SRM} << U_{AMS}$ and x=y.
- By using BATAELs as basis for new ELVs without accounting for the higher uncertainty we are endangering legal certainty for emission compliance.

To be continued….

Thank you!

Questions?