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The importance, for regulation, of uncertainty from sampling

In many regulated sectors where analysis is required (for example, soil, water, air, food, and animal feed), decisions are based on the composition of a sample. It has long been known (although seldom acknowledged) that samples are never *strictly* representative—they differ from the target* and from each other, giving rise to uncertainty from sampling. Hitherto this uncertainty term has been ignored, a simplistic strategy with the potential to produce flawed decisions. Now new guidance has been developed by Eurachem [1]. The Guide shows how the uncertainty arising from sampling can be effectively addressed. This Technical Brief draws attention to the implications of sampling uncertainty for policy making, and demonstrates how the Eurachem Guide is relevant to the reliability of regulatory decisions.

What is uncertainty from sampling?

When a regulatory decision is made on a batch of material it is usually necessary to know its composition, often in terms of a few key components (*e.g*., aflatoxin in nuts, or cadmium in soil). For this purpose a sample is taken to represent the batch. Traditional practice has regarded samples taken by a standard method as representative, effectively contributing zero uncertainty to the measurement result. However, it is easy to demonstrate that repeat samples vary in composition, and often to an important degree. This adds uncertainty to the measured value of the concentration of the component in the batch, in addition to that resulting from the analytical process.

Sampling uncertainty arises primarily from the heterogeneity of the target material, particularly in respect of components present at trace levels. There can also be contributions from variation in the implementation of the sampling protocol, which always contains some level of ambiguity.

What are the implications of sampling uncertainty for the regulators?

The uncertainty arising from sampling is sometimes much larger than the known contribution from the chemical analysis but has hitherto been unrecognised or not accounted for. Using the smaller estimate of uncertainty, based only on the chemical analysis, control authorities could be mistaken in assuming that a batch of a commodity is compliant with a legislative specification for (say) a contaminant. If the real value of uncertainty is much larger, then it is possible that the true concentration of the contaminant in the batch is greater than the legislative specification (Figure 1). This could lead to litigation and loss of reputation for those involved if the batch were found subsequently to be non-compliant. The legislators need to decide whether to incorporate sampling uncertainty into regulation and, if so, how to specify the decision rules on compliance.

* The preferred general term for the defined mass of material to be represented, for example a batch of product or specified volume of soil.

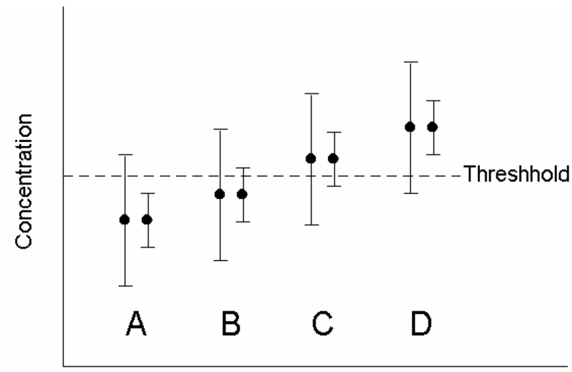

Figure 1. Schematic representation of how the uncertainty intervals (error bars) surrounding measurement results (•) affect the classification of batches of material against a regulatory threshold. A naive estimate of uncertainty, based only on chemical analysis (shorter error bars) would result in the acceptance of Batch A as having a concentration of a contaminant below the threshold for rejection. The true uncertainty, including the contribution from sampling (longer error bars) shows that there is a chance that the concentration of the contaminant exceeds the threshold: the batch should be considered for rejection or at least investigated further. The classification of Batches B and C is not affected by the different approaches to uncertainty estimation. For Batch D, we see that the naive estimate of uncertainty would result in the conclusion that the batch was definitely contaminated. However, the new estimate (including a contribution from sampling) shows that the concentration of the contaminant in the batch could be below the threshold. In a sector where the over-riding consideration is "beyond reasonable doubt", the inclusion of the sampling uncertainty would result in Batch D being considered compliant with the legislative specification.

What are the *benefits* of recognising and quantifying sampling uncertainty?

The benefits to the regulator of quantifying this uncertainty are that decisions on compliance will be more reliable. If the uncertainty only from the chemical analysis is allowed for, and that from sampling ignored, then material will potentially be misclassified (Figure 1). In the environmental sector, fewer instances of true contamination would go undetected in initial investigations, only to be detected at a later stage. This would lead to fewer criticisms that the contamination was found to be above the specification limit in a subsequent investigation. In other sectors, fewer batches would be erroneously accepted as complying with a legislative specification.

For the users of the regulations, the benefits comprise the smaller chance that batches of material will be needlessly rejected and financial losses made when, for example, unrepresentative samples give rise to overestimation of the concentration value of some constituent of the target.

For the environment as a whole, recognition of sampling uncertainty will facilitate the redevelopment of brownfield sites. This follows because the costs of needless remediation will be reduced. Regulators will have more confidence that a site investigation was fit for purpose if the uncertainty were made explicit.

"Sampling uncertainty? They just told me the sample was representative!"

What are the *costs* of recognising/quantifying sampling uncertainty?

For the regulator, the cost of implementing these ideas about uncertainty from sampling will in part stem from redrafting their guidance manuals. Instead of specifying '*take a representative sample'* their guidance could read '*aim to take a sufficiently representative sample, and report the uncertainty from sampling actually encountered*'. Such guidance could refer to the new Eurachem Guide[1], which describes how this could be achieved in practice.

For the users of the guidance, there will be an increased initial cost in making estimates of the sampling uncertainty. However this will be offset by savings resulting from fewer decision errors such as those erroneously condemning the target under investigation, or in the potential financial repercussions arising from unknowingly authorising the use of contaminated material.

Conclusions

Recognition that measurements used for control purposes are prone to sampling uncertainty is crucial to improving the reliability of decisions in all regulated sectors. Not only will this improve the effectiveness of the regulation and implementation of policy, but it will also often give financial benefits to the users of the regulations. The new Eurachem Guide provides the tools to make the quantification and the reporting of sampling uncertainty a practical proposition.

Reference

Ramsey M.H., and Ellison S. L. R.,(eds.) (2007) *Eurachem/EUROLAB/ CITAC/Nordtest/ AMC Guide: Measurement uncertainty arising from sampling: a guide to methods and approaches.*
Eurachem ISBN 978 0 948926 26 6.
(http://www.eurachem.org/guides/UfS_2007.pdf)

This Technical Brief was prepared for the Analytical Methods Committee by the Subcommittee for Uncertainty and Quality of Sampling under the Chairmanship of Michael Ramsey.

CPD Certification I certify that I have studied this document as a contribution to Continuing Professional Development.

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