Matrix Effects and Uncertainty

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A framework for further study

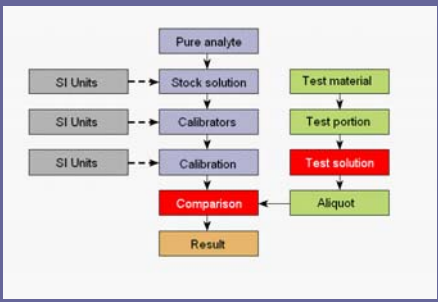
A review of interference effects and their correction in chemical analysis, with special reference to uncertainty

M Thompson and S L R Ellison (2005)
Accred Qual Assur **10**: 82-97

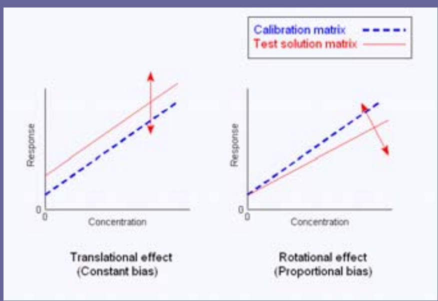
The two analytical problems

- ***Matrix effect***—loss or gain of analytical signal.
- ***Recovery effect***—loss (or gain!) of analyte.

Where the problems occur in traceability chains



Matrix effects--definitions



Methods of reducing matrix effects

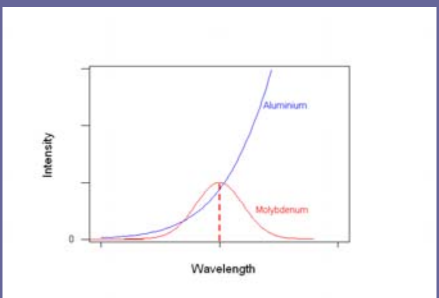
1. Matrix is effectively constant among test materials of the defined class.
   -Matrix matching
2. Matrix varies to a consequential degree between test materials of the defined class.
   -Matrix modification
   -Modelling
   -Internal calibration

Uncertainty estimation after matrix correction

- ***Systematic methods***
  Derive the uncertainty estimate directly from the calibration model.
- ***Random variations***
  Treat the matrix variation as a random variable.
- ***Worst case scenarios***
  Study an example with extreme deviation of the matrix from the calibrators.

Modelling

An example of modelling (simplified for clarity)



Calibration and uncertainty models

- $(S) = (Mo) + k*(Al)$

  where *(Mo)*, *(Al)* are the concentrations of molybdenum and aluminium, *k* is a calibration factor and *(S)* is the total signal.

- $(Mo) = (S) – k(Al)$

  $u^2(Mo) = u^2(S) + k^2 * u^2(Al)$

  (assuming that *k* is invariate).

Uncertainty terms

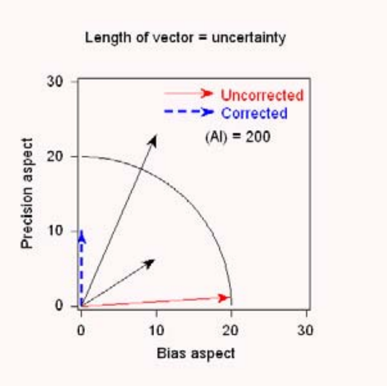
- $u^2(S) = v^2(Mo) + w^2(Mo)*(S)^2$
- $U^2(Al) = v^2(Al) + w^2(Al)*(Al)^2$

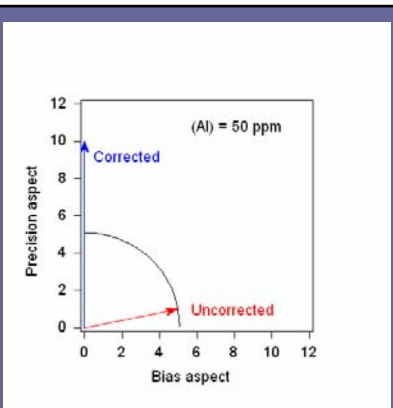
  where *v(.)* is a constant uncertainty related to the detection limit and *w(.)* provides an uncertainty proportional to the concentration.

Effect of correction on uncertainty

True molybdenum concentration *(Mo)* = 5 ppm

(Al)	Uncorrected signal (ppm Mo)	Uncertainty of uncorrected signal (ppm)	Uncertainty of corrected concentration (ppm)
0	5.0	1.0	10.1
50	10.0	1.1	10.1
200	25.0	1.3	10.1





Modelling--summary

- Correction for bias by modelling often increases the precision contribution to uncertainty but (hopefully!) decreases the combined uncertainty.
- In most instances, unnecessary bias correction will *increase* uncertainty.

Random studies

Random studies

This method is appropriate where the causes of the matrix effects are obscure or too complex to model.

- Take a number of representative test materials.
- Measure the apparent concentrations of the analyte (in duplicate).
- Calculate the differences (found minus expected).
- Calculate the between matrix standard deviation by analysis of variance.

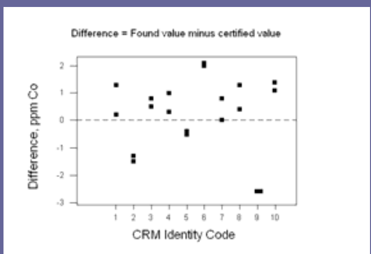
Analytical “health-warnings”

- Reference materials (i.e., with known true values) are best for this application, but the uncertainties on the reference values are often uncomfortably high.
- If reference materials are not available, a spike recovery procedure can be adopted.
- Uncertainties estimated by this procedure will include contributions from recovery variations.
- Unless the concentration range is small, allowance for heteroscedasticty must be made.

Example: 10 Geological CRMs: Analyte is Co

ID Code	Certified value	Result 1	Result 2	Difference 1	Difference 2
1	10,2	11,5	10,4	1,3	0,2
2	12,9	11,4	11,6	-1,5	-1,3
3	9,8	10,3	10,6	0,5	0,8
4	6,7	7,7	7	1	0,3
5	7,5	7	7,1	-0,5	-0,4
6	6,4	8,5	8,4	2,1	2
7	11,1	11,1	11,9	0	0,8
8	10,1	11,4	10,5	1,3	0,4
9	7,2	4,6	4,6	-2,6	-2,6
10	11,4	12,8	12,5	1,4	1,1

Results on CRMs



No net bias apparent

ANOVA gives:

MSW = 0.17
MSB = 3.67

from which
$\sigma_0 = 0.4$
$\sigma_1 = 1.3$

"Worst Case" Scenario

“Worst Case” Scenario

1. Select a material likely to produce an extreme matrix effect, and estimate its effect.
2. This effect can be regarded as the extreme of a range width 2*A*. The associated standard uncertainty is *A*/3.
3. This is a crude expedient, but it is sometimes has the useful outcome of eliminating a suspected matrix effect from further consideration.

More Health Warnings

- ***Uncertainty is very variable*** — it has large relative uncertainty when estimated from few (>20) results. It is seldom useful to report an uncertainty to better than one significant figure.
- ***Uncertainty is heteroscedastic*** — you may need to take this into account if the expected concentration range is large. This would require a ***large*** experiment.

and finally….

- Matrix effects come in two main forms – translational and rotational, and mixtures of the two. Failure to distinguish between them may give rise to misleading results.
- Many methods of treating rotational effects (*e.g.*, standard additions) rely for their effectiveness on the prior treatment of translational effects (*e.g.*, by background correction).