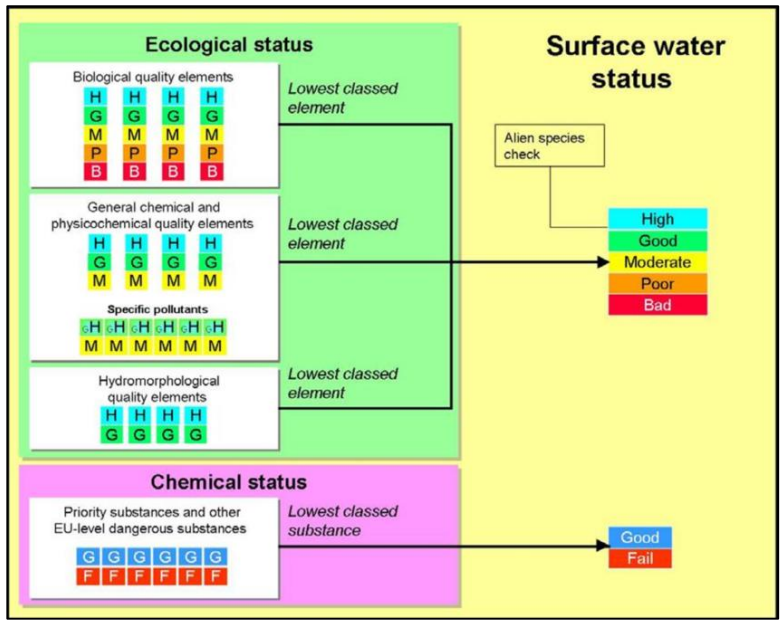
Data collection and infrastructure

Quality Assurance and Control

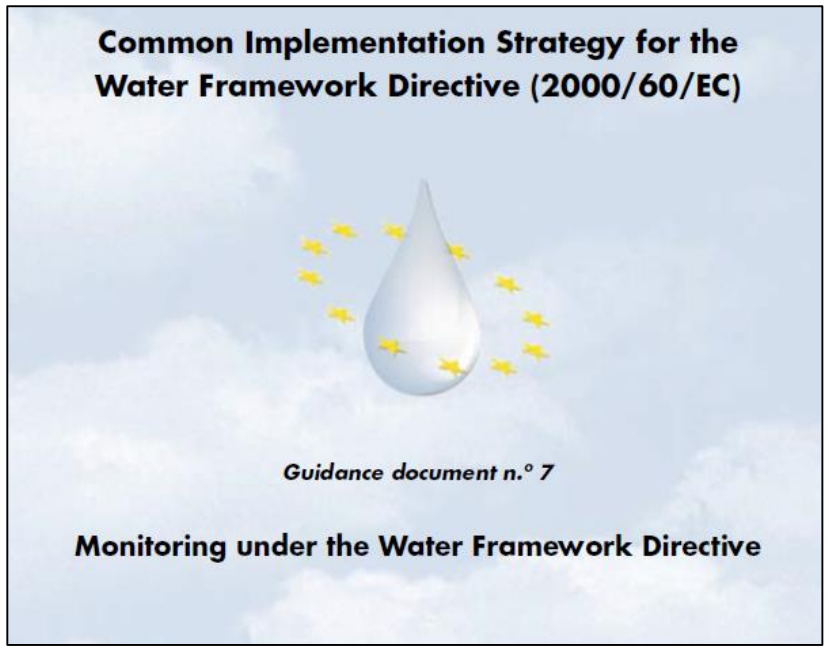
Quality Assurance and Control

Monitoring programs may not initially have been designed to cover all aspects of the WFD however it is desirable they should be capable of providing data which is robust enough to meet the relevant national / international criteria

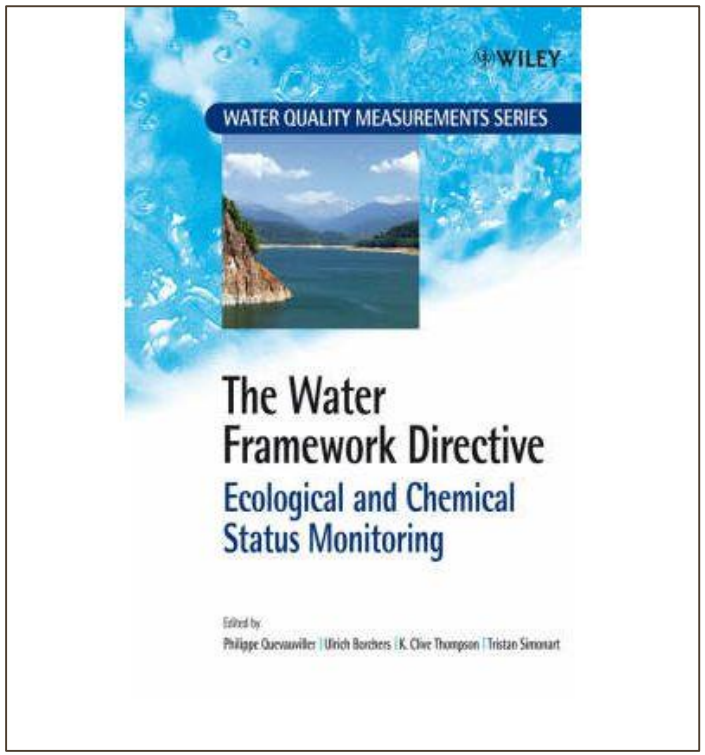


One out – All out approach to quality

WFD Ecological and Chemical status are assessed independently



https://circabc.europa.eu/sd/a/63f7715f-0f45-4955-b7cb-58ca305e42a8/Guidance%20No%207%20-%20Monitoring%20(WG%202.7).pdf



Print ISBN:9780470518366
Online ISBN:9780470716090

Quality Assurance and Control

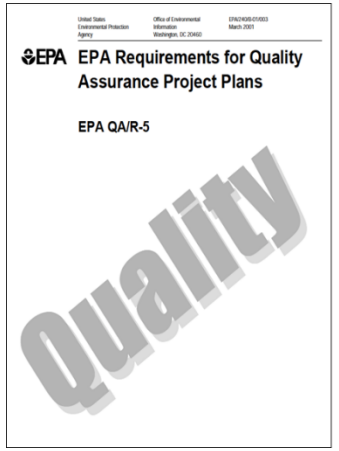
Quality Assurance (QA) is all the planned and systematic activities implemented within the Quality System (QS) that can be demonstrated to provide confidence that a product or service meets the requirements for quality.

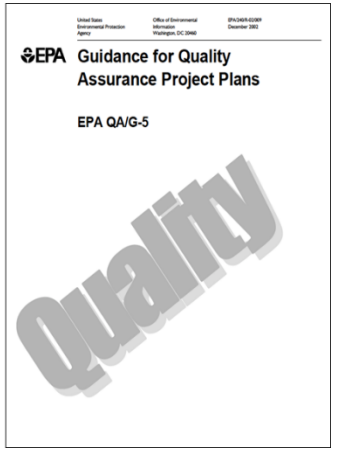
Quality Control (QC) describes the operational techniques and activities used to fulfil the requirements for quality.

Quality Assurance is ***process*** orientated and focuses on defect ***prevention***, while quality control is ***product*** orientated and focuses on defect ***identification***.

A **Quality Assurance Plan** (QAP) should be a central feature of any QA system

- It is prepared either as part of, or after, the monitoring programme planning process.
- Once the data quality objectives have been defined, the next important part of creating a QAP is to define the roles and responsibilities of team members.
- In all cases the QAP should be completed and approved by all stakeholders before monitoring is started and should be approved by all stakeholders.
- These two US EPA documents provide useful guidance for developing QAPs:





https://www.epa.gov/sites/production/files/2016-06/documents/r5-final_0.pdf

https://www.epa.gov/sites/production/files/2015-06/documents/g5-final.pdf

Quality Assurance – Field operations

- The sampling equipment required and sample collection methods should ideally be set out in **Standard Operating Procedures (SOPs)**

- These should describe in sufficient detail the approach to:

  - Preparation and decontamination of sampling equipment,
  - Selection and preparation of sample containers, volumes to be sampled, and any preservation reagents required
  - Sample collection methods
  - Sample preservation methods (as required).
  - Field data equipment and **calibration** procedures e.g. for Temp, DO, pH, EC
  - Standard references (used in the creation of the SOPs)
  - Sample storage and transit procedures
  - The individuals responsible for any corrective action should also be identified.

http://publications.gc.ca/collections/Collection-R/En40-498-2005-1E.pdf

Quality Assurance – Field operations

Sources of sample contamination in the field can include:

- Contaminated sampling equipment. Carryover of substances from one sample collection to the next may be caused by inadequate rinsing or cleaning of the sampling and field preparation equipment between samples, e.g. buckets, samplers, field filtration equipment, etc.
- The use of unsuitable sampling devices and containers (e.g. devices/containers that may introduce contaminants to the samples through leaching or abrasion of the container material, or from lubricants in pumps).
- Contamination from the general environment including:
  - import of contaminants during sampling procedure, e.g. soil contact from bank material and sediment, from abrasion of bridge railings,
  - filling and storing of samples in air contaminated by pollutants, e.g. from exhaust fumes
  - outgassing of preservatives, or volatilisation from strongly contaminated samples.
- Cross contamination from preservative chemicals.
- Mixing up the sample bottle lids.
- Inappropriate storage and transport arrangements.

Quality Assurance – Sample handling

- How samples will be physically handled, preserved (if required), transported and received **should** be documented and
- ***Chain-of-custody*** requirements should be described (as a minimum) in a Sampling Manual (or Laboratory Quality Manual)
- The maximum allowed holding time from collection to analysis, including any relevant laboratory preservation procedures must also be documented.
- Information should be provided on sample archiving, storage and retrieval, and the chain of responsibility for these processes.
- Example sub-sections of a Sampling / Lab Quality Manual include:
  - **Sample supplies (e.g. bottles)**
  - **Physical handling**
  - **Transportation / Refrigeration**
  - **Reception at laboratory**
  - **Hold times prior to analysis**
  - **Documentation**
  - **Sample archiving, storage and retrieval**

Quality Assurance – Use of Field kits

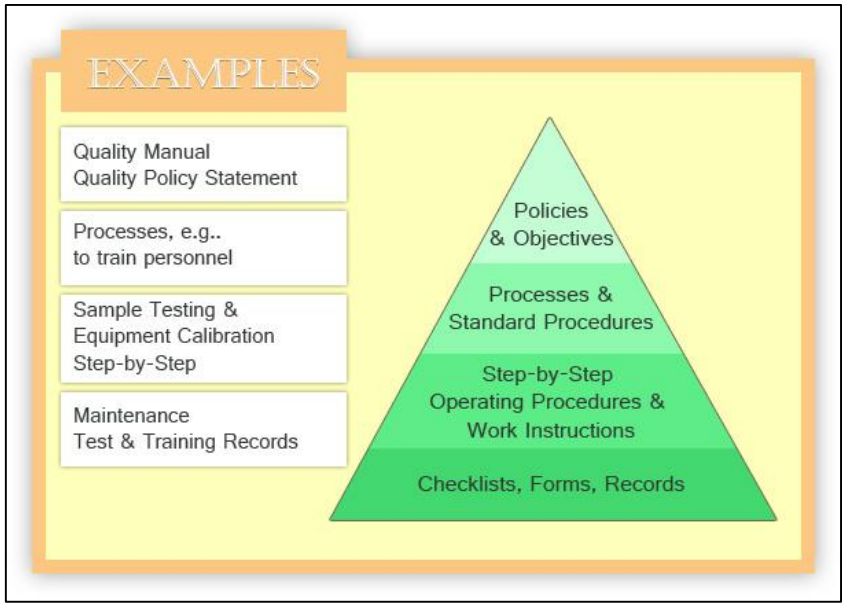
- In some circumstances it may be desirable, or simply more practicable, to undertake the analysis of specific substances of interest in the field as opposed to in the laboratory, particularly where long transport times may be needed.
- There are a wide range of proprietary test kits available **but, in general, their sensitivity, fails to match that of laboratory analysis**. Nonetheless they may present a viable option in some circumstances. The following standards provide some guidance on the selection and use of such field kits:
- **BS ISO 17381:2003** "Water Quality – Selection and Application of ready-to-use test kit methods for water analysis".
- **BS 1427:2009** "Guide to on-site test methods for the analysis of waters". This document provides practical guidance on the choice and limitations of test kits available for many routine water and wastewater analyses such as COD, BOD and nutrients. https://allcivilstandard.com/wp-content/uploads/2019/02/BS-01427-2009.pdf

https://www.epa.ie/pubs/conferencesandevents/aq/Analytical.pdf

Quality Assurance – ISO 17025: 2017

The **ISO/IEC 17025:2017** standard consists of several sections as outlined:

- Scope
- Normative References – the reference documents underpinning this standard
- Terms and Definitions – What specific terms in the standard mean
- *General Requirements – Impartiality / Confidentiality criteria*
- *Structural Requirements – Organizational structure / Roles & responsibil*ities
- Resource Requirements – Personnel, Facilities, Equipment, Metrological traceability, External products / services
- Process Requirements – (See later slide)
- Management System requirements
- Annex A – Metrological traceability (informative)
- Annex B – Management System options (informative)
- Bibliography –documentation referred to within the standard



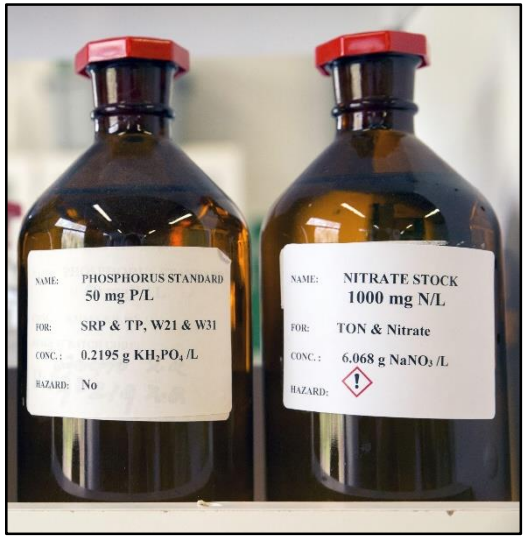
ISO/IEC 17025 requires different types of documentation, as illustrated in the documentation pyramid (Huber, 2009).

Of these, sections 5 – 8 and, in particular, section 7 (Process requirements) are perhaps the most critical.

Huber, L. (2009). *Understanding and implementing ISO/IEC 17025 – A Primer.* 1ST ed. [pdf] Agilent Technologies. Available at: http://www.demarcheiso17025.com/document/Understanding%20and%20Implementing%20ISO17025.pdf

Quality Assurance – ISO 17025: 2017

- Central to the operation of ISO 17025 is the **Quality Manual**
- This documentation provides a detailed account of how the laboratory works, its staff structure and responsibilities together with details of training, instrumentation calibration / servicing etc.
- A key feature is the requirement for routine audits (internal and external) and correction of any non-compliances observed
- The Quality Manual will contain (or at a minimum refer to) the laboratories SOPs for all processes undertaken within its facility
- Environmental conditions, Reagent preparation / storage, as well as sample retention times are also covered
- The Quality Manual will also provide details of data reporting procedures and action to be taken in the event of non-conforming work or customer queries
- Details of how AQC will be applied within the laboratory are also required and, in particular, what actions will be taken in the event of any non-conformance(s)
- Details of data approval procedures / reporting formats / data storage and security



Commonly requested / tested Parameters (Waters)

Physical / Discrete

pH) Physical
Conductivity)
Appearance)
Colour / Turbidity)
Suspended Solids)
Total Solids)
Dissolved Solids)

Empirical

COD) Empirical
BOD5) and defined
CBOD) by choice of
TOC) test method

Typical Nutrients

Ammonia)
Nitrate)
Nitrite)
TON / DIN)
Ortho-P)

Nutrients (Totals)

Kjeldahl N) Summed dets
Total Nitrogen) These 3 determined
Total Phosphorus) after sample
) digestion

Metals (Total / Dissolved)

Al, Cd, Cr, Cu, Ni, etc.) Single species
) but defined by
) by pre-treatment

Total Heavy Metals) No IUPAC definition!

Non-Specific parameters

Detergents / Surfactants) Generic terms
Fats, Oils Grease) defined by
Mineral Oils) test method used
Phenols) and reference
Cyanide) substance

Inorganic species

Fluoride
Chloride
Sulphate
Alkalinity (HCO_3)
Hardness

Organics

Specific organics e.g. $CHCl_3$
VOCs
Pesticides
PAHs
PCBs

Quality Assurance – Make sure you know what is being measured!

Laboratories can provide you with the information required only if they know unambiguously what is to be measured …

Common (generic) names are often used for chemical species which can have more than one form. The result obtained is therefore very much dependent on the analysis procedure e.g.

- **Cyanide … Readily dissociated (KCN), combined (KSCN), or complexed $K_4Fe(CN)_6$). Distillation form acid solution is required to measure the Total cyanide (CN-) in the sample. Other methods will only determine part of what might be there. Refs: ASTM D2036-09(2015) and D6994 (for metal complexed cyanides)**
  https://www.who.int/water_sanitation_health/dwq/cyanide.pdf

- **Phosphorus … Molydate / Soluble Reactive P (referred to a Ortho-P), Filtered (soluble -SRP) or unfiltered (total -TRP) or by difference (Particulate). Total P following acid digestion / colorimetry**

- **Phenols / Detergents/ Mineral Oils / DRO / TPH … Output is method specific and referenced against a standard such as Lauryl Sulphate / Sodium Dodecyl Benzene Sulphonate for Anionic Detergents, EPA Methods 604 / 625 / 8015B for Phenols** **https://www.researchgate.net/publication/263347874_Methods_for_the_determination_of_anionic_surfactants**

- **Nitrogen balance**

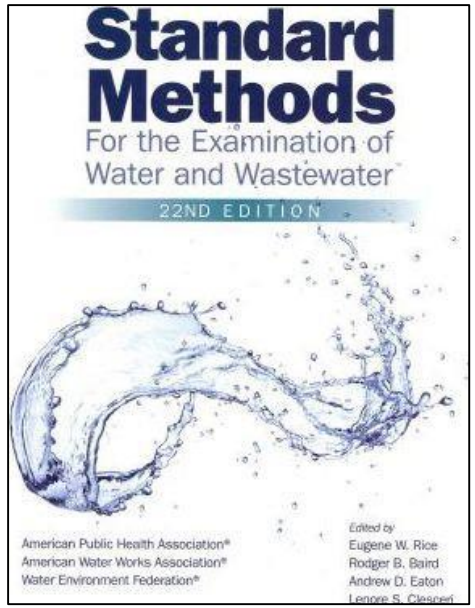
Total N … All reactive N in whole sample following Persulphate (OH-) digestion / colorimetery … best approach

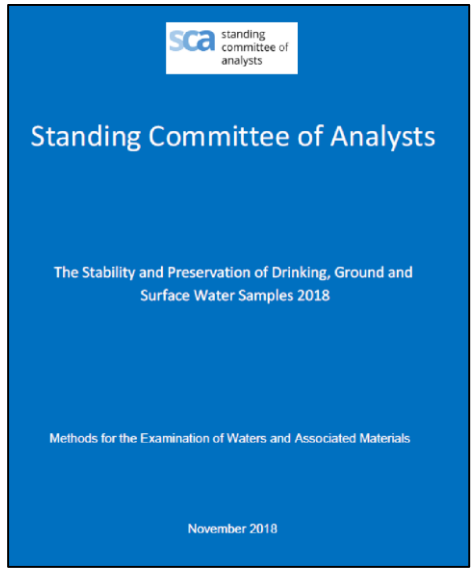
Total N … by Kjeldahl N (Protein N, NH_4, TON) … High error associated with KjN assays is water – OK for sewage or sludge

TON … Nitrate + Nitrite after Cd or Cu reduction (to NO_2) and colorimetry (very good accuracy)

Quality Assurance – Method selection

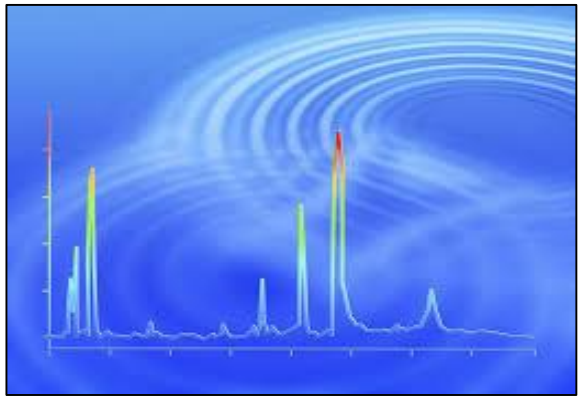
- There is wide range of national and international 'Standard' methods for water analysis. ISO / DIN / CEN methods are available for many common water parameters. Two of the most widely used references are :
- American Waterworks Association / American Public Health Association – "***Standard Methods for the Examination of Water and Wastewater***". This is updated every few years and the 23rd edition is the current version. Many of the more common procedures will be unchanged from the 22ND Edition (2012) which is available electronically at:
  https://www.mwa.co.th/download/file_upload/SMWW_1000-3000.pdf
  https://www.mwa.co.th/download/file_upload/SMWW_4000-6000.pdf
- Further information is available at: https://www.standardmethods.org/
- Another very useful reference source is the UK Standing Committee of Analysts series of 'Blue Book' publications (after their cover colour) entitled "***Methods for the Examination of Waters and Wastewater***" http://standingcommitteeofanalysts.co.uk/
- Older methods can be found in their archive section at:
  http://standingcommitteeofanalysts.co.uk/Archive/librarylist.html
- US EPA Methods are available at: https://www.epa.gov/cwa-methods
- A listing of UK Environment Agency methods (M18) is available at
  https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/646803/LIT_6898.pdf

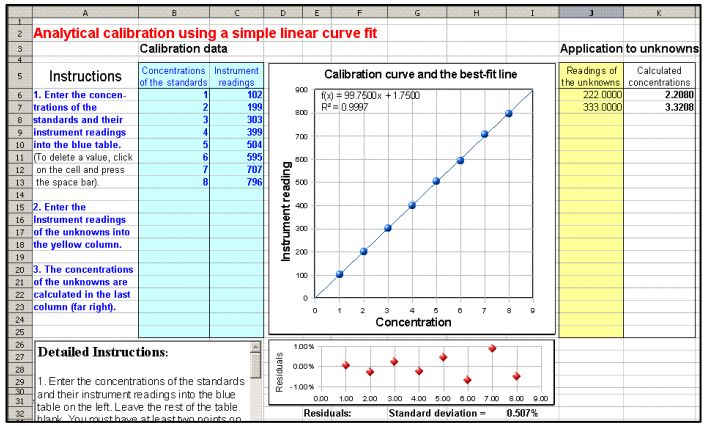




Quality Assurance – Method performance

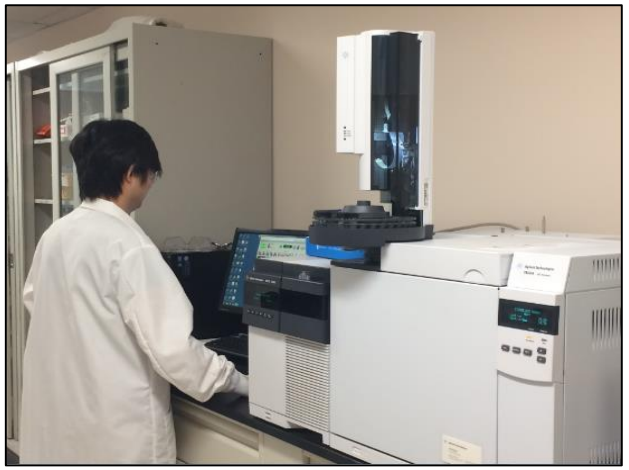
- **Choice of analytical method**
- A variety of documented analytical methods are usually available for determining the concentration of any variable in a water sample. The choice of method is critical to ensuring that the results of the analysis meet the requirements of the monitoring programme objectives, because methods often have different precision, sensitivity, and potential interferences.
- These "standard" methods frequently include extensive validation data, that allows them to be easily assessed for 'fitness for purpose' and many are sanctioned by appropriate national and international organisations.
- The performance of all analytical methods can be unpredictably affected by many factors which can lead to problems. Before a method is put into routine use, it is essential that it is properly **validated**. The following tests should be performed as a minimum programme of validation.
  - Linear range
  - Sensitivity / Selectivity
  - Limit of Detection / Quantitation
  - Precision
  - Accuracy
  - Recovery
  - Peak resolution (for chromatography methods)





Quality Assurance – Laboratory analysis

- Using an ISO 17025 accredited laboratory will (generally – but not always!) ensure that the analytical methodology applied:
  - Will be suitable for purpose and matrix.
  - Has had its performance criteria including the Limit of Detection, Sensitivity, and Linearity determined, and
  - Has had any known interferences identified and impacts assessed.
- **In general, analytical methods should be capable of achieving at least 1/10th of the concentration of interest (if possible) and no less than 1/3rd of the relevant concentration** e.g.
  - If the national target standard for ortho-P is 50 µg l^{-1} then the test method applied should ideally be capable of achieving a Limit of Detection of at least 5 µg l^{-1} P and no more than 16 µg l^{-1} P.
- For some analytical methods, such as chromatographic assays for pesticides, it may not be possible to achieve the above criteria. In such cases, the **best available methodology not exceeding excessive cost** should be applied.



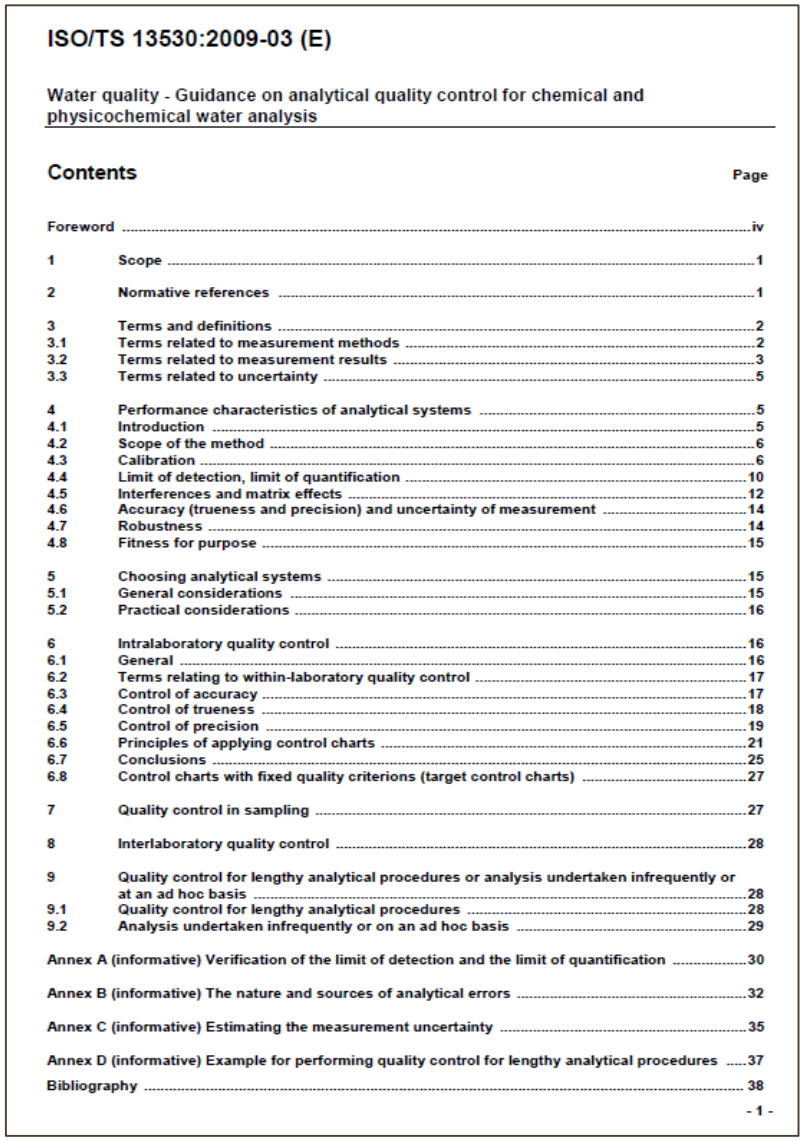
Quality Assurance – Method performance criteria

The previous slides present approaches to the implementation of quality assurance programs in a laboratory environment. Further guidance is available in **ISO/TS 13530:2009 – Water quality – Guidance on analytical quality control for chemical and physicochemical water analysis.**

This publication provides comprehensive guidance on within-laboratory and between-laboratory quality control for ensuring the production of results with a known level of accuracy in the analysis of waters. It is applicable to the chemical and physicochemical analysis of all types of waters. It is not intended for application to the analysis of sludge and sediments (although many of its general principles are applicable to such analysis). Whilst sampling is an important aspect, this is only briefly considered.

It does not address the biological or microbiological examination of water. Guidance on this aspect of freshwater monitoring is provided in **ISO 19548:2006** which provides guidance on planning water sampling regimes, on sampling procedures for microbiological analysis and on transport, handling and storage of samples until analysis begins.

ISO 8199:2018 provides guidance on the analysis of bacteria, yeasts and moulds, but some aspects are also applicable to bacteriophages, viruses and parasites. It excludes techniques not based on culturing microorganisms, such as polymerase chain reaction (PCR) methods. Other ISO and SCA Blue Book methods are available for common water microbiology parameters such as E.coli and Enterococci.



ISO/TS 13530:2009-03 (E)

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

Contents Page

- 1 -

Quality Assurance – Method Validation

- After a method has been selected as suitable for use its overall performance characteristics need to be validated. This is the confirmation – via the provision of objective evidence - that the requirements for the specifically intended use or application have been met.

https://www.inab.ie/Documents-Forms/Policy/Guide-to-Method-Validation-for-Quantitative- Analysis-in-Chemical-Testing-Laboratories-17025-PDF-36-Pages-349KB-.pdf

- The most widely used approach to this the analysis, in duplicate, of a series of solutions comprising:
  - **Blank (typically DI water)**
  - **Low Standard (ca. 20% of calibration range)**
  - **High Standard(ca. 80% of calibration range)**
  - **Low concentration sample of suitable matrix**
  - **Spike low concentration sample (spiked to ca. 50 - 80% of range)**
- The overall approach is outlined in detail in Annex C of the following document:

UK Environment Agency – *"Performance Standard for Organisations undertaking the Sampling and Chemical Analysis of Water"* – available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/769332/MCERTS__Performance_Standard__for_organisations_undertaking_sampling_and_chemical_testing_of_water.pdf

Performance Assessment Example Calculation: Ref. UK Environment Agency

Batch	Replicate	Sewage Efflt	Spiked Sewage	Recovery	Sewage Recovery %	Trade Effflt	Spiked T.Efflt	Recovery	Trade Efflt Recovery %
			(+ 5 mg/l)				(+15mg/l)		
1	1	0.327	5.073	4.746	94.9265	9.133	22.899	13.766	91.9560
1	2	0.45	5.311	4.861	97.2290	9.55	22.33	12.78	85.3910
	Batch Mean	0.3885	5.192	4.8035	96.07777	9.3415	22.6145	13.273	88.67349667
	Batch SD	0.08697	0.16829	0.08132		0.29486	0.40234	0.69721	
	Variance	0.00756	0.02832	0.00661		0.08694	0.16188	0.48610	
2	1	0.614	5.431	4.817	96.3523	9.688	24.227	14.539	97.1204
2	2	0.519	5.138	4.619	92.3904	9.376	23.38	14.004	93.5475
	Batch Mean	0.5665	5.2845	4.718	94.37133	9.532	23.8035	14.2715	95.33397333
	Batch SD	0.06718	0.20718	0.14001		0.22062	0.59892	0.37830	
	Variance	0.00451	0.04292	0.01960		0.04867	0.35870	0.14311	
3	1	0.281	5.427	5.146	102.9256	9.56	23.637	14.077	94.0379
3	2	0.412	5.394	4.982	99.6482	9.417	24.336	14.919	99.6483
	Batch Mean	0.3465	5.4105	5.064	101.28693	9.4885	23.9865	14.498	96.84310333
	Batch SD	0.09263	0.02333	0.11597		0.10112	0.49427	0.59538	
	Variance	0.00858	0.00054	0.01345		0.01022	0.24430	0.35448	
4	1	0.43	5.87	5.44	108.8086	9.77	21.871	12.101	80.8687
4	2	0.557	6.086	5.529	110.5911	9.564	21.039	11.475	76.6913
	Batch Mean	0.4935	5.978	5.4845	109.69987	9.667	21.455	11.788	78.78000667
	Batch SD	0.08980	0.15274	0.06293		0.14566	0.58831	0.44265	
	Variance	0.00806	0.02333	0.00396		0.02122	0.34611	0.19594	
5	1	0.698	5.289	4.591	91.8340	10.189	23.114	12.925	86.3704
5	2	0.744	5.899	5.155	103.1149	10.882	23.565	12.683	84.7710
	Batch Mean	0.721	5.594	4.873	97.47442	10.5355	23.3395	12.804	85.57071
	Batch SD	0.03253	0.43134	0.39881		0.49002	0.31891	0.17112	
	Variance	0.00106	0.18605	0.15905		0.24012	0.10170	0.02928	
6	1	0.495	5.395	4.9	98.0099	10.055	23.389	13.334	89.0944
6	2	0.415	5.845	5.43	108.6083	10.72	22.773	12.053	80.5677
	Batch Mean	0.455	5.62	5.165	103.3091	10.3875	23.081	12.6935	84.83108333
	Batch SD	0.05657	0.31820	0.37477		0.47023	0.43558	0.90580	
	Variance	0.00320	0.10125	0.14045		0.22111	0.18973	0.82048	
7	1	0.787	5.414	4.627	92.5557	9.239	22.304	13.065	87.2848
7	2	0.57	5.735	5.165	103.3114	9.678	23.836	14.158	94.5802
	Batch Mean	0.6785	5.5745	4.896	97.93357	9.4585	23.07	13.6115	90.93250333
	Batch SD	0.15344	0.22698	0.38042		0.31042	1.08329	0.77287	
	Variance	0.02354	0.05152	0.14472		0.09636	1.17351	0.59732	
8	1	0.94	5.391	4.451	89.0388	10.271	23.437	13.166	87.9788
8	2	0.647	5.201	4.554	91.0929	10.31	23.736	13.426	89.7129
	Batch Mean	0.7935	5.296	4.5025	90.06587	10.2905	23.5865	13.296	88.84581
	Batch SD	0.20718	0.13435	0.07283		0.02758	0.21142	0.18385	

Double left click to open the example.

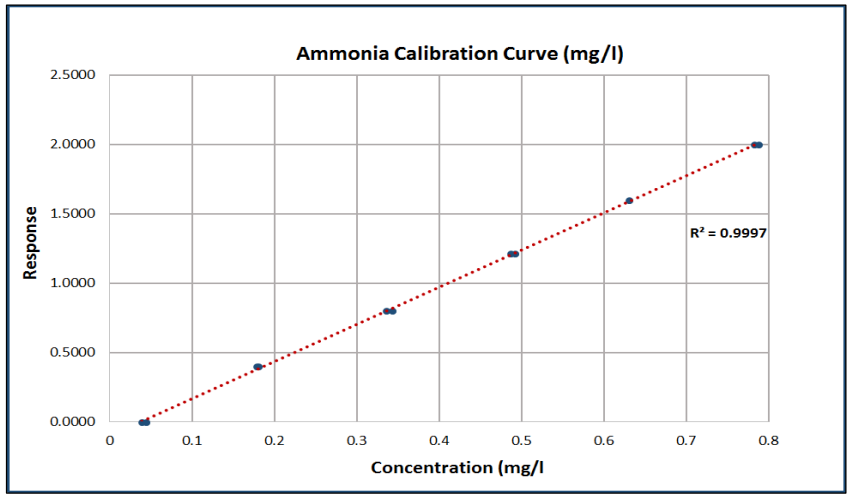
Esc to return to pptx

Quality Assurance – Method performance

Linearity / Linear range

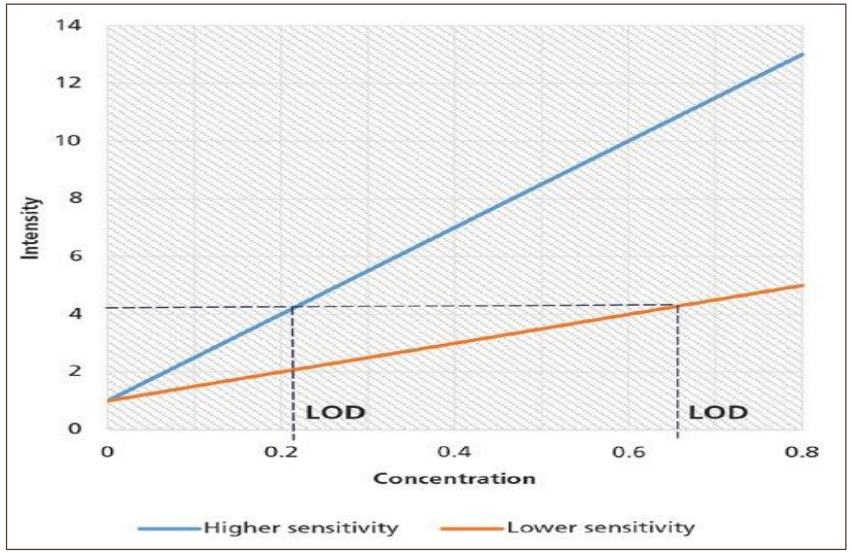
It is preferable to undertake a specific calibration response for each batch of analysis. For **very** stable systems it may be sufficient to check the linear response / sensitivity using both a low / high range standards e.g. 20% / 80% of the linear range and reviewing their response against pre-determined criteria (e.g. peak area counts). The ideal calibration curve is one which is linear within the most useful range, with a regression coefficient of 0.95 or better. It is not unusual however to see some curvilinear response at both low and high concentrations.

Data should generally be reported only if in the linear range of the calibration.



Sensitivity

Sensitivity is the ability to distinguish between small increments in concentration. The larger the signal to concentration ratio the more sensitive a method is.



Eurachem Guide: Fitness for Purpose of Analytical Methods
https://www.eurachem.org/images/stories/Guides/pdf/MV_guide_2nd_ed_EN.pdf

Quality Assurance – Method performance

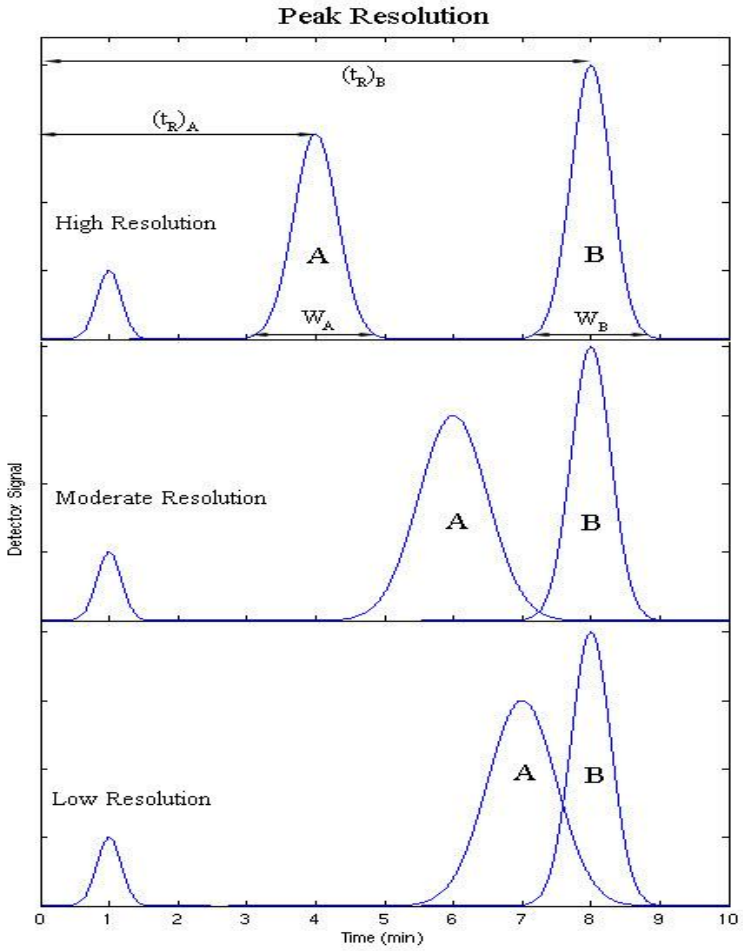
Recovery

For those test methods which rely on conversion of one form of a substance to another for analysis (e.g. in the determination of Total Nitrogen or Total Phosphorus) recovery is a measure of the degree of conversion. It is generally expressed as a percentage value and is based on the assessment of substances which require to be converted before analysis e.g. organic phosphorus compounds -> ortho-P. In general recovery should be > 90%

It can also be applied to methods such as solid phase extraction techniques to assess the extent to which a determinant can be extracted from the test sample

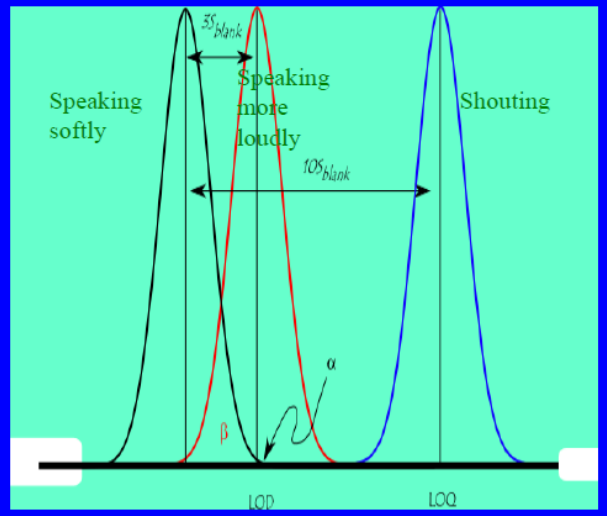
Resolution

In chromatographic methods, resolution is the degree to which one analyte can be distinguished from another. Other critical chromatographic criteria include the assessment of peak asymmetry (Tailing factor) and Retention time (how long the component takes to elute). This is usually assessed relative to a reference substance.



Source: Chemistry Libre Texts

Quality Assurance – LoD vs LoQ



It is often difficult to understand the concept of detection limit. The following example may help to clarify some of the concepts defined previously.

(Source : Wikipedia)

Suppose you are at an airport with lots of noise from jets taking off. If the person next to you speaks softly, you will probably not hear them. Their voice is less than the LOD. If they speak a bit louder, you may hear them but it is not possible to be certain of what they are saying and there is still a good chance you may not hear them. Their voice is >LOD but <LOQ. If they shout then you can understand them and take action on what they are saying and there is little chance you will not hear them. Their voice is then >LOD and >LOQ. Likewise, their voice may stay at the same loudness, but if the noise from jets is reduced allowing their voice to become >LOD you will hear them.

Detection limits are thus dependent on both their voice (signal intensity) and background noise (jet noise)

Limit of Detection

The LoD is the lowest concentration of the variable that can be distinguished from a zero concentration (blank) with a stated level of confidence (e.g. 95%). (Ref: ISO 13530:2009). It is generally taken to be three times the standard deviation of a series of repeated blank sample outputs.

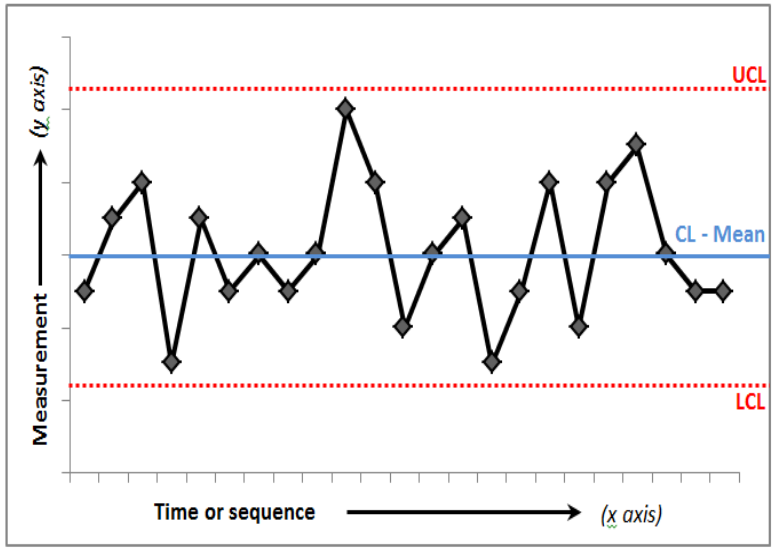
Limit of Quantitation / Practical reporting limit

The LoQ is generally taken to be the lowest concentration of the variable that can be reliably quantified subject to defined accuracy and precision criteria. It is generally taken to be 10 times the standard deviation of repeated blank sample outputs.

Quality Assurance – Analytical Quality Control

Quality Control Procedures

- Analytical Quality Control (AQC) procedures are fundamental in ensuring that data quality is not compromised by factors such as analytical bias, inaccuracy or poor precision.
- At its simplest it involves the use of a series of Shewart style Control Charts to assess the ongoing performance of each batch of analyses.
- It can utilize duplicates of real samples, surrogate controls, such as a bottled mineral water, or synthetic standards of the determinant.
- Whatever the source material, compliance with predefined limit values is necessary before data can be considered to be of suitable quality.

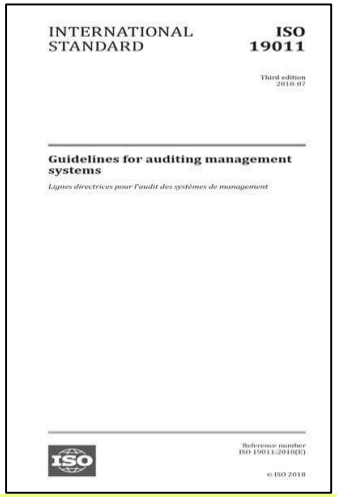


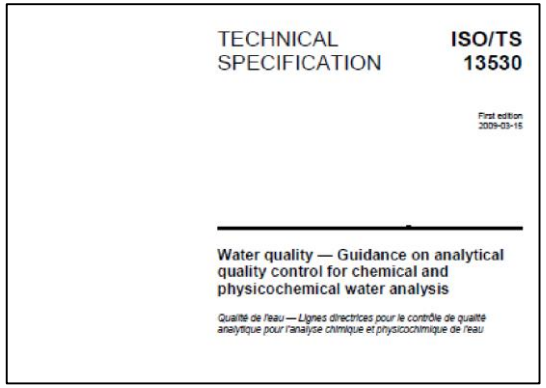
Source: East London NHS Foundation Trust

Auditing QA / QC procedures

QA systems should be subject to regular audit to determine their effectiveness

Guidance is available in **ISO 19011:2018**, **ISO 17025:2017**, and **ISO 13530:2009**





Quality Assurance – Internal checks

Checking precision using replicates

The use of replicate analysis of the same sample provides valuable information on the relative precision of the analytical method but only limited information on accuracy / bias. Results from duplicate analyses can be used to calculate a relative range value, R, by using the equation:

$$R = \frac{(X_1 - X_2)}{(X_1 + X_2)/2}$$

Where X_1 and X_2 are the duplicate results from an individual sample and $(X_1 - X_{2)}$ is the absolute difference between X_1 and X_2. These values are then compared with the mean relative range values previously calculated for the analyses during validation.

The simplest method of assessment is to use the upper concentration limit (UCL), where the UCL =3.27 × mean R value. When any value is greater than the UCL, the analytical procedure is out of control. This method, although statistically valid, provides no indication of deteriorating precision. A better approach is to use acceptance criteria based on both warning and action limits.

External proficiency testing schemes

There are a number of commercial external proficiency testing schemes which facilitate the analysis of unknown test samples between multiple laboratories. Where practicable the use of these is encouraged as it provides comparison of any systematic errors against other laboratories. Use of these materials is covered in more detail in coming lessons.

Quality Assurance – Inter-lab performance testing

Checking accuracy and precision using Proprietary or Certified Reference materials

The use of –proprietary waters (e.g. a commercial bottled water) or alternatively Certified reference materials and participation in inter-laboratory performance testing schemes provides valuable information on any systematic errors in the test methodology.

For bottled / mineral waters a general chemical analysis is provided by the supplier. For Certified Reference materials a Certificate of Analysis specifying the nominal concentration and uncertainty estimates are provided.

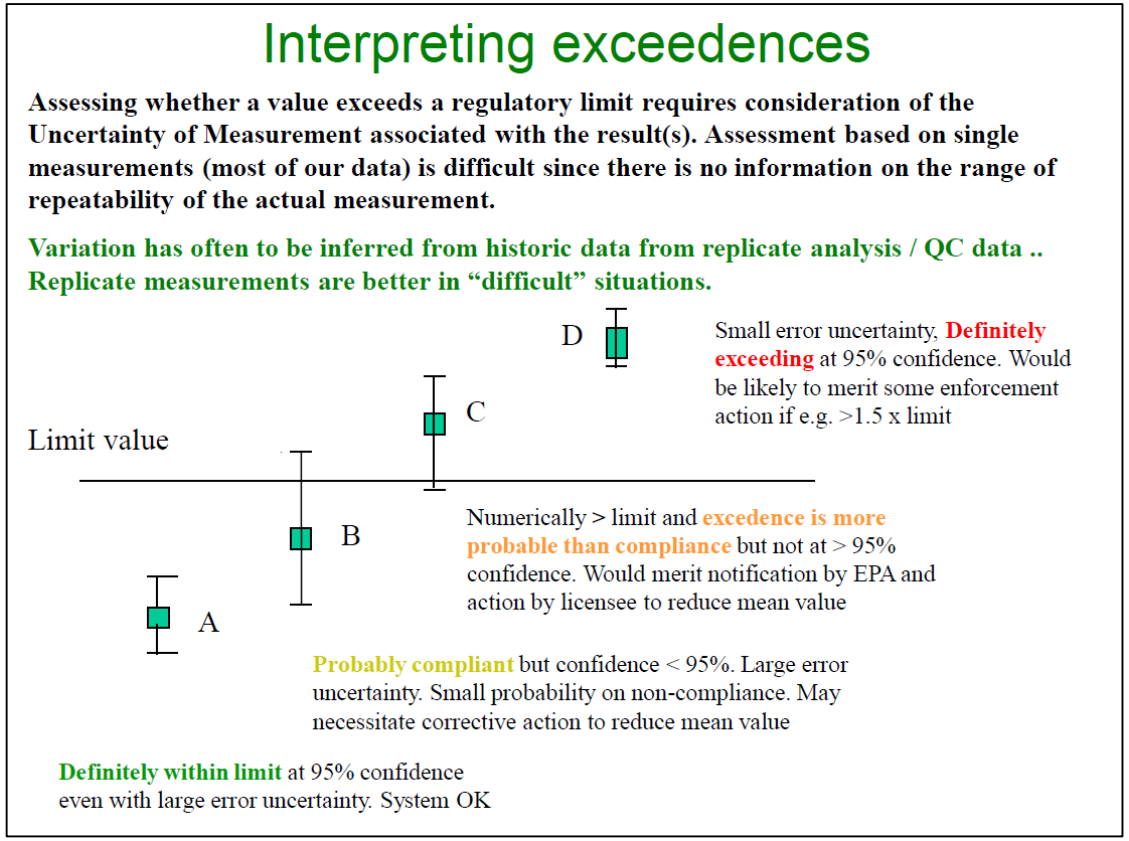
From a series of replicate analysis the variability of each parameter can be determined. The mean and standard deviation become the basis of the acceptance criteria for the analytical method and may be used to draw up control charts.

In-house standards can also be used but each preparation must be dated with an expiry data and new solutions run in parallel with the old to ensure continuity. The variability between the two sets of solutions should fall within the range acceptance criteria.

http://www.eptis.org/

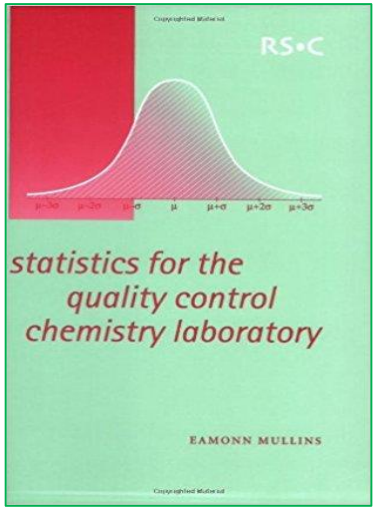
Quality Assurance – Method Uncertainty

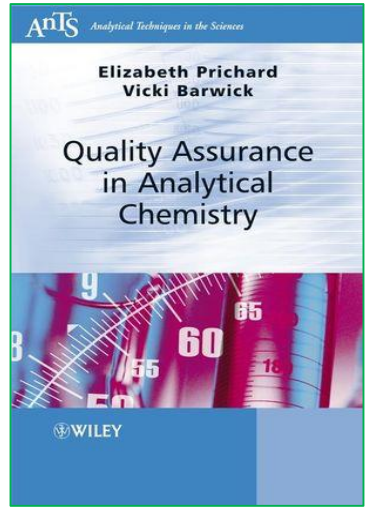
- All analytical methods carry some element component of measurement uncertainty. This can be defined from the bottom up but it is more usual to use the known QC data to estimate this.
- The GUM 'Bible' … An extensive reference but fairly unreadable even if you have a degree in statistics! – EURACHEM / CITAC Guide "Quantifying Uncertainty in Analytical Measurement" www.measurementuncertainty.org
- Nordtest Report TRV 537 "Handbook for calculation of Measurement Uncertainty in Environmental Laboratories Ed.2" http://www.nordtest.info/index.php/technical-reports/item/handbook-for-calculation-of-measurement-uncertainty-in-environmental-laboratories-nt-tr-537-edition-3.html
- Nordic Committee for Food Analysis (NMKL) "Estimation and Expression of Measurement Uncertainty in Chemical analysis" www.nmkl.org
- A Beginners Guide to Uncertainty of Measurement (NPL) https://www.npl.co.uk/special-pages/guides/gpg11_uncertainty

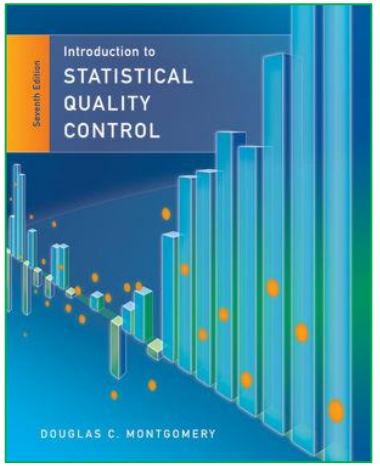


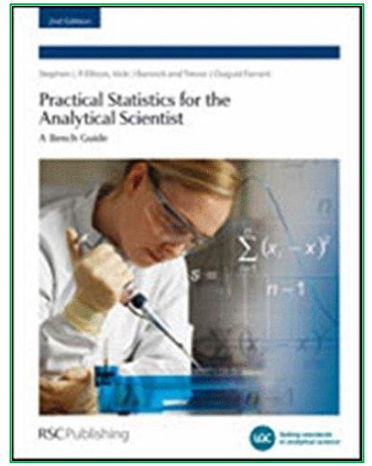
Quality Assurance – Suggested references

- Eurachem Guide to Quality (2016) (free / downloadable)
- **Useful information**
- Cohen, J. (1988), Statistical Power Analysis for the Behavioral Sciences, 2nd Edition. Hillsdale: Lawrence Erlbaum.
- Nelson, L. S. (1984). Technical Aids: The Shewhart Control Chart -Tests for Special Causes. Journal of quality technology, 16(4).
- Montgomery, D.C. *Introduction to Statistical Quality Control* 7th Ed., Wiley publishing, ISBN 978-1-118-14681-1 (very detailed) (Earlier versions of this text are available as Ebooks from some suppliers)
- Pritchard, E. and Berwick, V. *Quality Assurance in Analytical Chemistry*. Wiley Publishing, ISBN 978-0-470-01204-8 (Highly readable)
- Mullins, E. S*tatistics for the quality control chemistry laboratory*. RSC publishing, ISBN 978-0854046713 (quite readable)
- Ellison, S. *et al*. *Practical Statistics for the Analytical Scientist*. RSC publishing, ISBN 9780854041312 (quite readable)
- ISO 13530:2009 - Water quality – "Guidance on analytical quality control for chemical and physicochemical water analysis"









Thank you

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