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Measurement Uncertainty – Surveys about Customers' Knowledge, Reactions and Needs

This report contains contributions from:

Abstract

Measurement uncertainty - Surveys about customers' knowledge, reactions and needs

During discussions early 2000, representatives of accredited analytical laboratories, through their Swedish interest organisation (FaL), expressed concern about what the customers' reactions might be when the new requirements for evaluating and reporting uncertainty are implemented. SP proposed the development of a simple information leaflet, which the laboratories could distribute together with the test report. The idea was anchored with the accreditation body, authorities and interest organisations. Further contacts revealed that the issue of the customers' reactions had been on the agenda in the two organisations Eurolab and Eurachem. Also within the British Food Standards Agency, a similar educational approach had been discussed. A two-page leaflet was produced and translated into English in consultation with Eurolab, Eurachem, the European co-operation for Accreditation (EA) and the Swiss institute EMPA. From August 2000 to June 2001, ten thousand Swedish and two thousand English copies of the leaflets were distributed. They were also made available in electronic form on several homepages of the contributing organisations.

To gain further insight into the customers' views on measurement uncertainty, SP conducted two surveys covering some 1 200 customers. The result shows that the majority of customers need and value uncertainty statements in the test report.

Key words: Measurement uncertainty, SME, testing, chemical analysis, education and training

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Sammanfattning

Våren 2000 hölls ett telefonmöte med deltagare från Föreningen ackrediterade Laboratorier (FaL) och SP. I fokus stod begreppet "mätosäkerhet". Inledningsvis inriktades diskussionerna på framtagningen av ett enklare vägledningsdokument om mätosäkerhet. FaL befarade nämligen att den reviderade guiden från Eurachem/CITAC trots allt skulle komma att upplevas som för svår av många yrkesverksamma kemister.

Under diskussionen framkom också att flera kemilaboratorier kände oro för de reaktioner som kunde komma från kunderna då de nya kraven beträffande mätosäkerhet började implementeras. SP tog fasta på detta och föreslog ett enkelt informationsblad som laboratorierna kunde bifoga med provningsrapporten. Idén förankrades hos Swedac, Naturvårdsverket, Livsmedelsverket, och hos Svenska vatten- och avloppsverksföreningen (VAV) och ledde fram till ett tvåsidigt informationsblad.

Vid kontakter med Eurolab Sverige framkom att problemställningen med kundernas reaktioner diskuterades i de båda europeiska intresseorganisationerna Eurolab och Eurachem. Tankarna om ett informationsblad fanns också vid brittiska Food Standards Agency. Detta intresse medförde att informationsbladet översattes i samråd med Eurolab, Eurachem, det europeiska ackrediteringsorganet EA, och det schweiziska institutet EMPA. Under perioden augusti 2000 – juni 2001 distribuerats totalt cirka 12 000 exemplar av de båda informationsbladen och de finns numera också tillgängliga i elektronisk form på flera hemsidor.

För att få mer insyn i kundernas reaktion på mätosäkerhet har SP i två olika enkäter vänt sig till sammanlagt 1 200 kunder. I en av dessa enkäter har informationsbladet ovan använts. Svaren visar att kunderna anser mätosäkerheten utgör viktig information i provningsrapporten och att de flesta kunder vill ha sådan information.

Arbetet har delvis skett inom ramen för ett SMF-projekt med ekonomiskt stöd från NUTEK.

1 Introduction

1.1 Background and project description

Recent national and international standards¹ and regulations^{2,3,4} request accredited laboratories to evaluate and report the reliability of many measurement results as “measurement uncertainty”, as defined in international documents.^{5,6} This will lead to changes in the quality assurance work including:

1. The reliability statement delivered by the laboratory will normally be an expanded uncertainty $U=k \cdot u_c$ ($k=2$). The approach used so far, i.e. statements based on the variation observed from control charts (normally expressed as percent relative standard deviation) within the laboratory is no longer considered sufficient as it does not provide details about various uncertainty components.²
2. The measurement uncertainty should normally be stated in the test report delivered to the customer.³ This means that general exemption by the Swedish accreditation body (Swedac), to provide such information only when the customer asks for it, comes to an end.

The deadline for implementing the new uncertainty concept was initially set by Swedac to end of the year 2000.² This has not been possible, although the work has come quite far.⁷ Recently the deadline was postponed to the end of 2002 with parts of the work to be ready six months prior to this date.⁸

In February 2000 representatives of accredited Swedish chemistry laboratories, through their interest organisation FaL, expressed concern about the customers' reactions when the new regulations are implemented. Negative response could be due to

- uncertainties being larger than those reported previously for the same test, and/or
- confusion on how to interpret and use the information in the test report.

An educational initiative directed towards the customer/end-user of measurement results was considered necessary. SP proposed a simple leaflet that could be distributed together with the test report. This idea was supported by Swedac, the National food administration (SLV), the Swedish environmental protection agency (SNV), and the Swedish water and wastewater association (VAV).^{*} Further contacts revealed that the issue of customers' reactions had been on the agenda at meetings of Eurolab and Eurachem.^{9,10} The idea of an information leaflet also existed at the British Food Standards Agency.¹¹ An English version of the leaflet was, therefore, produced after consulting these organisations, the European co-operation for accreditation (EA) and the Swiss institute EMPA.

To gain more insight into the customers' views on measurement uncertainty, SP conducted two surveys among 1 200 of its customers. The main objectives were

- to inform and to create awareness of the limitations in the quality of measurement results among customers/end-users,
- to understand better customers/end-users' present knowledge, reactions and needs of measurement uncertainty.

^{*} There are 450 accredited testing laboratories in Sweden (2000-03-06). Approximately 65% of them perform quantitative chemical analysis in the areas of environment, food and laboratory medicine.

In one of the surveys the information leaflet was used. We here report on feedback from use of the information leaflets and the result of the two surveys.

1.2 Project overview

1.2.1 Facts, figures and project partners

The development of the Swedish information leaflet¹² was done in the frame of an SME activity (Table 1 and Table 2) with financial support from the Swedish National Board for Industrial and Technical Development (NUTEK).¹³

Table 1. The information leaflets were developed in the frame of an SME-project.

SME Project code	KMoo P0 07313
Starting date	2000-02-25
Completion date	2001-06-30
Project manager	SP
Main partner	The Swedish Industry Association (SINF) representing analytical laboratories through their branch organisation (FaL)
Address of main partner	Barnhusgatan 3, Box 1133, SE-111 81 Stockholm, phone +46 (0)8 440 1170
Other partners	VAV, Swedac, SLV, SNV
Project form	Network
Total cost (SEK)	64 190 of which 27 000 was covered by the partners and the rest by NUTEK

Table 2. Partners in the Swedish part of the project

<i>Organisation</i>	<i>Acronym</i>	<i>Representative(s)</i>	<i>Further information</i>
Swedish board for accreditation and conformity assessment	Swedac	Mrs Gunilla Fransson Mrs Annika Norling	www.swedac.se
Swedish water and wastewater association	VAV	Mr Per Kristiansson	www.vav.se
Swedish environmental protection agency	SNV	Mr Gunnar Ekedahl	www.environ.se
Swedish national food administration	SLV	Mr Sören Wretling	www.slv.se
The Swedish industry association	SINF	Mr Åke Larsson	www.sinf.se
Föreningen ackrediterade laboratorier†	FAL	Mr Gillis Lundgren	www.sinf.se
SP Swedish national testing and research institute	SP	Mr Ulf Örnemark	www.sp.se

In the translation and adaptation into English of the leaflet,¹⁴ representatives of the EA Secretariat, the Eurachem uncertainty working group, the Eurachem/Eurolab/EA permanent liaison group, and EMPA St Gallen were consulted. The development of the questionnaires and the subsequent evaluation of the customer surveys (Section 1.3) were done at SP.

† A branch within SINF for accredited environmental laboratories.

1.3 Surveys among SP's customers

The information is based on two different surveys conducted during the first half of 2001.

1.3.1 Survey A

Survey A is an annual survey to a wide variety of SP's customers. The objective is to get a general opinion about the customers' degree of satisfaction with *i*) the work carried out at each department for specific test assignments, and *ii*) with the overall performance of the services provided.

The questions are more or less the same from one year to another. This time, however, the customers were also asked to value the inclusion of a statement of the measurement uncertainty in the test report. The specific question of relevance for this report) was:

"Rank the importance of the test result being accompanied by an uncertainty statement"

The customer could indicate a number between 1 and 6, where 1 corresponded to "not important at all" and 6 to "very important". An additional option was "not relevant".

In total some one thousand questionnaires were distributed to the following three categories of customers:

1. all customers involved in an SME project (Survey A1),
2. to those ten customers each department considered most important (Survey A2),
3. to those who received a test report between September and November 2001 (Survey A3).

In this report we include answers from four of the departments dealing with testing and quantitative chemical analysis (Energy technology, Chemistry & materials technology, Building technology, Mechanics). Results from four other departments are excluded in Survey A for the following reasons: There are no uncertainty statements provided with results from SP's fire testing activities, and no future requirements indicated by Swedac for those tests. The staff at Measurement technology, Weights and measures, and Electronics either perform mainly calibrations and always state the uncertainty, or conduct investigations/perform tests according to individual customer requirements.

1.3.2 Survey B

Survey B was conducted between 1 March and 30 June 2001 and focused entirely on measurement uncertainty. The objective was to get a more detailed picture of the customers' knowledge, reactions and needs. This survey was limited to customers of the three departments Chemistry and Materials Technology, Mechanics, and Energy Technology.

The questionnaire was included in an information package, which was sent to the customers on the occasion of returning a test report.

The information package consisted of

- a letter explaining the scope of the survey,
- the Swedish version of the questionnaire (Appendix 2),
- the Swedish version of the information leaflet (Appendix 1),¹²
- an envelope with postage pre-paid for return of the questionnaire.

The questionnaire was provided in two versions, including either Question 5a or 5b depending on the customer group. At the time of Survey B, the Department for Chemistry and Materials Technology did not yet provide uncertainty statements in its test reports. The customers of this department were therefore asked if they contact laboratories to obtain such information (Question 5b). The other two departments had, to a large extent, already met the accreditation body's requirements and provided uncertainty statements in their test reports since several years. In certain testing areas, e.g. where failure of complying with specified tolerances will lead to demands for financial compensation, customers have received uncertainty statements in the test report for as long as twenty years. The customers of these departments were asked to which extent they understood the uncertainty information in the test report (Question 5a). All customers were also asked to:

- rate their knowledge of measurement uncertainty before they received the information leaflet,
- state their degree of need and reason(s) for asking for uncertainty statements,
- indicate how they value the information in the leaflet,
- state who completed the questionnaire,
- to indicate their main occupation and the size of their organisation.

2 Results and discussion

2.1 Feedback on the information leaflets

The English information leaflet is enclosed as Appendix 1 to this report. Comments from the testing community are favourable. A German version has been produced by the German Accreditation Council (DAR) and Eurolab Germany.¹⁵ Recently a Dutch version appeared.¹⁶ Additional interest, and/or requests to translate the leaflet, has been announced from France, Finland, Denmark, Slovenia and Switzerland.^{17,18,19,20} The Swedish partners have distributed the leaflet at meetings and training courses or together with other information material from their respective organisations. Some analytical laboratories requested copies to provide with their test reports. The Swedish and English leaflets are available in electronic form (pdf files), e.g. from the SP and Eurachem homepages.^{9,21}

In Survey B (Sections 1.3.2 and 2.2.3) customers were asked to comment on the extent of the information in the leaflet (Question 4, Appendix 2). The vast majority (Figure 1) found the information appropriate. Those who considered it insufficient were mainly customers to the Departments of Energy technology and Mechanics, i.e. sectors where uncertainty statements have already been provided several years.

Figure 1. Opinions about the content of the information leaflet. a) Too little; b) Appropriate; c) Too much; d) Not relevant/do not know.

2.2 Customer surveys

2.2.1 Response to the surveys and customer information

Information about distributed and returned questionnaires in the respective survey is summarised in Table 3.

The answers showed that the vast majority of the customers dealt with manufacturing, service and maintenance, trading, construction, public administration and authoritative work. In Survey B, 86% of the questionnaires were completed by the person who would act on basis of the result in the test report. The surveys had accordingly reached the intended category of end-users (those not directly involved in calibration and testing). Fifty-one per cent of the customers in Survey B represented organisations with more than 100 employees. The rest had <10 (15%), 11-25 (13%) and 26-100 (23%) staff members.

Table 3. Response to SP's customer surveys A and B.

	<i>Testing fields of SP</i>	<i>Distributed questionnaires</i>	<i>Returned questionnaires</i>	<i>% Replies</i>
Survey A				
A1	All	54	26	49
A2	All	75	46	61
A3	<ul style="list-style-type: none"> • Energy technology • Chemistry and materials technology • Building technology • Mechanics 	400	203	51
Survey B				
	Inorganic and organic chemical analysis	110	47	43
	Mechanics, Energy technology	100	31	31

2.2.2 Results of Survey A

An overview of the results is given in Table 4. The average score is high and indicates that the customers consider uncertainty statements in the test reports important. The detailed evaluation showed no differences between customers from small and large organisations. There were only minor differences between the various testing areas. Customers to the department for Mechanics had a somewhat larger fraction of replies "not relevant" and lower scores.

Table 4. Overview of the results in Survey A. Customers were asked to value the inclusion of a statement of the measurement uncertainty in the test report. A score of 1 corresponds to "not important at all" and 6 to "very important".

<i>Survey</i>	<i>Customer category</i>	<i>Average score</i>	<i>Fraction of replies as "not relevant"</i>
A1	Participants in SME projects	5.1	6%
A2	Ten most important customers of each department	5.0	15%
A3	Customers who received a test report between September and November 2001	5.1	8%

2.2.3 Results of Survey B

Information concerning customers' knowledge of, need for and understanding of measurement uncertainty (Questions 1-3 and 5a-b) are summarised in the Figures 2-6 below.

2.2.3.1 Customers' knowledge of uncertainty

Figure 2. Response to the question “How much knowledge did you have about measurement uncertainty before you received this leaflet?” a) None; b) Some; c) Much; d) Not relevant/do not know.

2.2.3.2 Customers' need for uncertainty statements

Figure 3. Response to the question “How often do you have a need for a statement concerning the measurement uncertainty in the test report?”: a) never; b) sometimes; c) often; d) always; e) not relevant/do not know.

2.2.3.3 Reasons for asking for uncertainty statements

Figure 4. Response to the question “If you have a need for a statement concerning measurement uncertainty, what is the reason?” a) Own interest (e.g. to be able to make decisions); b) The clients demand it; c) Authorities demand it; d) The accreditation body demands it; e) Other reasons; f) Not relevant/do not know.

2.2.3.4 Customers’ understanding of uncertainty statements

Figure 5. Response to the question “To what extent do you understand the measurement uncertainty stated in the test report? a) Not at all; b) Partly, c) Fully; d) Not relevant/do not know. Remark: The laboratories in question have provided uncertainty statements for several years:

2.2.3.5 Customers' requests for uncertainty statements

Figure 6. The extent to which customers contact the laboratory to obtain information about measurement uncertainty when this is not stated in the test report: a) Never; b) Sometimes; c) Often; d) Not relevant/do not know. Remark: The answers come from customers to SP's analytical chemistry laboratories.

3 Additional comments and conclusions

The publication of the international guidance document ("GUM") by ISO et al. in 1993 was the starting point for the uncertainty concept.⁵ Initially, the debate focused a lot on whether or not it was a good thing to use negative wording such as "error" and "uncertainty" when communicating measurement quality. There were those who feared that it could reflect badly on the profession, and promoted the use of other terms, e.g. "reliability".

Eurachem quickly prepared a first sector-specific document for analytical chemistry,⁶ but comments were not entirely positive. The more mathematical approach was unfamiliar. SP's experience from ten training courses the 2000-2001 shows that the main obstacle for many chemists is the setting up of a model (a functional relationship) for the measurement and the application of uncertainty propagation.

During method development and validation, many testing sectors, are used to evaluate random and systematic errors and present these separately to describe the measurement quality. An important inhibitor for the introduction of measurement uncertainty has been the failure of explaining how the better known and more widely applied "accuracy" concept, relate to measurement uncertainty.[‡] Where manufacturers of calibrators and measurement systems fail to provide convincing information concerning traceability and uncertainty, the comparability of the laboratories' results is restricted, often to a defined measurement procedure or to within a specified method group. This has led to doubts about the added value of the uncertainty concept.

There are also many examples in testing where the main limitation is the properties of the tested material. Although the instrumentation can be carefully characterised for its uncertainty components, these will only constitute a small part of the combined uncertainty of the tested property. In such cases, and for qualitative testing, accreditation and regulatory bodies must agree with the respective profession on how elaborate the uncertainty evaluation should be.

This report focuses on the customer/end-user of the measurement result. Some laboratories have argued that the customer does not want or understand numbers expressing the reliability of the measurement result and provided such information only on request. SP's surveys give a slightly different picture of the customers' knowledge, as well as of their need and interest in measurement uncertainty. The new quality standard ISO/IEC 17025¹ stresses that the laboratory must understand the customer's needs and adapt the technical work to assure results are fit for their intended use. The reported uncertainty should demonstrate this. Information leaflets of the type described here constitute a simple and cost-efficient way of improving the dialogue between producers and users of measurement information.

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[‡] The ISO 5725 series describe accuracy by the two terms "trueness" and "precision".

Copies of this report are available from SP Swedish National Testing and Research Institute. The price per copy is 15 Euro for orders of 1-5 copies) and 10 Euro for >6 copies. Orders are placed by payment to SP's account 6668-275 695 611, Svenska Handelsbanken, Swift address HAND SE SG. State report number (SP Report 2001:07), number of copies and project number SPle 8501.

Appendix

Appendix 1 Information leaflet SP INFO 2000:27

Appendix 2 Questionnaire in English

Important information to our customers concerning the quality of measurements

1 Do you use results of chemical analyses as a basis for your decisions and judgements?

Those of us working in accredited laboratories or dealing with issues concerning the quality of measurements, would like to inform you about some important changes concerning the way the results of measurements are presented. These changes make it easier for you as an end-user to make correct decisions.

2 Nobody is perfect!

Results of analyses cannot be perfect! We hope this does not come as a big surprise to you. We use the term **measurement uncertainty** to describe this lack of perfection.

3 The analytical process

In each step of the analytical work, from sampling to the final measurement, deviations from the true value occur and measurement conditions vary. We take measures and perform controls regularly to assure that these deviations and variations together are small enough to make sure the end result fulfils your requirements. When we don't have full information about all of the steps, e.g. when sampling and initial sample preparation are performed by you as a customer, you can assist us by providing detailed information about how that work was performed. Our experts are ready to advise on all matters regarding sampling. Please contact the laboratory beforehand.

4 Results should be fit-for-the-purpose

The accuracy of the results must of course not be too low nor too high since this would increase the costs. It should be fit for the intended purpose. If you are unsure on what level of accuracy you need, do not hesitate to contact the laboratory.

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European
co-operation for
Accreditation

5 Uncertainty and limiting values

Many analyses are made to assure that limiting values are not exceeded. Without information about the measurement uncertainty it may appear to be very easy to make decisions, but these decision may be incorrect, with, e.g. economical consequences when rejecting instead of accepting a product, judicial consequences when returning a verdict of guilty instead of not guilty, or medical consequences when carrying out an unnecessary treatment. There are numerous examples!

A result with and without measurement uncertainty

With a realistic measurement uncertainty the information included in the result becomes much more useful.

6 It will be easier to compare results

Most laboratories have until now chosen not to state measurement uncertainty in the test report. Instead, such information has only been given when the customer has asked for it.

In the future, information about the measurement uncertainty will appear more frequently in the test report. It is also possible that you will bump into new and unfamiliar quality terms. This is due to the fact that there are new international guides and standards describing a common and partly new terminology. One of the objectives is to make it easier for you as a customer to compare test results.

7 What could it look like?

When reporting the test result we will give the normal information about what we have measured. When the results are followed by uncertainty statements, they are presented as intervals within which the true values are expected to lie with a certain level of confidence (usually 95%). In the example below the lead content is $1.65 \pm 0.15 \text{ mmol}\cdot\text{kg}^{-1}$, that is between 1.50 and 1.80. The measurement uncertainty is also often reported relatively, in %.

Total lead content (Pb)	$1.65 \text{ mmol}\cdot\text{kg}^{-1}$
Measurement uncertainty	$0.15 \text{ mmol}\cdot\text{kg}^{-1}$ (9.1%)

The stated uncertainty is an expanded measurement uncertainty (U). It was obtained by multiplying the combined standard uncertainty u_c with a coverage factor k equal to 2. This corresponds approximately to a 95 % confidence interval.

8 All's well that ends well...

The requirements for a consistent way of reporting test results are increasing. Therefore, those of us involved in measurements are eager to assure ourselves that we understand your needs. You will notice this in your contacts with us before, during and after the test assignment. We hope that you will be satisfied with the final result.

"Based on SP INFO 2000:23, developed by SP and Föreningen Akkrediterade Laboratorier (FaL), in collaboration with the National Food Administration, SWEDAC, the Swedish Environmental Protection Agency and the Swedish Water and Wastewater Association (VAV)."

Appendix 2 Questionnaire for Survey B

Questionnaire concerning measurement uncertainty in test reports

1. How much knowledge did you have about measurement uncertainty before you received this leaflet?

- ☐ None ☐ Some ☐ Much ☐ Not relevant/do not know

2. How often do you have a need for a statement concerning the measurement uncertainty in the test report?

- ☐ Never ☐ Sometimes ☐ Often ☐ Always ☐ Not relevant/do not know

3. If you have a need for a statement concerning measurement uncertainty, what is the reason?

- ☐ Own interest (e.g. to be able to make decisions)
☐ The clients demand it
☐ Authorities demand it
☐ The accreditation body demands it
☐ Other reasons
☐ Not relevant/do not know

4. How do you find the extent of the information in the leaflet?

- ☐ Too little ☐ Appropriate ☐ Too much ☐ Not relevant/do not know

5a. To what extent do you understand the measurement uncertainty stated in the test report?

- ☐ Not at all ☐ Partly ☐ Fully ☐ Not relevant/do not know

5b. If the measurement uncertainty is not stated in the test report, do you then contact the laboratory to obtain such information?

- ☐ No, never ☐ Yes, sometimes ☐ Yes, often ☐ Not relevant/do not know

6. Was this questionnaire completed by the same person who requested the test and who will act on the test results?

- ☐ Yes ☐ No

7. How many employees are there in your organisation?

- ☐ <10 ☐ 10-25 ☐ 26-100 ☐ >100

8. What is the main occupation of your organisation? (Laboratory work, authoritative, manufacturing, import, sales, etc.)

.....

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