Life+ FutMon - Working Group on QA/QC in Laboratories
Meeting of the Heads of the Laboratories
12-13 October 2009 in Warsaw

Limit of Detection (LOD)
and
Limit of Quantitation (LOQ)

estimation and use in the chemical lab

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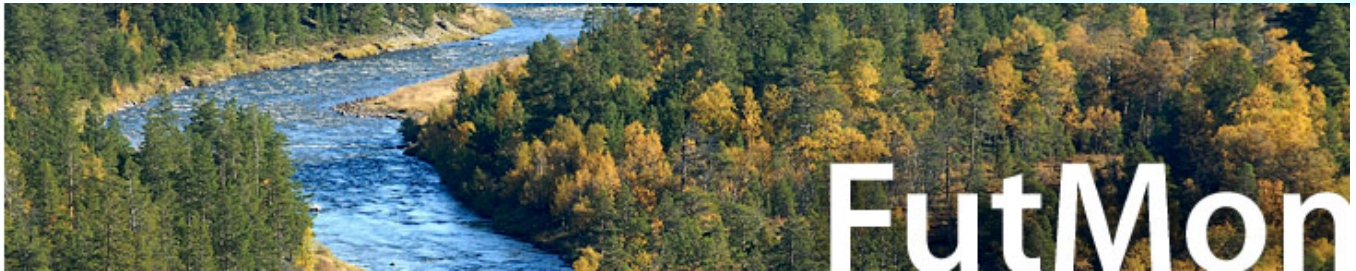

Internal and external QC

- **Internal quality cntrol**
  - calibration
  - blank control charts
  - mean control charts
  - **LOD & LOQ**
  - result validation using ion balance and conductivity check

- **External quality control**
  - use of certified standard
  - analyses of certified samples
  - participation to WRTs

Why to estimate LOD and LOQ?

- To evaluate the suitability of the used analytical technique and conditions to the aims of the monitoring.

- To compare the quality of the determination with other published results in order to evaluate if there is necessity and possibility of improvement.

Aim of this presentation

- To show simple approaches in order to encourage laboratories to start to estimate their LOD and LOQ using data they still have or they can collect at zero cost.

- Not to present a state-of-the-art review of the literature about this subject.

IUPAC definition

IUPAC GOLD BOOK

IUPAC > Gold Book > alphabetical index > D > **detection limit *in analysis***

The minimum single result which, with a stated probability, can be distinguished from a suitable blank value. The limit defines the point at which the analysis becomes possible and this may be different from the lower limit of the determinable analytical range.

The Limit of Detection (LOD), expressed as the concentration, c_L, or the quantity, q_L, is derived from the smallest measure, x_L, that can be detected with reasonable certainty for a given analytical procedure.

The value of x_L is given by the equation

$$x_L = x_{bi} + ks_{bi}$$

where x_{bi} is the mean of the blank measures, s_{bi} is the standard deviation of the blank measures, and k is a numerical factor chosen accor

IUPAC definition

Pure & Appl. Chem., Vol. 69, No. 2, pp. 297–328, 1997.
Printed in Great Britain.

1997

INTERNATIONAL UNION OF PURE
AND APPLIED CHEMISTRY

ANALYTICAL CHEMISTRY DIVISION
COMMISSION ON ELECTROANALYTICAL CHEMISTRY*

A STATISTICAL OVERVIEW OF STANDARD (IUPAC AND ACS) AND NEW PROCEDURES FOR DETERMINING THE LIMITS OF DETECTION AND QUANTIFICATION: APPLICATION TO VOLTAMMETRIC AND STRIPPING TECHNIQUES

(Technical Report)

Prepared for publication by

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A. Classical approach based on IUPAC and ACS definitions

The most common application based on the IUPAC and ACS definitions employs the mean blank signal, $\bar{y}_b$, as the basis (reference point value) for the calculation of the signal LOD and LOQ values, *regardless of the intercept position* of the calibration plot. These values are y_D and y_Q, as expressed by eqs. (2) and (3) with μ_b and σ_b replaced by $\bar{y}_b$ and s_b, or, alternatively, by $k_D s_b$ and $k_Q s_b$, for gross and net (mean blank corrected) signals, resp. On this basis, it follows that the *line parallel* to the calibration plot has to be used for the projection of the LOD and LOQ signals onto the concentration axis in order to fit geometrically to the accepted (ref. 6) numerical relationships:

$$\mathrm{LOD} = (y_D - \bar{y}_b) / q_1 = (k_D s_b) / q_1 ; \quad (23)$$

$$\mathrm{LOQ} = (y_Q - \bar{y}_b) / q_1 = (k_Q s_b) / q_1 \quad (24)$$

which are valid for $k_D = 3$ and $k_Q = 10$, resp. The mentioned auxiliary parallel line passes through $\bar{y}_b$ on the gross signal axis (or through zero on the net signal axis) and has the same slope q_1 as the calibration line (Fig. 2a).

This calculation method, denoted as **SA1** (standard approach, alternative 1), only gives correct LOD and LOQ values by assuming: (*a*) $q_0 = \bar{y}_b$; (*b*) all calibration points lie exactly on the calibration curve (which is equivalent to the assumption that the signals measured in the calibration procedure are without errors and therefore q_0 and q_1 are errorless); (*c*) $\bar{y}_b = \mu_b$, which means that the measured mean blank signal equals to the population mean, μ_b, i.e. the true blank signal value. Such requirements are never achieved in a real experiment. If the intercept value $q_0 > \bar{y}_b$, then the found LOD and LOQ concentration values may be overestimated (too large); in the opposite case, if $q_0 < \bar{y}_b$, the found LOD and LOQ may be underestimated.

RECENT DEVELOPMENTS

Ideally, the LOD and LOQ calculation method need to be fairly simple if they are to be widely used. Some published analytical papers do not meet this requirement. In practice, the LOQ is much less frequently used than the LOD and it seems therefore impractical to recommend the reporting of three limits which are connected to the use of the factors k_D, k_I, and k_Q. For practical reasons, we therefore recommend only the use of the **LOD** defined via $k_D = 3$ and the **LOQ** defined via $k_Q = 9$ for a large number of observations (where the assumption of the normal distribution is correct) and in other cases, for a limited number of observations, the use

IUPAC definition

Pure Appl. Chem., Vol. 74, No. 5, pp. 835–855, 2002.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

ANALYTICAL, APPLIED, CLINICAL, INORGANIC, AND PHYSICAL CHEMISTRY DIVISIONS
INTERDIVISIONAL WORKING PARTY FOR HARMONIZATION OF QUALITY ASSURANCE SCHEMES FOR ANALYTICAL LABORATORIES*

HARMONIZED GUIDELINES FOR SINGLE-LABORATORY VALIDATION OF METHODS OF ANALYSIS

(IUPAC Technical Report)

Resulting from the Symposium on Harmonization of Quality Assurance Systems for Analytical Laboratories, Budapest, Hungary, 4–5 November 1999, held under the sponsorship of IUPAC, ISO, and AOAC International

Prepared for publication by
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2002

A8. Detection limit

In broad terms, the detection limit (limit of detection) is the smallest amount or concentration of analyte in the test sample that can be reliably distinguished from zero [22,23]. For analytical systems where the validation range does not include or approach it, the detection limit does not need to be part of a validation.

Despite the apparent simplicity of the idea, the whole subject of the detection limit is beset with problems outlined below:

- There are several possible conceptual approaches to the subject, each providing a somewhat different definition of the limit. Attempts to clarify the issue seem ever more confusing.
- Although each of these approaches depends of an estimate of precision at or near zero concentration, it is not clear whether this should be taken as implying repeatability conditions or some other condition for the estimation.
- Unless an inordinate amount of data is collected, estimates of detection limit will be subject to quite large random variation.
- Estimates of detection limit are often biased on the low side owing to operational factors.
- Statistical inferences relating to the detection limit depend on the assumption of normality, which is at least questionable at low concentrations.

For most practical purposes in method validation, it seems better to opt for a simple definition, leading to a quickly implemented estimation that is used only as a rough guide to the utility of the method. However, it must be recognized that the detection limit as estimated in method development, may not be identical in concept or numerical value to one used to characterize a complete analytical method. For instance, the "instrumental detection limit", as quoted in the literature or in instrument

A9. Limit of determination or limit of quantification

It is sometimes useful to state a concentration below which the analytical method cannot operate with an acceptable precision. Sometimes that precision is arbitrarily defined as 10 % RSD, sometimes the limit is equally arbitrarily taken as a fixed multiple (typically 2) of the detection limit. While it is to a degree reassuring to operate above such a limit, we must recognize that it is a quite artificial dichotomy of the concentration scale; measurements below such a limit are not devoid of information content and may well be fit for purpose. Hence, the use of this type of limit in validation is not recommended here. It is preferable to try to express the uncertainty of measurement as a function of concentration and compare that function with a criterion of fitness for purpose agreed between the laboratory and the client or end-user of the data.

ISO 13530 1997

Water quality - Guidance on analytical quality control for chemical and physicochemical water analysis

5.8 Limit of detection

1997

There has been much diversity in the way in which the limit of detection of an analytical system is defined. Most approaches are based on multiplication of the within-batch standard deviation of results by a factor (usually between 2 and 10, depending on the degree of confidence required for detection).

The limit of detection may thus be defined as that concentration of the determinand for which there is 95 % probability of detection when a single analytical result is obtained, detection being defined as obtaining a result which is significantly greater (p=0,05) than zero.

The magnitude of the limit of detection can be determined from the within-batch standard deviation, s_w, of results for a solution, such as a blank, containing a very small (preferably zero) concentration of the determinand. s_w is expressed in concentration terms so that the effects of calibration procedures on the variability of results for determinations on low concentration samples are accounted for. The limit of detection is given by $2 \times \sqrt{2} \times t_{0.05} \times s_w$ where $t_{0.05}$ is the tabulated value of Student's t (single-sided) at the 95 % probability level and for the relevant number of degrees of freedom (which should also be stated).

When a number of estimates of limit of detection is available from more than one source, the range may be of interest and could be quoted (together with the number of degrees of freedom in each case). Other indicators of measurement capability have been proposed, for example `limit of quantification' at $10 s_w$.

Eurachem definition

The Fitness for Purpose of Analytical Methods — EURACHEM Guide

1998

The Fitness for Purpose of Analytical Methods

A Laboratory Guide to Method Validation and Related Topics

Eurachem — A FOCUS FOR ANALYTICAL CHEMISTRY IN EUROPE

A10 **Limit of Detection:**

'The lowest content that can be measured with reasonable statistical certainty.'
[AOAC - PVMC]

'The lowest concentration of analyte in a sample that can be detected, but not necessarily quantitated under the stated conditions of the test'.
[NATA Tech Note#13]

'The limit of detection, expressed as the concentration c_L, or the quantity q_L, is derived from the smallest measure x_L, that can be detected with reasonable certainty for a given analytical procedure. The value of x_L is given by the equation:

$x_L = x_{bl} + ks_{bl}$

where x_{bl} is the mean of the blank measures and s_{bl} the standard deviation of the blank measures, and k is a numerical factor chosen according to the confidence level desired.'
[IUPAC Compendium of Chemical Technology, 1985]

It may also be known as **Minimum detectable net concentration**, or **Limit of Determination /Limit of Decision,** which are respectively defined as:

'The true net concentration or amount of the analyte in the material to be analysed which will lead with probability (1-β), to the conclusion that the concentration of the analyte in the analysed material is larger than that of the blank matrix.'
[ISO/DIS 11843-1]

and

'The lowest analyte content, if actually present, that will be detected and can be identified.'
[AOAC - PVMC]

This whole subject is dealt with in great detail by IUPAC [12].

A11 **Limit of Quantitation**:

'(The content) equal to or greater than the lowest concentration point on the calibration curve.'
[AOAC - PVMC]

It is also known as **Limit of Reporting:**

'The lowest concentration of an analyte that can be determined with acceptable precision (repeatability) and accuracy under the stated conditions of the test.'
[NATA Tech Note #13]

It is also known as **Quantification Limit:**

'Quantification limits are performance characteristics that mark the ability of a chemical measurement process to adequately 'quantify' an analyte.

Note: *The ability to quantify is generally expressed in terms of the signal or analyte (true) value that will produce estimates having a specified relative standard deviation (RSD), commonly 10%.*

Thus: $L_Q = k_Q \sigma_Q$

Where L_Q is the Quantification Limit, σ_Q is the standard deviation at that point, and k_Q is the multiplier whose reciprocal equals the selected quantifying RSD. The IUPAC default value for k_Q is 10.'
[IUPAC 'Orange' Book]

I.S.E.

EPA Document 815-R-05-006

Statistical Protocol for the Determination of the Single-Laboratory Lowest Concentration Minimum Reporting Level (LCMRL) and Validation of Laboratory Performance at or Below the Minimum Reporting Level (MRL)

3.1 History of Selected Detection and Quantitation Procedures

2004

International Union of Pure and Applied Chemistry (IUPAC) (Currie) Detection Limit Procedure

The Currie detection limit procedure (Currie, 1968; Currie, 1999) describes three types of detection limit relations:

Critical level (L_C). The critical level, L_C, is the lowest value that, with specified confidence, does not result from a blank. The probability of exceeding L_C when analyte is absent is α. A value for α of 0.01 signifies the interval at or above L_C should contain only 1% false positives. The L_C is a minimum value of estimated net signal or concentration applied against background noise.

Detection limit (L_D). The detection limit (L_D) is the minimum detectable value of the net signal (or concentration) for which the false negative error is β, which is the probability that a true value at the L_D is not measured as less than or equal to L_C. Given a normal distribution of results, when samples contain an analyte at the L_D, there is a 50% chance that analyzed results will fall below this limit and not be reported (i.e., a false negative).

Determination or Quantitation limit (L_Q). The quantitation limit (L_Q) marks "the ability of the chemical measurement process to adequately 'quantify' an analyte." Replicate analysis at L_Q will produce estimates with a relative standard deviation ($\%RSD_Q$), such as the 10% RSD mentioned by Currie.

Currie (IUPAC) procedure issues. Two issues with the IUPAC procedure are the lack of bias accountability for the quantitation limit, and the difficulty with the determination of blank variance in chromatographic methods. Since variance from replicate blanks determines the region of reliable quantitation, there is not an accuracy requirement for the quantitation limit. Measurement bias at low level is not addressed except to say that the bias bounds "require skilled and exhaustive scientific evaluation of the entire structure of the chemical measurement process."

EPA Document 815-R-05-006 2004

The EPA Method Detection Limit

The EPA's Method Detection Limit (MDL) procedure (40 CFR 136, Appendix B) avoids the problems of determining variance at zero concentration by fortifying samples at low levels which must be 1 to 5 times the calculated estimated MDL. The MDL is defined as:

(2) $MDL = t_{(n-1,1-\alpha)} * s$

where:

t = Student's t;
s = the standard deviation of replicate spikes at low-level;
$1-\alpha$ = the probability point; and
n-1= degrees of freedom.

The derivation is found in Glaser *et al.* (1981). The USEPA's MDL procedure uses the standard deviation from low-level fortified replicates to estimate a confidence interval around zero concentration that includes 99% of all false positives.

EPA Document 815-R-05-006 2004

ASTM International's Interlaboratory Quantitation Estimate ($IQE_{Z\%}$)

The following description is "adapted from ASTM D 6512-00 Standard Practice for Interlaboratory Quantitation Estimate, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19083. The information is used with permission; ASTM International, however, is not responsible for any changes made by the Exchange."

The $IQE_{Z\%}$ is the lowest concentration for which a single measurement from a laboratory selected from the population of qualified laboratories will have an estimated Z% RSD (relative standard deviation), where Z is dictated by data quality objectives. This procedure uses a regression approach to determine the point of 10% RSD among cross-lab mean values, with no simplifying assumptions about the dependence of standard deviation on concentration. The IQE is a minimum concentration at which most laboratories can be expected to reliably measure a specific chemical contaminant during day-to-day analyses. The procedure is an interlaboratory extension of the RSD approach used in the Gibbons AML procedure. In addition, the $IQE_{Z\%}$ basically corresponds to the L_Q (Currie, 1968), as the lowest concentration that produces Z% RSD.

EPA Document 815-R-05-006

Statistical Protocol for the Determination of the Single-Laboratory Lowest Concentration Minimum Reporting Level (LCMRL) and Validation of Laboratory Performance at or Below the Minimum Reporting Level (MRL)

2004

LCMRL
Lowest Concentration Minimum Reporting Level

3.2 Basis of the LCMRL

The existence of several methods for establishing detection and quantitation levels has created a need for uniformity in the process. EPA considered the procedures described in Section 3.1, as well as others, and decided that a regression/prediction interval approach that also combines desirable features of these procedures, with consideration for ease of application, transparency, and cost, would best meet the objectives of the UCMR. Thus, the MRL described in this paper is proposed as a quantitation metric that considers not only the standard deviation of low concentration analyses (precision), but also the bias of the measurements. The predefined QC interval and the confidence level of the Student's *t* value are quality assurance objectives that can be tailored to fit future analytical and policy needs. The decision on how, or if, to report values below the MRL will depend on the objectives of the study being conducted. The QC interval of recovery chosen for use in this paper, 50 to 150%, is based upon experienced judgement from chemical analysts. The prediction interval for the regression line that is derived from the Student's *t* distribution was chosen as 99% because it is conservative, consistent with other DQO's used in this procedure, it minimizes false positives, and is often used in other statistical tests. It should be noted that this procedure is designed for data that are continuous (e.g., Gaussian) rather than with data that are discrete, such as "counting" methods.

MRL Minimum Reporting Level
UCMR Unregulated Contaminant Monitoring Regulation

Standard Methods 21° Ed. 2005: definitions

2005

3. Description of Levels

Figure 1030:1 illustrates the detection levels discussed above. For this figure it is assumed that the signals from an analytical instrument are distributed normally and can be represented by a normal (Gaussian) curve.[4] The curve labeled B is representative of the background or blank signal distribution. As shown, the distribution of the blank signals is nearly as broad as for the other distributions, that is $\sigma_B = \sigma_I = \sigma_L$. As blank analyses continue, this curve will become narrower because of increased degrees of freedom.

The curve labeled I represents the IDL. Its average value is located $k\sigma_B$ units distant from the blank curve, and k represents the value of t (from the one-sided t distribution) that corresponds to the confidence level chosen to describe instrument performance. For a 95% level and $n = 14$, $k = 1.782$ and for a 99% limit, $k = 2.68$. The overlap of the B and I curves indicates the probability of not detecting a constituent when it is present (Type II error).

The curve at the extreme right of Figure 1030:1 represents the LLD. Because only a finite number of determinations is used for calculating the IDL and LLD, the curves are broader than the blank but are similar, so it is reasonable to choose $\sigma_I = \sigma_L$. Therefore, the LLD is $k\sigma_I + k\sigma_L = 2k\sigma_L$ from the blank curve.

4. References

1. American Society for Testing and Materials. 1983. Standard Practice for Intralaboratory Quality Control Procedures and a Discussion on Reporting Low-Level Data. Designation D4210-83, American Soc. Testing & Materials, Philadelphia, Pa.
2. Glaser, J.A., D.L. Foerst, J.D. McKee, S.A. Quave & W.L. Budde. 1981. Trace analyses for wastewaters. *Environ. Sci. Technol.* 15:1426.
3. U.S. Environmental Protection Agency. 1985. National Primary Drinking Water Standards: Synthetic Organics, Inorganics, and Bacteriologicals. 40 CFR Part 141; *Federal Register* 50: No. 219, November 13, 1985.
4. Oppenheimer, J. & R. Trussell. 1984. Detection limits in water quality analysis. *In* Proc. Water Quality Technology Conference (Denver, Colorado, December 2-5, 1984). American Water Works Assoc., Denver, Colo.

times the signal-to-noise ratio. The IDL is useful for estimating the constituent concentration or amount in an extract needed to produce a signal to permit calculating an estimated method detection level.

The LLD is the amount of constituent that produces a signal sufficiently large that 99% of the trials with that amount will produce a detectable signal. Determine the LLD by multiple injections of a standard at near zero concentration (concentration no greater that five times the IDL). Determine the standard deviation by the usual method. To reduce the probability of a Type I error (false detection) to 5%, multiply s by 1.645 from a cumulative normal probability table. Also, to reduce the probability of a Type II error (false nondetection) to 5%, double this amount to 3.290. As an example, if 20 determinations of a low-level standard yielded a standard deviation of 6 µg/L, the LLD is $3.29 \times 6 = 20$ µg/L.[1]

The MDL differs from the LLD in that samples containing the constituent of interest are processed through the complete ana-

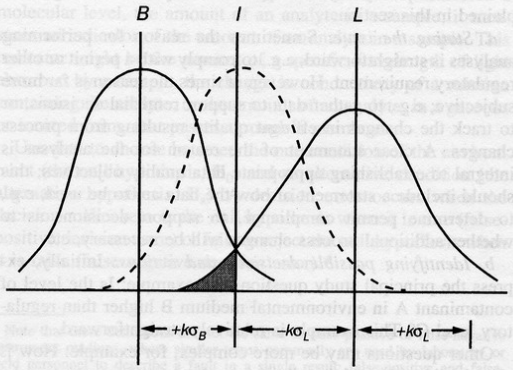


Figure 1030:1. Detection level relationship.

Standard Methods 21° Ed. 2005: definitions

LOD

Detection levels—Various levels in increasing order are:

Instrumental detection level (IDL)—the constituent concentration that produces a signal greater than five times the signal/noise ratio of the instrument. This is similar, in many respects, to "critical level" and "criterion of detection." The latter level is stated as 1.645 times the *s* of blank analyses.

Lower level of detection (LLD)—the constituent concentration in reagent water that produces a signal 2(1.645)*s* above the mean of blank analyses. This sets both Type I and Type II errors at 5%. Other names for this level are "detection level" and "level of detection" (LOD).

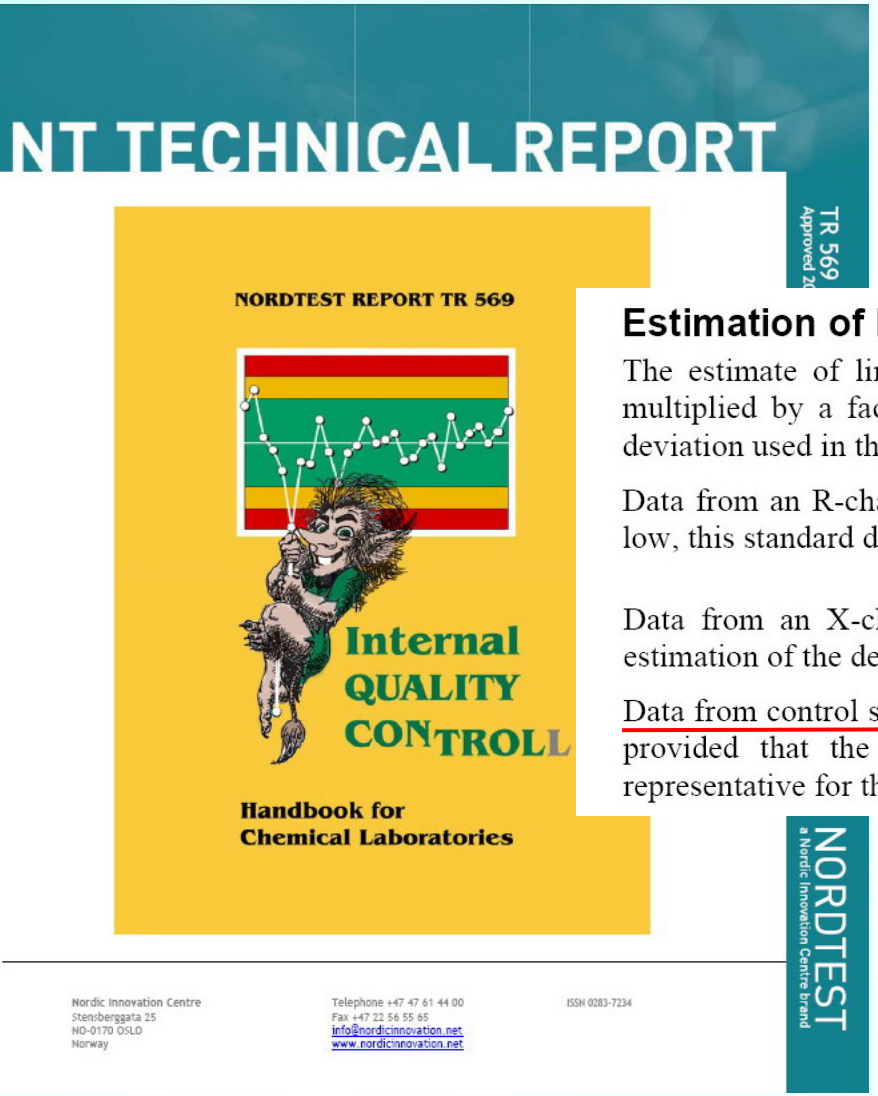
Method detection level (MDL)—the constituent concentration that, when processed through the complete method, produces a signal with a 99% probability that it is different from the blank. For seven replicates of the sample, the mean must be 3.14*s* above the blank where *s* is the standard deviation of the seven replicates. Compute MDL from replicate measurements one to five times the actual MDL. The MDL will be larger than the LLD because of the few replications and the sample processing steps and may vary with constituent and matrix.

LOQ

Level of quantitation (LOQ)/minimum quantitation level (MQL)—the constituent concentration that produces a signal sufficiently greater than the blank that it can be detected within specified levels by good laboratories during routine operating conditions. Typically it is the concentration that produces a signal 10*s* above the reagent water blank signal.

Detection Limit in analysis

NORDTEST definition



2007

Estimation of limit of detection (LOD)

The estimate of limit of detection used by many sectors is repeatability standard deviation multiplied by a factor. The factor is normally between 3 and 5. The repeatability standard deviation used in the calculation must be valid at low concentrations.

Data from an R-chart will give the repeatability standard deviation, and if the concentration is low, this standard deviation is useful for estimation of the limit of detection.

Data from an X-chart with a test sample at low concentration will also be useful for the estimation of the detection limit for the method in routine use.

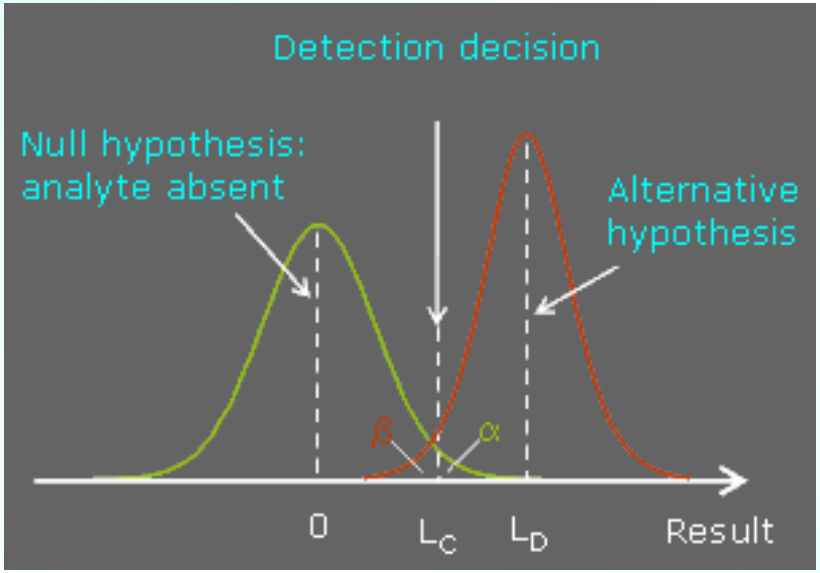
Data from control sample type III (blank sample) may in some cases be used for the estimation, provided that the laboratory has evidence that the standard deviation for the blank is representative for the standard deviation for test samples with low concentration.

SD of blank samples

The Limit of Detection (LOD) expressed as the concentration is derived from the smallest measure, x_L, that can be detected with reasonable certainty for a given analytical procedure.

$$x_L = x_{bi} + ks_{bi}$$

where x_{bi} is the mean of the blank measures, s_{bi} is the standard deviation of the blank measures, and k is a numerical factor chosen according to the confidence level desired ($2 < k < 3$)



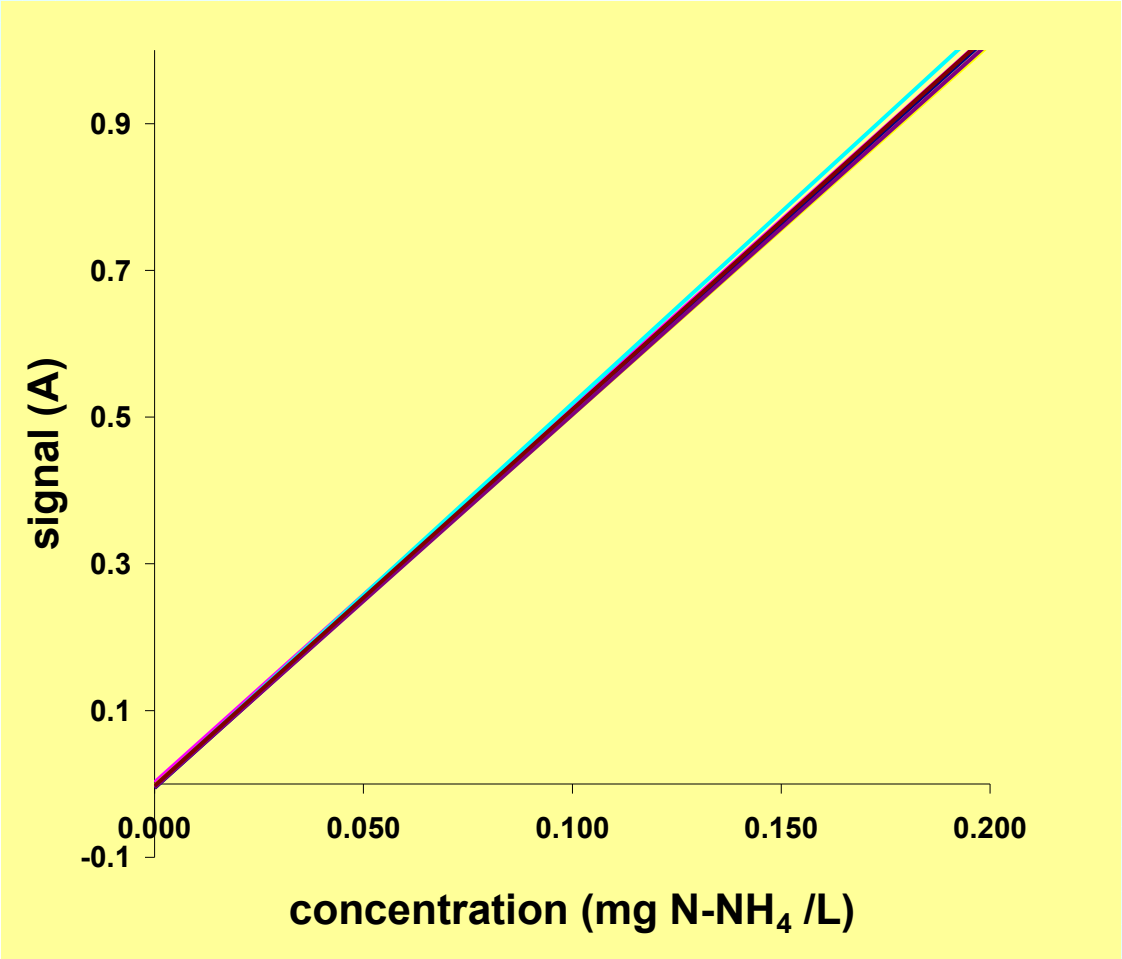
signal

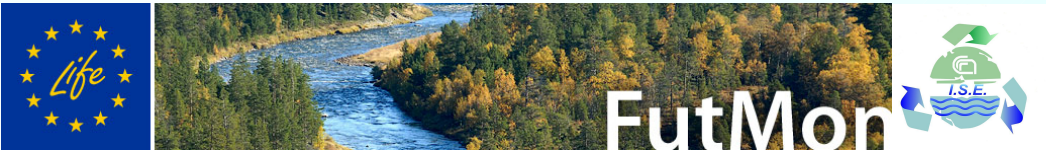
**To obtain LOD,
signals are transformed in
concentrations using the
calibration curve**

Calibration curve

$N\text{-}NH_4$ spectrophotometry indophenol blue

5 cm optical path

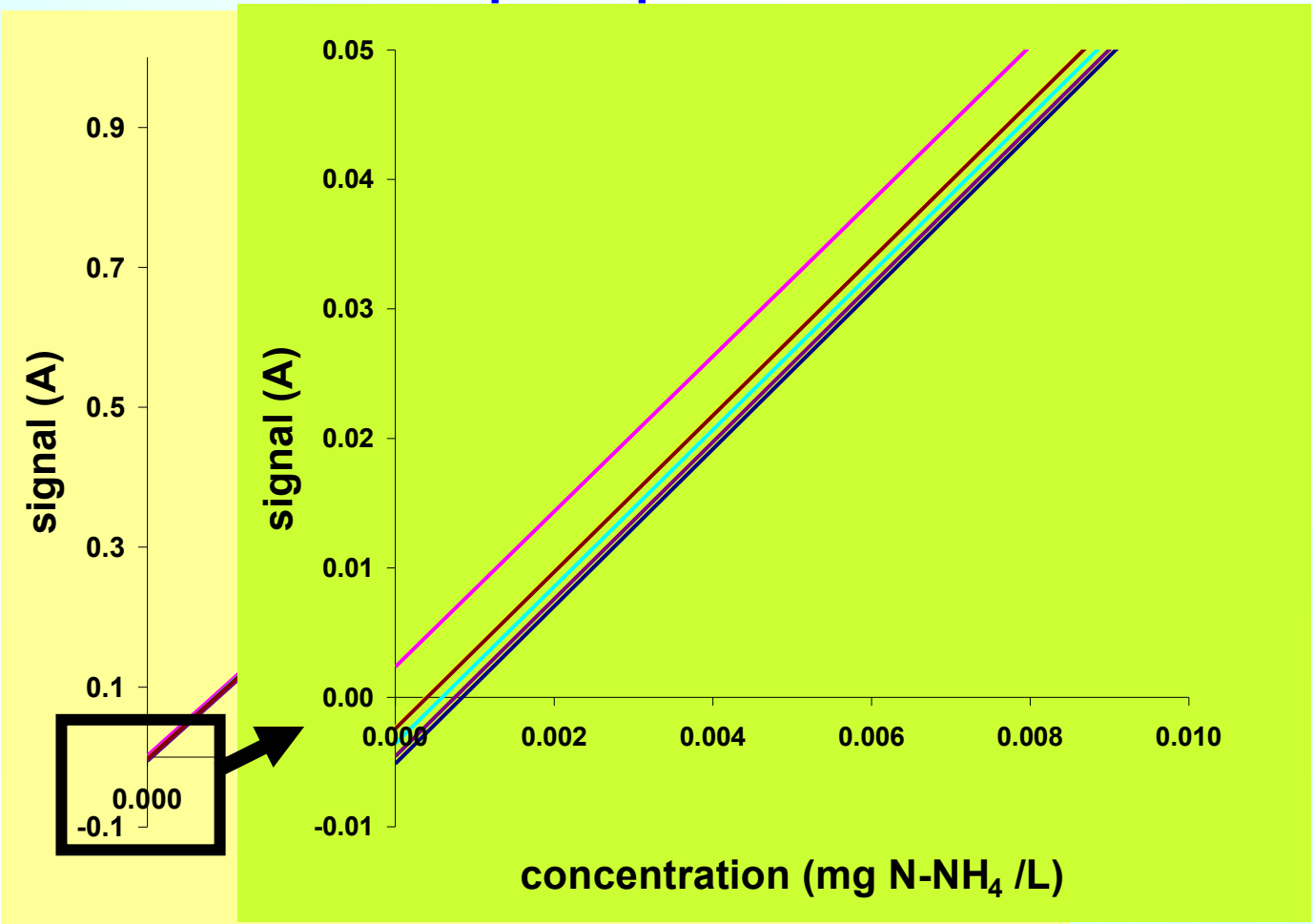




Calibration curve

N-NH_4 spectrophotometry indophenol blue

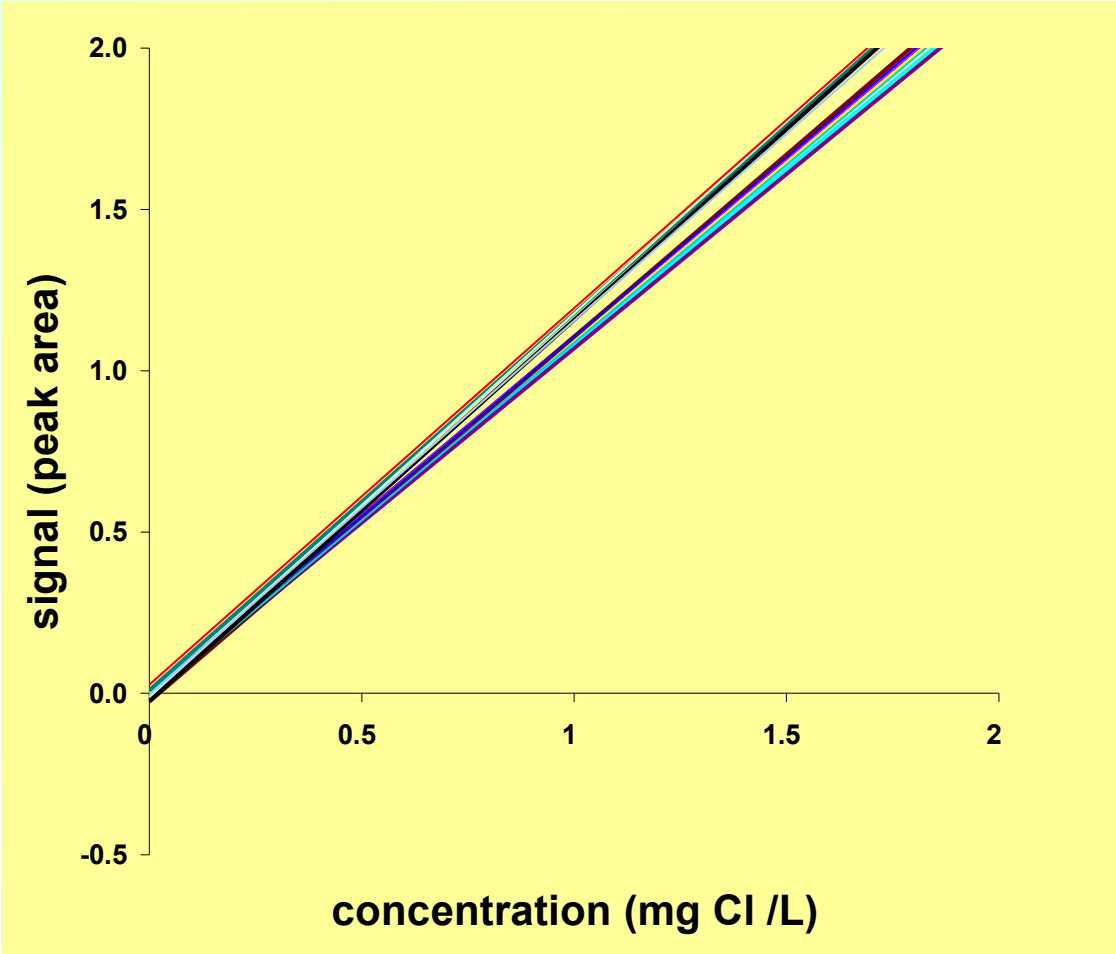
5 cm optical path



Calibration curve

Chloride by Ion Chromatography determination

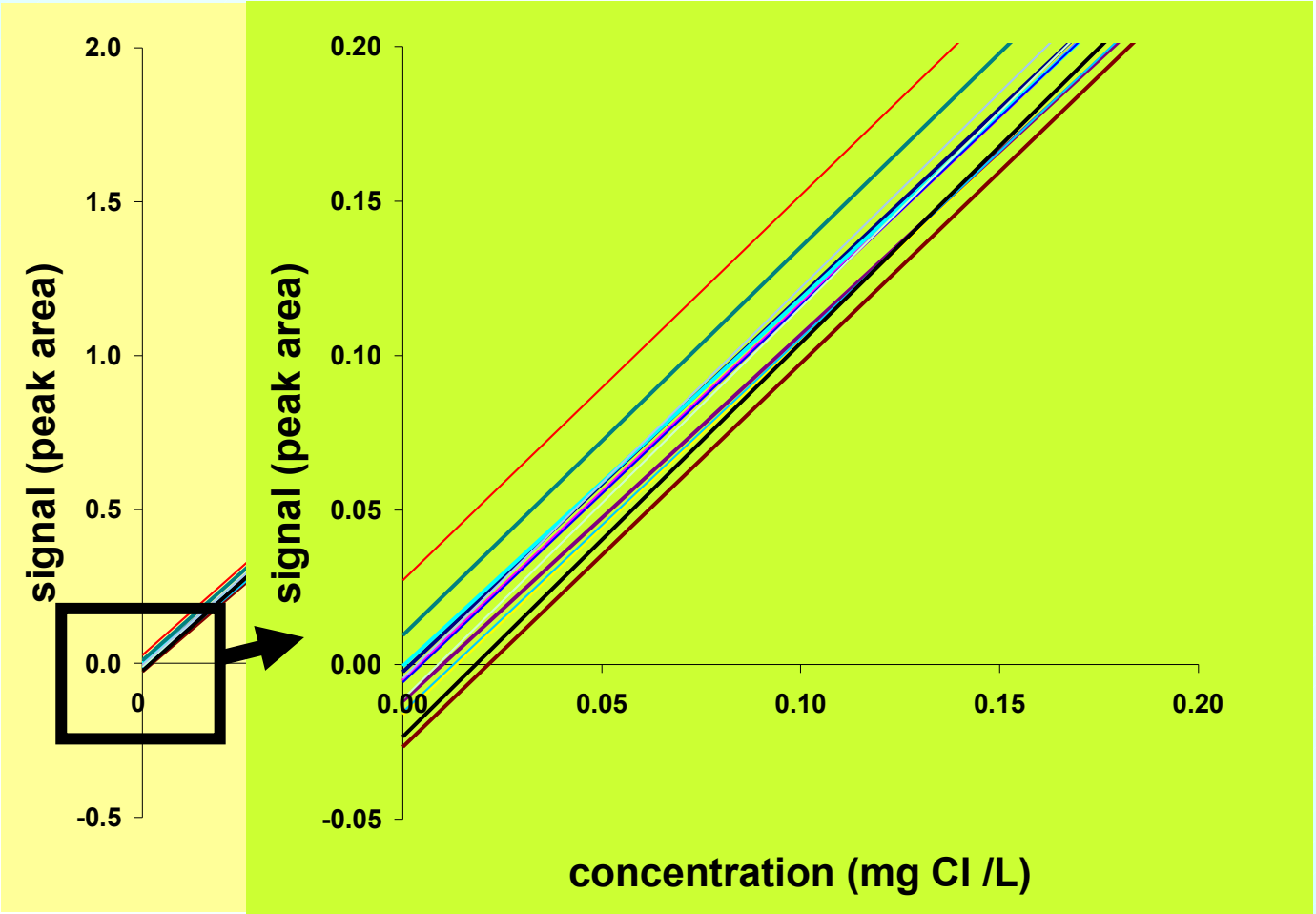
Dionex AG19-AS19-AAES 100µL sample loop



Calibration curve

Chloride by Ion Chromatography determination

Dionex AG19-AS19-AAES 100µL sample loop



In practice…

If you have mean control charts at different concentration,

use them to evaluate LOD and LOQ

else, if calibration slope is very stable (i.e. spectrophotometry)

use SD of the blanks (if possible)

or of a control sample of low concentration

or of the lowest standard

else,

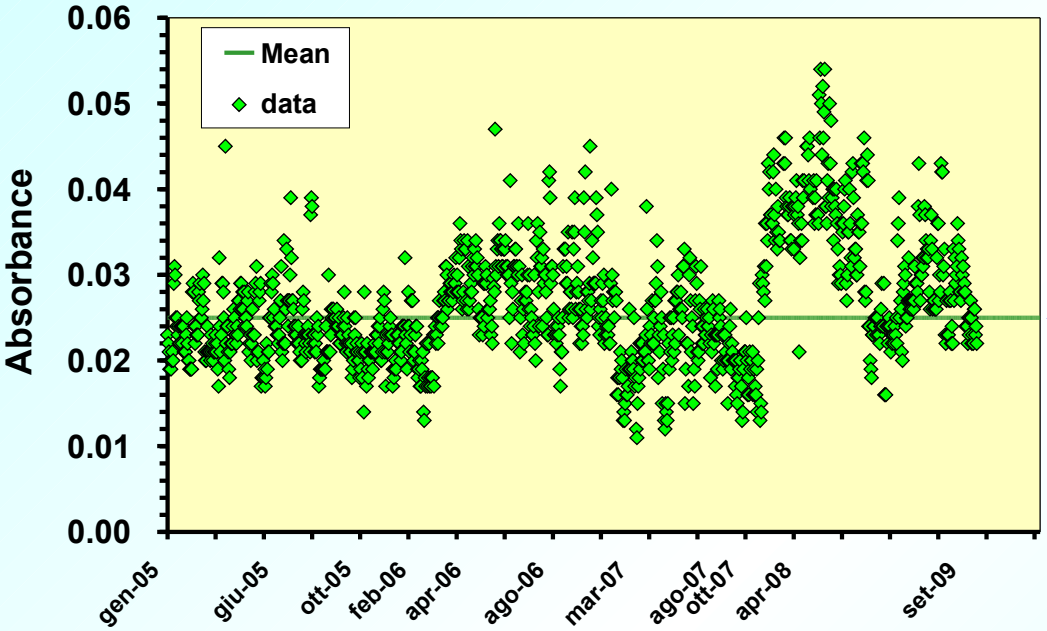
apply Hubax-Vos method on as many calibrations possible,

or use the variability of the calibration standards

SD of blank samples

N-NH_4 spectrophotometry indophenol blue

5 cm optical path



Mean = 0.025 mA

SD = 0.007 mA

$x_L = x_{bi} + ks_{bi}$

x_L = 0.025 + 3 x 0.007 = 0.046 mA

Calibration

mg N/L = 0.196 A + 0.0006

In the daily determinations and in the calibration, blank mean is subtracted from the values, then for estimating LOD use 3SD (0.021 A), not mean + 3SD (0.046 A)

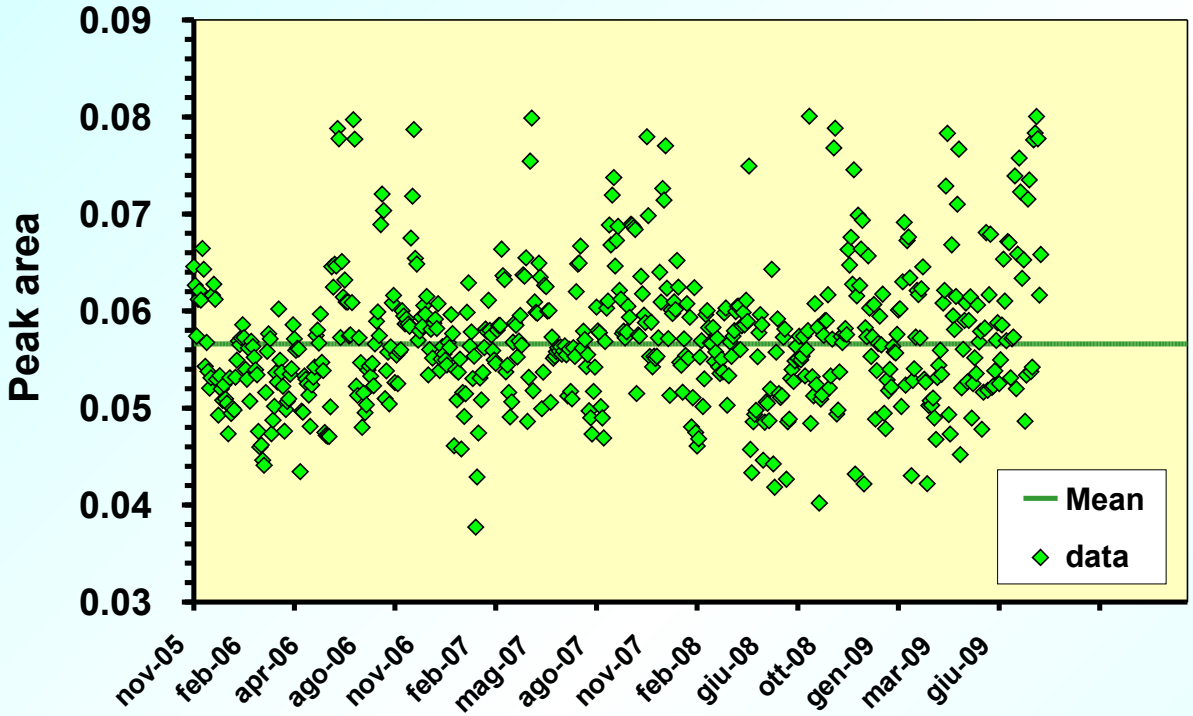
LOD 0.005 mg N/L = 0.196 x 0.021 + 0.0006

LOQ 0.014 mg N/L = 0.196 x 0.070 + 0.0006

Variability of the lowest standard

Chloride by Ion Chromatograpy determination

Dionex AG19-AS19-AAES 100µL sample loop



Lowest standard

0.05 mg Cl/L

Peak area mean = 0.057

Peak area SD = 0.007

$x_L = x_{bi} + ks_{bi}$

for lowest standard

$x_L = ks_{bi}$

$x_L = 3 \times 0.007 = 0.021$

Ratio Factor = peak area / ST concentration

RF = 0.057/0.05 = 1.14

LOD 0.018 mg Cl/L = 0.021/1.14

LOQ 0.061 mg Cl/L = 0.070/1.14

Variability of calibration standards

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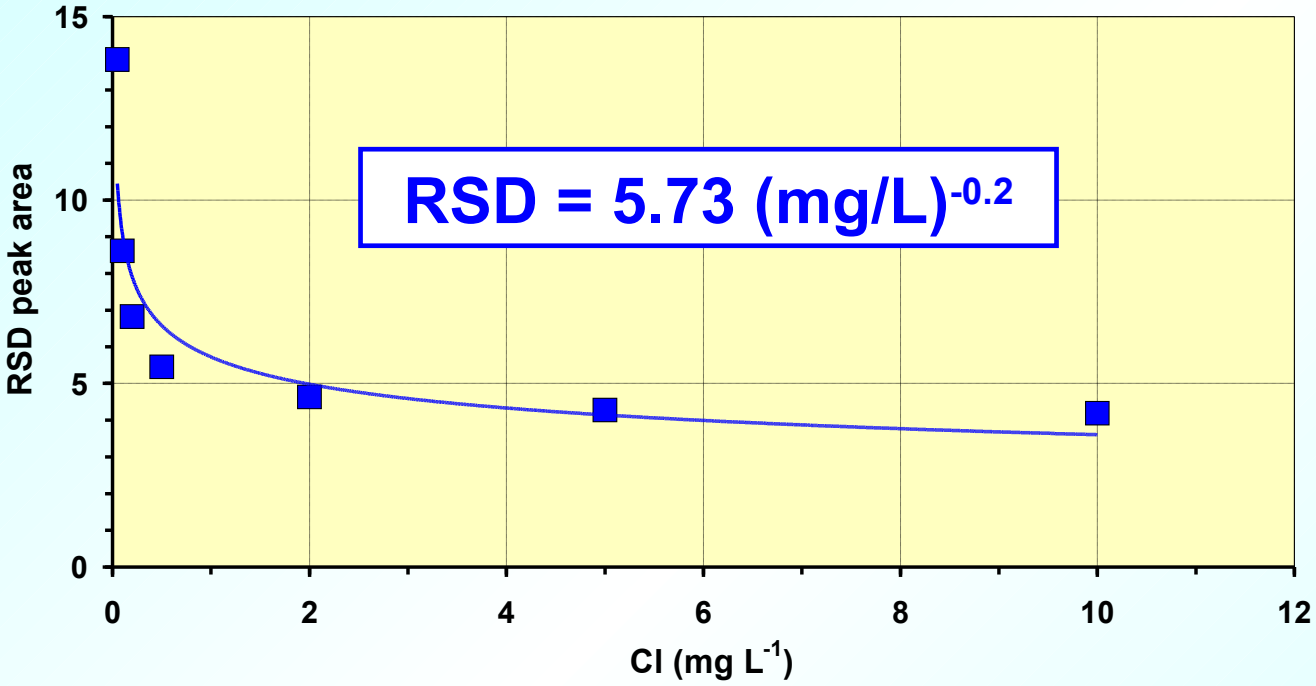


Standard mg/L	Peak area	RSD
0.05	0.058	13.8
0.10	0.108	8.6
0.20	0.218	5.8
0.50	0.558	5.5
2.00	2.277	4.6
5.00	5.701	4.3
10.00	11.439	4.2

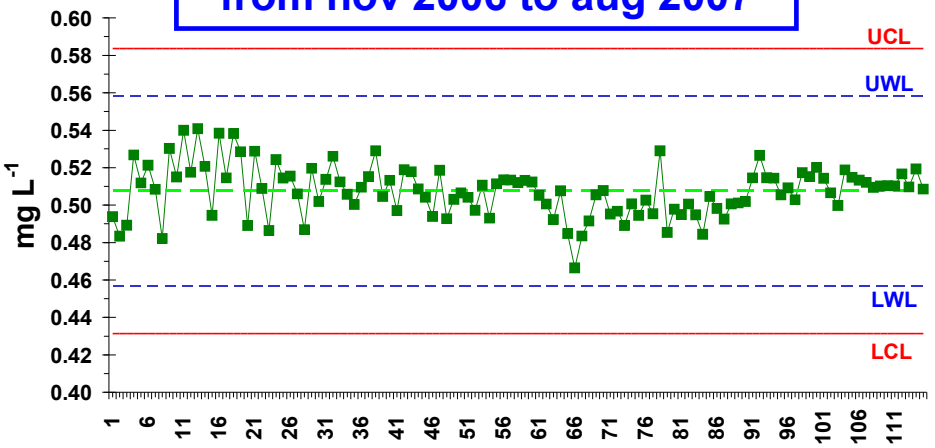
n >300 and 2-3 years of calibrations

LOD = RSD 33% = (5.73/33) $^{(1/0.2)}$ **LOD 0.0002 mg Cl/L**

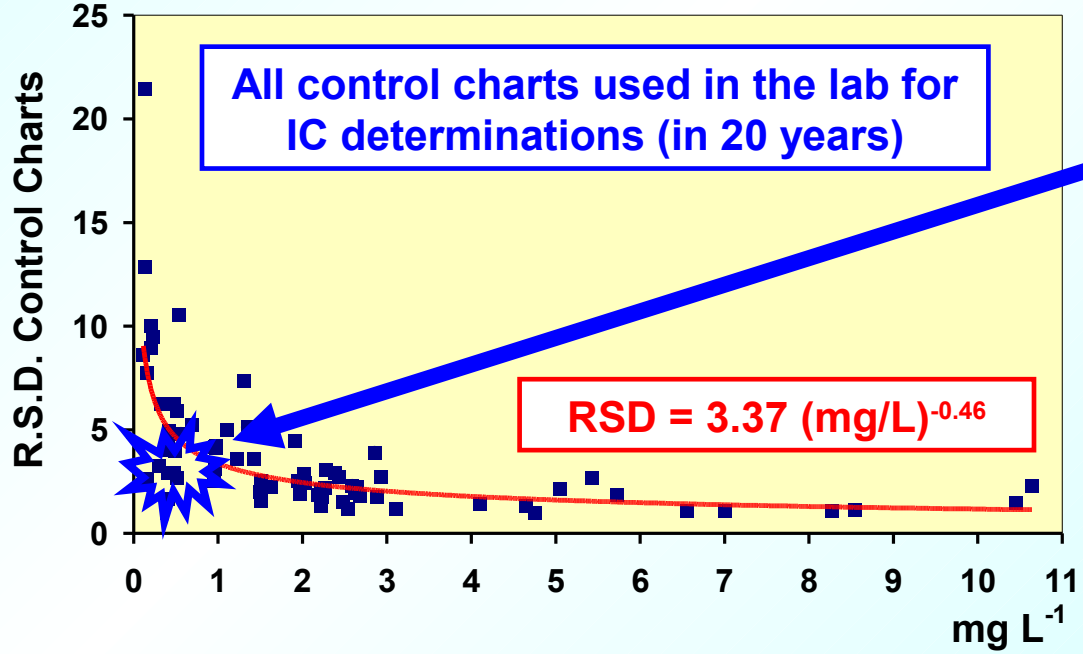
LOQ = RSD 10% = (5.73/10) $^{(1/0.2)}$ **LOQ 0.062 mg Cl/L**

Using control chart

Single control chart in use from nov 2006 to aug 2007

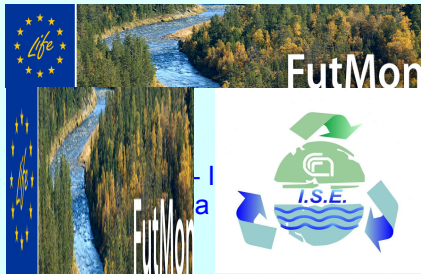


Statistics	mg L^{-1}
Average	0.508
Standard Deviation	0.013
Standard Deviation recommended	0.025
RSD %	2.7
RSD % recommended	5.0
Minimum	0.47
Maximum	0.54
N. data	115



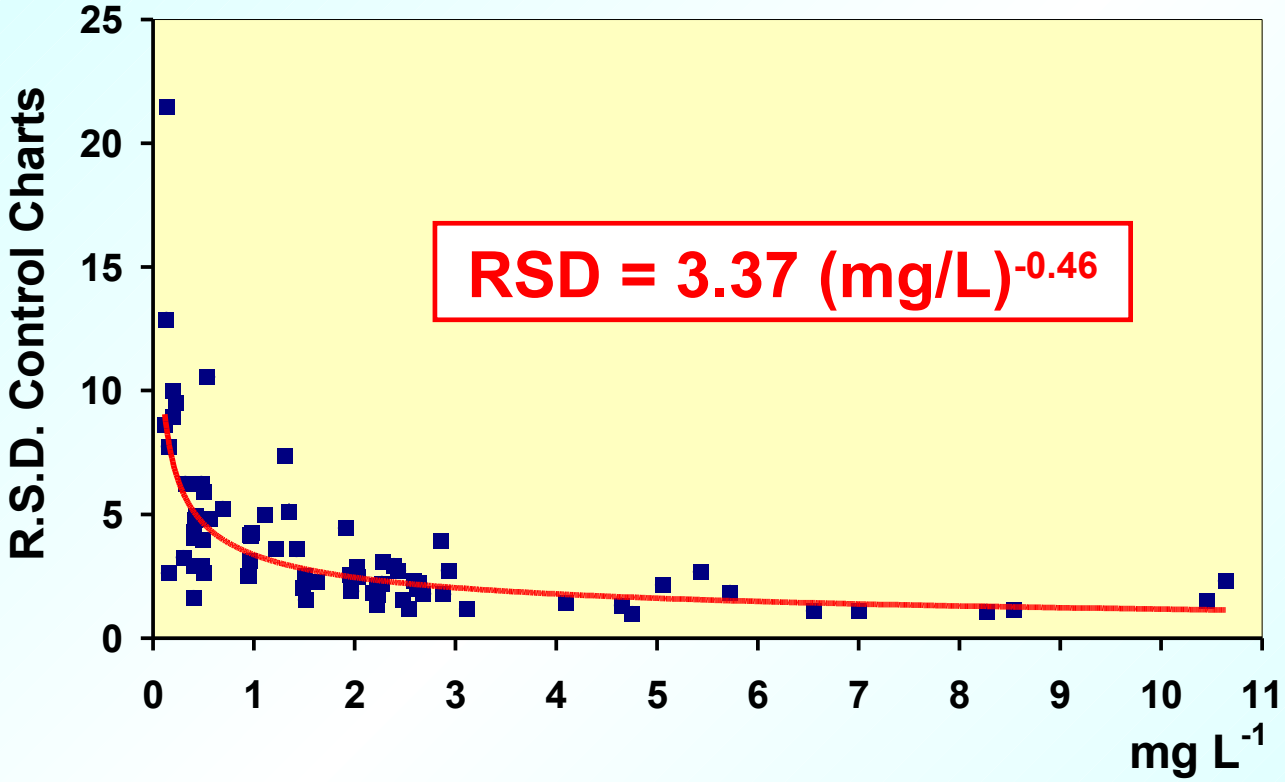
Chloride

Ion Chromatography



LOD from control charts

Chloride by Ion Chromatography determination (100µL sample loop)



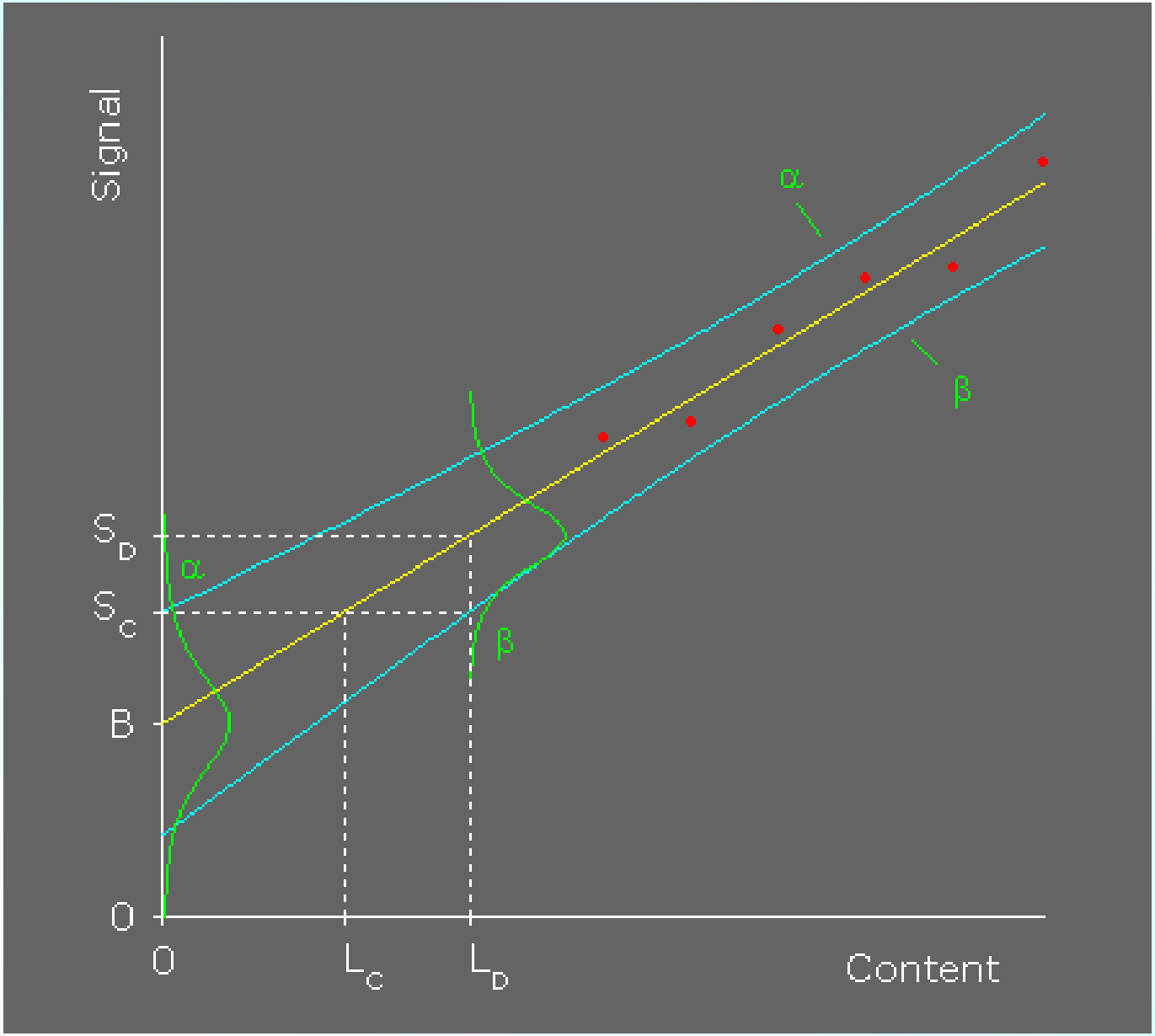
LOD = RSD 33% = (3.37/33) (1/0.46)

LOD 0.007 mg Cl/L

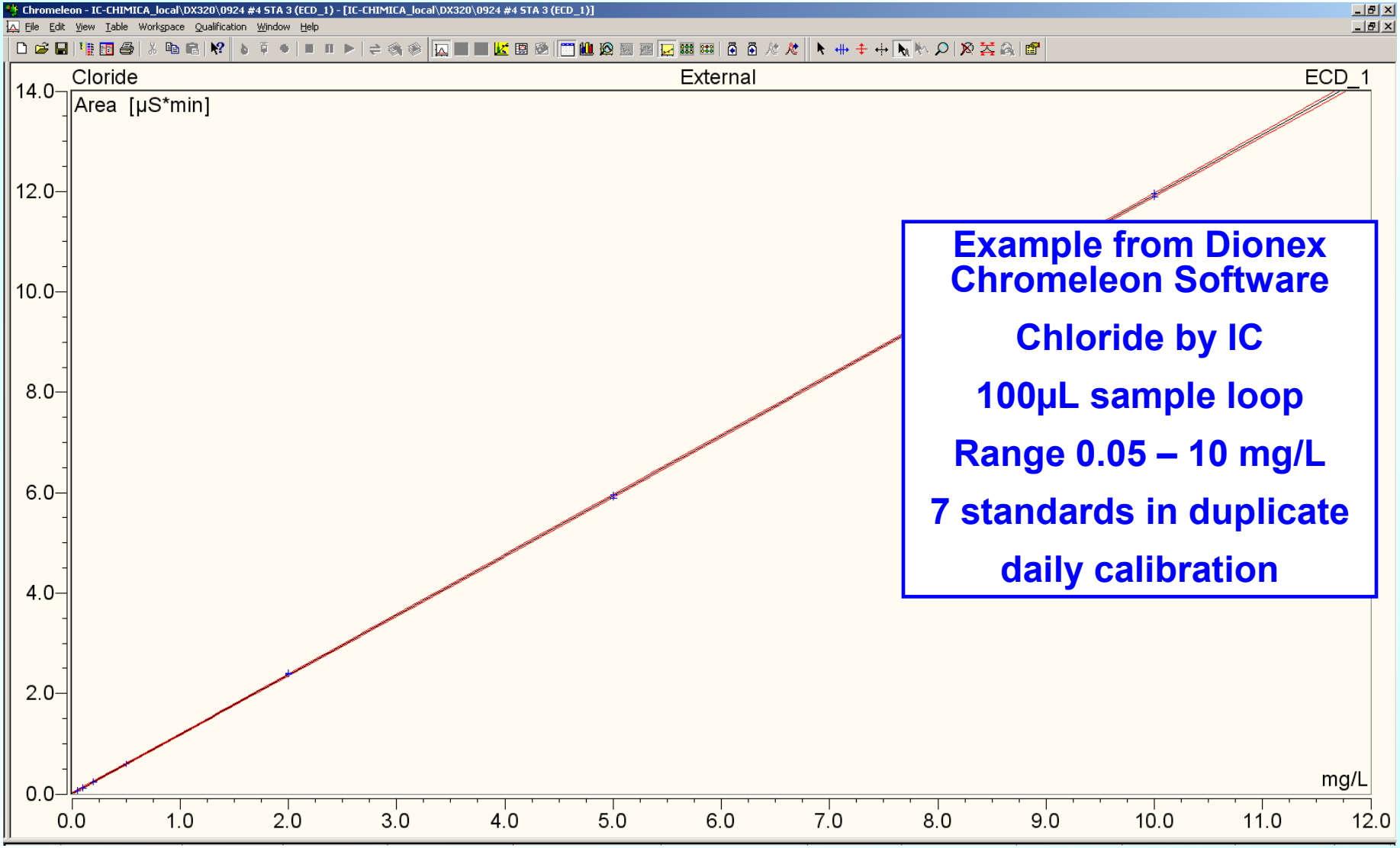
LOQ = RSD 10% = (3.37/10) (1/0.46)

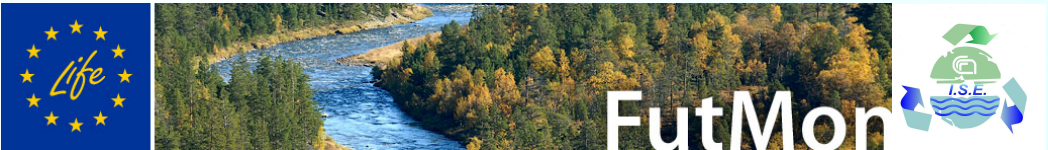
LOQ 0.094 mg Cl/L

Hubaux-Vos

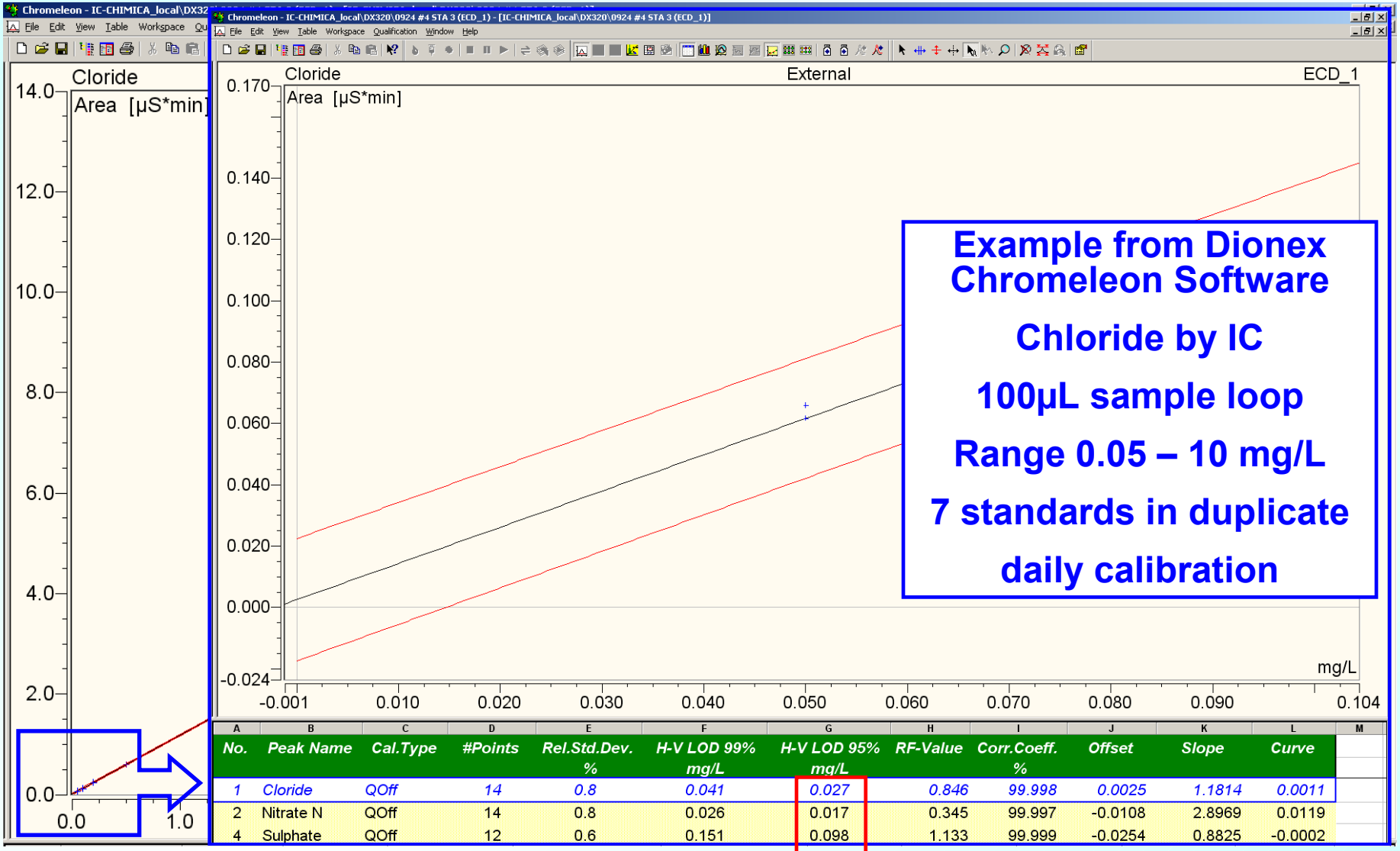


LOD from daily calibration (Hubaux-Vos)





LOD from daily calibration (Hubaux-Vos)



Example from Dionex Chromeleon Software

Chloride by IC

100µL sample loop

Range 0.05 – 10 mg/L

7 standards in duplicate daily calibration

A	B	C	D	E	F	G	H	I	J	K	L	M
No.	*Peak Name*	*Cal.Type*	*#Points*	*Rel.Std.Dev. %*	*H-V LOD 99% mg/L*	*H-V LOD 95% mg/L*	*RF-Value*	*Corr.Coeff. %*	*Offset*	*Slope*	*Curve*	
1	*Cloride*	*QOff*	*14*	*0.8*	*0.041*	*0.027*	*0.846*	*99.998*	*0.0025*	*1.1814*	*0.0011*	
2	Nitrate N	QOff	14	0.8	0.026	0.017	0.345	99.997	-0.0108	2.8969	0.0119	
4	Sulphate	QOff	12	0.6	0.151	0.098	1.133	99.999	-0.0254	0.8825	-0.0002	

LOD 0.027 mg Cl/L

LOD from average calibrations (Hubaux-Vos)

Chloride by Ion Chromatography determination

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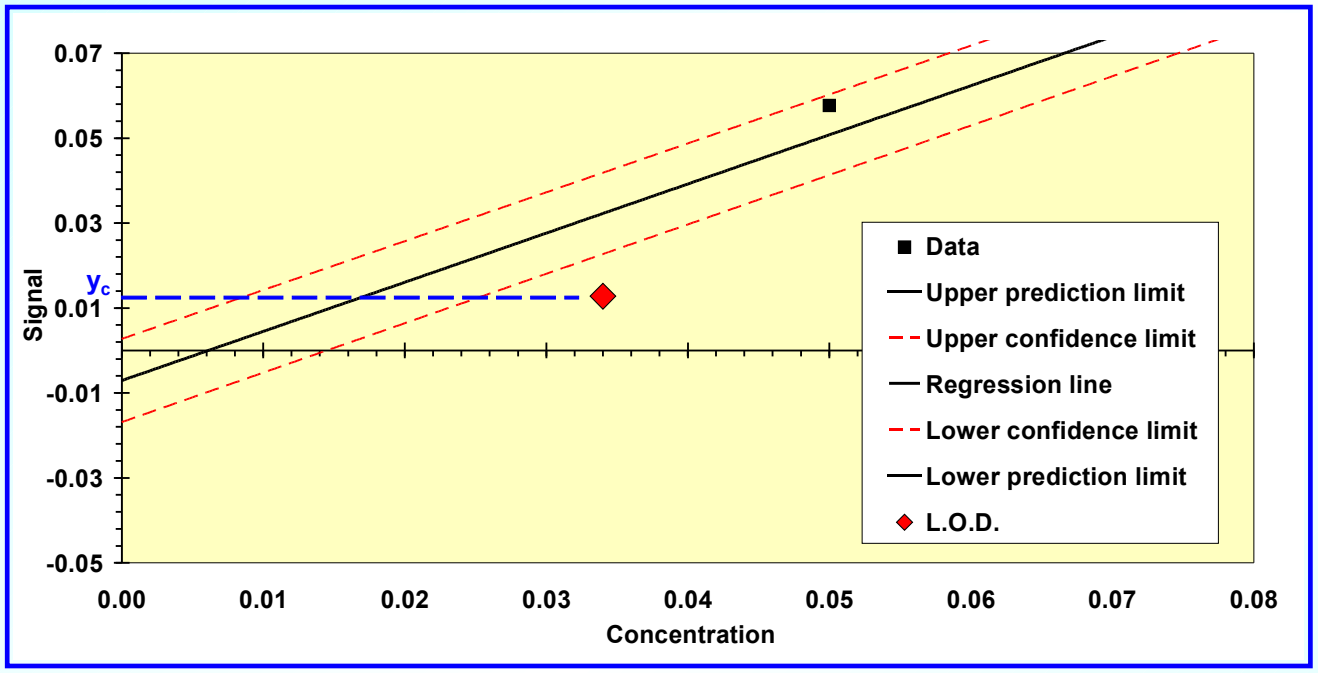

Range 0.05 – 10 mg/L
7 standards
More than 300 calibrations
in 2-3 years

Standard mg/L	Peak area	RSD
0.05	0.058	13.8
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0.50	0.558	5.5
2.00	2.277	4.6
5.00	5.701	4.3
10.00	11.439	4.2

LOD 0.038 mg Cl/L

Values obtained:

Chloride by Ion Chromatography determination

Dionex AG19-AS19-AAES 100µL sample loop

Results obtained (mg Cl / L)	LOD	LOQ
Lowest standard variability	0.018	0.061
Standards variability RSD 33/10%	0.0002	0.062
Control charts RSD 33/10%	0.007	0.094
Hubaux-Vos daily calibration	0.027	0.089
Hubaux-Vos average calibrations	0.038	0.073 *

* Gibbons's AML

In practice…

If you have mean control charts at different concentration,

use them to evaluate LOD and LOQ

else, if calibration slope is very stable (i.e. spectrophotometry)

use SD of the blanks (if possible)

or of a control sample of low concentration

or of the lowest standard

else,

apply Hubax-Vos method,

or use the variability of the calibration standards

Conclusions

- Quality Control is an important tool to criticize analytical activity, to improve it and to assure that it is suitable for the purpose of monitoring.
- The estimation of LOD and LOQ is an important part of Quality Control.
- LOD and LOQ can be simply evaluated using results of control charts, blank samples or calibration curves.
- If you do not store these data yet, please store them anywhere and in a few years you will have years of data...

Thank you for your attention