The six principles of Valid Analytical Measurement

United Kingdom National Measurement System

The results of analytical measurements need to be fit for their purpose and results obtained in different locations or at different times should be consistent. Laboratories make measurements to fulfil specific customer requirements. If results are not fit for purpose then performing the analysis is a waste of time and money. If a laboratory knows, or suspects, that results are unreliable then it will incur the costs associated with repeating the measurements. The release of unreliable results to customers carries a risk and therefore a potentially significant cost to the laboratory.

Valid measurements and agreement between laboratories can be achieved by implementing a set of basic principles. The six principles of Valid Analytical Measurement provide a framework to enable organisations to deliver reliable results first time, every time, and achieve bottom line improvements through increased operational efficiency and reduction in risk. Laboratories that adopt VAM provide customers and users of data with increased confidence that results of analytical measurements are valid and fit for purpose.

The VAM Principles were developed as part of the Valid Analytical Measurement programme, to set out a philosophy which is appropriate for any laboratory carrying out analytical measurements. The principles were designed to encapsulate the key issues for achieving valid measurements and to provide a useful reminder for those already familiar with the concepts.

- **Principle 1** Analytical measurements should be made to satisfy an agreed requirement.
- **Principle 2** Analytical measurements should be made using methods and equipment which have been tested to ensure they are fit for purpose
- **Principle 3** Staff making analytical measurements should be both qualified and competent to undertake the task.
- **Principle 4** There should be a regular independent assessment of the technical performance of a laboratory.
- **Principle 5** Analytical measurements made in one location should be consistent with those elsewhere.
- **Principle 6** Organisations making analytical measurements should have well defined quality control and quality assurance procedures.

Principle 1: Analytical measurements should be made to satisfy an agreed requirement.

The reason for performing any analysis will be to solve a defined problem. The analyst needs to understand that problem so that a suitable analytical procedure can be proposed which is capable of providing the information needed to solve the problem. The proposed analytical methodology needs to be delivered in the most cost effective manner consistent with fitness for purpose.

Identify a 'responsible analyst' who has the knowledge and understanding to interpret the customer's problem. The responsible analyst will be able to offer analytical solutions which will help solve the customer's problem. It is best to obtain as full an understanding as possible of the customer's problem early on, to reduce the risk of performing measurements which are not capable of addressing the problem.

Define how the samples are to be obtained and delivered to your laboratory. If samples are not taken in a suitable way, all subsequent analytical work will be a waste of time and money. Samples must arrive at your laboratory with no loss of integrity.

Discuss with the customer the use to which the analytical results will be put. This will determine the level of confidence required in the results. This in turn will influence the choice of analytical methodology. Discuss with the customer issues of qualitative composition. You will be more confident in the validity of the results if you have information about the composition of the samples. You should decide if there is a need for some qualitative analysis before a complete analytical solution is proposed. Help the customer identify critical and non-critical aspects of the problem. This will enable you and the customer to agree the appropriate balance between time, cost and quality, and therefore to implement the most cost effective solution.

After discussing and agreeing requirements with the customer, it should be possible to draw up an analytical specification which contains the information which will enable an appropriate analytical strategy to be chosen.

The analytical specification should cover the following points:
History of the sample and nature of the matrix
Work needed to identify the sample constituents
Any additional confirmation requirements needed
Criticality of results
Confidence levels/measurement uncertainty aspects
Time and cost constraints
QA/QC requirements
Third party acceptance and traceability
Regulatory/legislative constraints

Example: Reducing the cost of analysis through dialogue with customers

A customer wants to ensure that a concentration limit of 2 mg/kg for a certain species is not breached in waste discharge. There is a choice of methods available. One is fast, low cost, and gives results with an uncertainty of 50%. The other is slower, more expensive, but gives results with an uncertainty of 10%. The optimum choice depends on the nature of the samples to be analysed. If it is expected that the concentrations in the samples will always be close to the limit, the more expensive method must be used. However, if most of the concentrations are likely to be around 50 pg/kg, a more cost effective solution is to use the cheaper method for screening

Principle 2: Analytical measurements should be made using methods and equipment which have been tested to ensure they are fit for purpose.

Performance characteristics of published make an assessment of the suitability of a method for the application. You cannot expect reliable results from validated methods unless the measurements are being undertaken within the range and scope (e.g. levels of analyte and types of sample matrix) The performance characteristics are determined during method development (validation). Attempts to apply a method outside its documented scope can lead to serious errors. If you cannot achieve

in your laboratory the documented performance characteristics of a method, application to customer samples is a waste of time.

Review the original sources of the methods currently in use in your laboratory.

- Original method documentation should include a statement of the expected uncertainty.
- Provide a (validated) step by step procedure which will help analysts to select appropriate methods taking into account the analytical specification and any additional constraints.
- The procedure should specify that samples of well characterised materials are used in a 'blind' test of performance. The samples should be as similar as possible to the expected customer's samples. If available, certified reference materials could be used as samples.
- Ensure that equipment used operates according to a specification appropriate to the requirements of the method. Instruments used in a method cannot be relied upon unless they have been properly maintained and calibrated.

Careful selection of a method is critical to obtaining reliable data.

Methods which have been collaboratively studied by several laboratories. Collaboratively studied methods are published by a number of bodies such as AOAC, BSI, ISO, etc.
Methods which have been validated by more than one laboratory, or are recommended by a panel of experts e.g. the Environment Agency Standing Committee of Analysts or EPA.
As long as the method complies with the customer's requirement, choose the most familiar method.

Method Validation

The key criterion is that the method as applied in your laboratory provides data which are fit for the intended purpose. The development of standard methods will have included consideration of all the necessary aspects of the validation, however the responsibility still lies with you to ensure that the validation documented in the method is sufficiently complete to meet your customer's needs.

Even if the validation covers your intended application, you will still need to verify that performance can be met in your laboratory. Validation does not imply that the method is free from error. It is confirmation that the method can yield acceptable results within the limits of the scope of the method. Wherever possible validation should include the use of certified reference materials and calibration standards and should result in a method with known confidence.

A single sample

In reaching agreement over the appropriate level of effort for a single sample, it is important that both the analyst and customer understand what is required to achieve fitness for purpose . For one-off samples, your analysts should consider assembling a method using well known and authenticated steps un quality control which may have been proven in similar contexts from previous work.

Principle 3: Staff making analytical measurements should be both qualified and competent to undertake the task.

Analysts with adequate understanding of the principles underlying a method are more likely to achieve reliable results. Within any method there will be aspects which could be interpreted slightly differently by different analysts. This could mean that the method is being applied outside the scope of validation. There may be a temptation to cut corners to save time without understanding the

consequences. Analysts with the right knowledge and understanding will appreciate the risks involved and act appropriately.

Ensure that appropriate training programmes are devised and implemented for all analysts. Staff should not be allowed to produce results without close supervision until they have been trained and have demonstrated that they can produce reliable results on previously characterised samples. Good training will address both competence and underpinning knowledge. Training requirements should be reviewed regularly and the outcomes of training recorded.

Use training courses which include an assessment of the knowledge and skills gained on the course. Some courses offer certificates of attendance which give no measure of what has been accomplished. Assessment should be graded according to: competent to work unsupervised, competent to work supervised, or in need of re-training. Levels of competence should be assessed against agreed criteria, preferably national standards of competence recognised by the National Council for Vocational Qualifications. Training records also give customers confidence.

Samples When dealing with samples unexpected results can happen. The analyst needs to be able to spot these and ideally work out what might be happening. Slavish adherence to written procedures, without being alert to what is actually happening with a sample/analysis, will always run the risk of producing unreliable results. Staff therefore need to have an understanding of the science which underlies the analysis.

Motivation plays a large part in determining the quality of output. Motivation is best achieved by employing a variety of management approaches, such as:

- Make sure staff understand their work and the desired outcomes
- Provide regular feedback and recognition of achievements
- Provide training and support continuing professional development
- Involve staff in decisions relevant to their work
- Try to make the work as interesting and varied as possible

Through this kind of approach, all staff can be encouraged to think carefully about their contribution to the work of the laboratory, and to particular projects. With this comes greater commitment to quality, and an acceptance of responsibility for delivering quality.

Formal qualifications need to be supported and enhanced by continuing education and training. Analytical chemistry is a practical career, and competence in practical work is essential. The best place to acquire competence is the workplace, and staff must be given on-the-job training which equips them to carry out their professional duties. The value of senior experienced staff as role models and mentors cannot be over-estimated. The work of staff should be closely supervised until they have demonstrated that they can produce reliable results on, for example, check samples or other well characterised materials which closely resemble real samples.

Principle 4: There should be an independent assessment of the technical performance.

An external benchmark gives you feedback on your laboratory's technical performance compared with other competent laboratories. There are a large number of pitfalls in the process of performing an analysis. However much care is taken, there may be some key unidentified factors which influence the results. The entire process from sample receipt to reporting results should be tested using samples and procedures which closely follow day-to-day work.

As a manager, you will be able to use data from external assessment for both internal management purposes, and as part of your strategy for winning new business. In some areas, participation in external assessment programmes is a legal requirement for carrying out some kinds of work.

Participate in an appropriate Proficiency Testing (PT) scheme.

Although proficiency testing schemes exist for many of the more commonly executed types of analysis, there might not be any scheme with a sample which closely matches those routinely dealt with in your laboratory. You should aim for a scheme where you would apply the same analytical technique to a similar analyte/matrix combination at similar concentration levels.

The PT samples should be treated in all respects as a routine sample, and the staff involved should not be specially selected. Find out if your customer can provide some suitable assessment materials. It might be satisfactory to arrange with the customer for assessment samples to be included in a batch of work. The assessment material must be stable, homogeneous and well characterised. This approach would be most valuable where no proficiency testing schemes exist.

In PT schemes, an independent and authoritative third party arranges for the distribution of appropriate test samples to laboratories. The organiser of the scheme collates the results which are returned by the laboratory on an agreed timetable, and analyses them statistically and prepares a report which enables laboratories to compare their performance with that of peer laboratories. All results are treated confidentially, and no individual laboratory's performance can be identified, except by itself.

Proficiency testing schemes exist for many of the more commonly executed types of chemical analysis. There cannot, however, be complete coverage of all types of analyses, and a laboratory might find that, for the type of analyses they were doing, no suitable PT scheme existed. In this case, it would be sensible for the laboratory to speak to the customer and discuss alternative arrangements, such as use of a reliable check sample. Proficiency testing schemes may differ in the way they are organised and administered. One of the major differences is whether or not it is left up to individual laboratories to choose the method of analysis, or whether the method is specified by the organisers. There may also be differences in the statistical treatment of the results from laboratories.

In some countries, laboratories have to demonstrate satisfactory performance in a PT scheme before they are allowed to carry out the particular analysis for 'official' or regulatory purposes. In the UK, this is not the way in which proficiency testing is used. However, it is open to accreditation or certification bodies, and customers, to ask to see the results of participation in appropriate PT schemes and to draw their own conclusions on the objective evidence provided.

Principle 5: Measurements made in one location should be consistent with those elsewhere.

Disagreements between companies or other organisations over analytical measurements wastes time and costs money.

If a supplier and purchaser reach different conclusions about a product or a service in which they are trading, both will have to bear costs in resolving their differences. The laboratories used may

lose business or face legal costs if the dispute escalates. Regulations cannot be fairly enforced if the relevant analytical data show inconsistencies.
Undetected long term inconsistency may be misinterpreted as real and significant effects.

Results from process QC analyses which drift over time may be misinterpreted as process variations, and trigger unnecessary investigative work, possibly even halting production processes. Local contamination might go undetected without a firm external reference comparison. Long term studies with environmental or health implications need long term consistency to make sure that no false trends are deduced from the analytical results.

- Check or calibrate the entire method using relevant, stable, well established reference materials. The use of stable reference materials as quality control samples for the analysis in association with control charts will show up short term and long term drift.

- Ensure all instruments used are calibrated with traceable reference standards. Traceable reference standards are working standards which have been calibrated against national or international standard materials or methods. Traceability is needed to allow valid comparisons to be made with the results from other laboratories using similarly calibrated standards.

- Understand the factors which contribute to uncertainty in the method and estimate the overall uncertainty in your results. Laboratories which overestimate uncertainty will tend to do more work than necessary to ensure adequate accuracy. Understanding the method and the sources and magnitude of component uncertainties is important if the uncertainty in the final results needs to be reduced to meet requirements.

- Try to identify laboratories carrying out similar work and investigate the possibilities of collaboration. Where no other means of forming an external assessment exists, you should use contacts such as professional bodies to see if informal intercomparison exercises can be set up. Sections which deal with analytical science exist in professional and industrial bodies and can be important sources of advice and a route to ad-hoc intercomparisons.

- Certified reference materials (CRMs) and reference standards are highly specialised materials. Unfortunately, there will be many measurements for which appropriate reference materials do not exist. In this case, it is important to apply alternative approaches in order to underpin consistency and comparability. One possibility is to develop your own reference material. This should be characterised by the application of more than one well-established method. The wider the variety of methods which are used the more reliable is the material likely to be as a reference point. Collaboration and sharing of materials and results between expert laboratories is also highly recommended as a procedure for helping to ensure comparability and consistency.

Principle 6: Organisations making analytical measurements should have well defined quality control and quality assurance procedures.

Procedures are needed which will give assurance that VAM principles 1 to 5 are being implemented. Recording procedures need to be sufficient to allow results to be checked, or the whole analysis reconstructed to the extent required by the customer. Quality control procedures are necessary to show that measurement procedures are in statistical control.

'Check' samples need to be measured regularly and recorded systematically to ensure that instruments are not drifting and that environmental or other factors are not changing.

Quality systems need to respond to changing requirements and encourage continuous improvement. Regular review of quality performance and existing quality systems against customer requirements are needed to ensure results are always fit for purpose.

- Select a quality management system appropriate to the needs of your customers. There are formal quality management systems where assessment is by an independent third party such as the ISO 9001 (for quality Systems, most commonly used by manufacturing or supplying products or services), Good Laboratory Practice (intended primarily for laboratories carrying out evaluations of substances for regulatory purposes, such as toxicity testing involving animal experiments or environmental impact studies), or ISO/IEC 17025 (for testing and calibartion laboratories).

  These schemes differ significantly in the way in which they deal with the technical validity of the work areas they cover. For example, accreditation to ISO/IEC 17025 involves thorough technical evaluation of the methods by appropriate experts. Under GLP, the responsibility for technical validity rests with the regulatory authorities who will assess the data submitted by laboratories and make decisions regarding fitness for purpose of that data. In contrast, certification to ISO 9001 does not involve an assessment of technical competence. Instead it is concerned with controlling processes as a means of meeting customer requirements.

- Implement the selected quality system. Quality management systems bring together quality management, quality assurance and quality control. The cost of implementing a quality system will depend on the state of existing, possibly informal, quality management arrangements. There will also be a recurrent cost, which can be expected to be out-weighed by the benefits of efficiency improvements.

- Review quality control procedures regularly. The level of quality control should he determined by customer requirements and will be covered in the analytical specification.

- Review quality assurance procedures regularly. Implementing VAM principles 1 to 5 will form part of quality assurance. In addition, quality system audit and review are essential components of quality assurance.