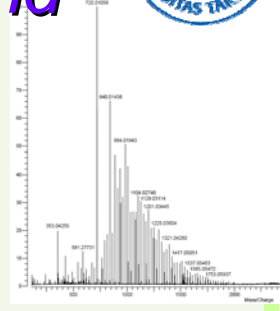
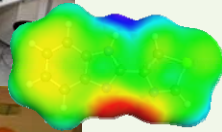
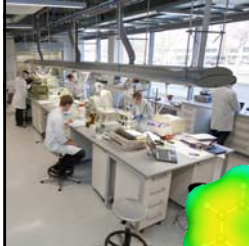


Education in Metrology in Chemistry – why and how?



Ivo Leito
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Metrology = Science of measurement

- Metrology is relevant for any measurement: from the simplest to the most sophisticated

Chemical measurements \approx Chemical analysis

Are Measurements Important?

**Measurements:
80 billions of EUR or 1% of the
GDP in Europe**

The Assessment of the Economic Role of Measurements and Testing in Modern Society.
Survey directed by Geoffrey Williams, Pembroke College, Oxford, **2002**

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Legislation?

**Ca 25% of the EU legislation
specifies chemical measurements
(chemical analysis)**

Estimated by the EC JRC IRMM

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Some EU legislation ...

Water Framework Directive (2000/60/EC)
Priority Substances Decision (2455/2001/EC)
Bathing Water Directive (76/160/EEC)
Birds Directive (79/409/EEC ; 97/49/EC)
Drinking Water Directive (80/778/EEC ; 98/83/EEC)
Environment Impact Assessment Directive (85/337/EEC)
Habitats Directive (92/43/EEC)
Integrated Pollution Prevention Control Directive (96/61/EC)
Major Accidents Directive (96/82/EC)
Nitrates Directive (91/676/EEC)
Plant Protection Products Directive (91/414/EEC ; 98/47/EEC)
Sewage Sludge Directive (86/278/EEC)

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Urban Wastewater Treatment Directive (91/271/EEC)
Cadmium Discharge Directive (83/513/EEC)
Hexachlorocyclohexane Discharge Directive (84/491/EEC)
Mercury Directive (84/156/EEC)
Mercury Discharges Directive (82/176/EEC)
Directive (79/869/EEC) concerning the methods of measurement and frequencies of sampling and analysis of surface water intended for the abstraction of drinking water
Fish Life Directive (78/659/EEC)
Groundwater Directive (80/68/EEC)
Shellfish Waters Directive (79/923/EEC)
Surface Water Abstraction Directive (75/440/EEC)
Technical guidance document in support of Commission Directive (93/67/EEC)

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Radioactivity Council Decision 87/600 Emergency Information Exchange
Dir 97/24/EC Vehicle emission
2001/81/EC national emission ceilings for certain atmospheric pollutants
2002/3/EC ozone in ambient air

The list continues ...

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Estimated Water Framework Directive (2000/60/EC) monitoring cost



1) Direct cost: for EU estimated at **billions of €**

2) Cost of wrong decision: amplification

- incorrect trend analysis
- incorrect water protection measures
- incorrect environmental remediation measures

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BSE testing in the EU

Since 2001 animals older than 30 months & fallen stock above 24 months must be tested for BSE before entering food chain

[Regulation (EC) No 999/2001]

➔ 10 - 11 million BSE tests/year in the EU

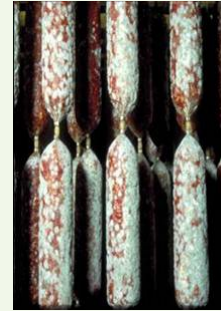
~ €500 million €/year

(on average ~ €45 - 50 / test)
Estimation by DG SANCO 2005

Data from the EC JRC IRMM

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So, chemical analysis is a big business...

Are labs up to the task?

Between 5 and 30% of chemical analysis results are unsatisfactory!

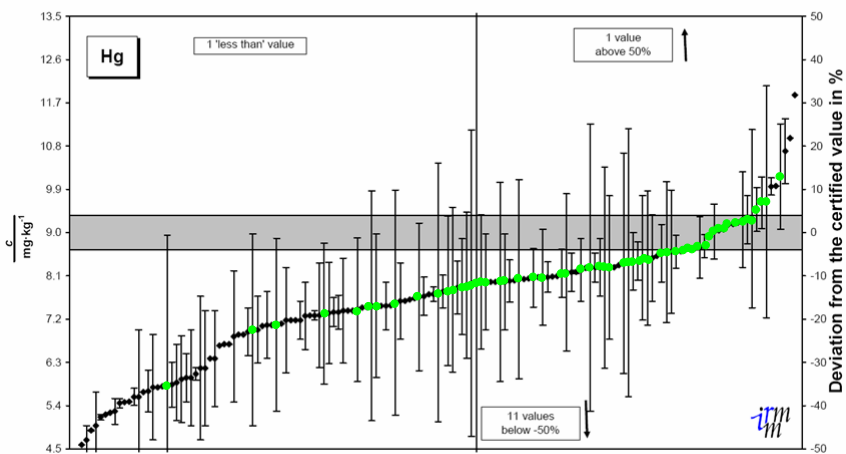
Not quite ...

*Metrology in Chemistry. Current Activities and Future Requirements in Europe.
Prepared by B. King, EUR 19074 EN, Luxembourg, 1999*

Example:

IMEP- 21: Trace elements, PCBs and PAHs in Sewage Sludge

Certified value for Hg : $9.03 \pm 0.36 \text{ mg}\cdot\text{kg}^{-1}$ [$U=k\cdot u_c$ ($k=2$)]



IMEP
★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

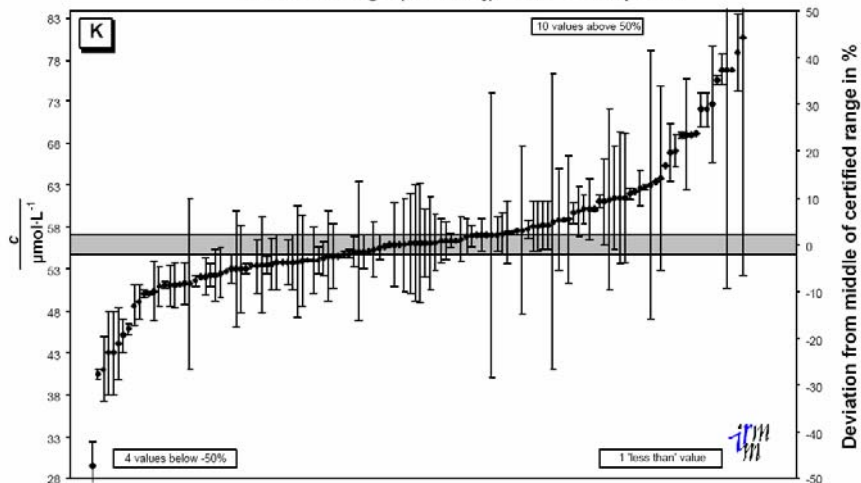
Results for Hg from all participants

http://www.irmm.jrc.be/interlaboratory_comparisons/imep/

Another example:

IMEP- 9 : Trace elements in Water

Certified range ($\pm U=2u_c$): $54.7 - 56.9 \mu\text{mol}\cdot\text{L}^{-1}$

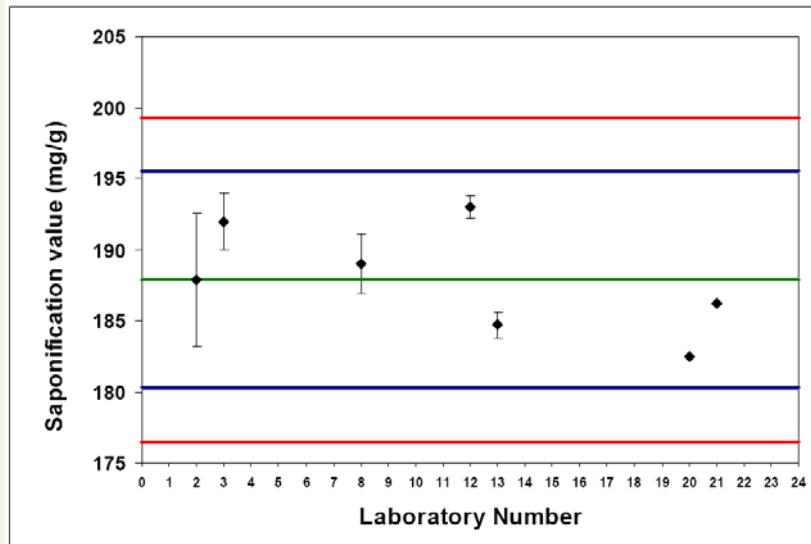


IMEP
★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Results from all participants.

http://www.irmm.jrc.be/interlaboratory_comparisons/imep/

Yet another example:



EstOil-5

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Two kinds of problems

- **Measurement poorly performed**
 - Measured value significantly different from the reference value
- **Uncertainty poorly estimated**
 - The agreement between the measured value and the reference value is by itself not so bad, but the uncertainty of the lab's value is underestimated

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How to achieve correct results?

- Be **educated!**
- Use **validated** measurement procedures
- Estimate and report measurement **uncertainty**
- Establish **traceability** of measurement results
- Participate in **interlaboratory comparisons**
- Accredited **quality management system**

Not new ...

**... but not included in most
chemistry curricula!**

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Key to success: Education

**There is a huge need for
educated workers and managers
in laboratories, industry, agencies, ...**

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The Paradox

- There is a huge need for measurement-related knowledge
- Measurements are “big business”
- And yet, laboratories fail to find competent people ...
 - not enough students are educated in this field
 - important issues not included in curricula ...

Some widespread misconceptions

Analytical chemistry is just a tool,
you just apply it

Everybody can measure, no
special knowledge needed

You just buy the kit, no?

The plug and play idea !



analysis is trivial ?

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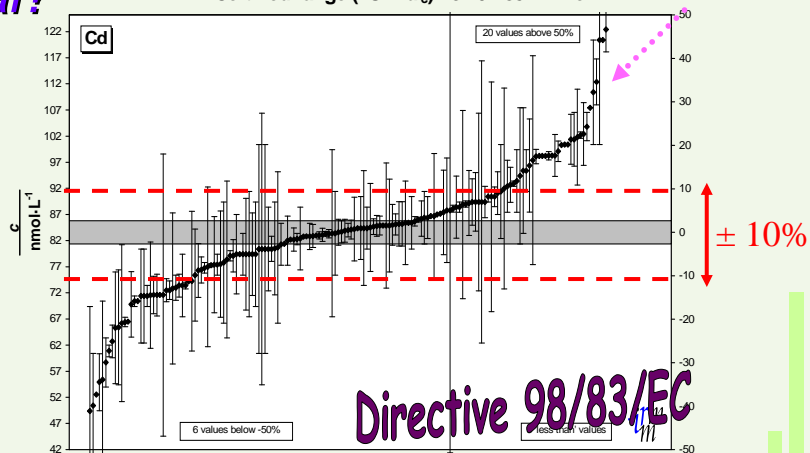
Slide: Philip Taylor, EC-JRC IRMM

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Trivial?

IMEP- 9 : Trace elements in Water

Certified range ($\pm U=2u_c$): 81.0 - 85.4 nmol.L⁻¹ ??



Directive 98/83/EC

Results from all laboratories.

Water for human consumption



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Does education help?

Estoil 3

Table 6. Participant 3 scores.

Lab number*	Mothers content	FFA content	PV content	P content	SAFV content	B.NTO content	ERIC content
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Estoil 4

Table 6. Participant 4 scores.

Lab number*	Mothers content	FFA content	PV content	P content	SAFV content	B.NTO content	ERIC content
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							

Estoil 5

Table 6. Participant 5 scores.

Lab number*	Mothers content	FFA content	PV content	P content	SAFV content	B.NTO content	ERIC content
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							

Estoil 6

Table 6. Participant 6 scores.

Lab number*	Mothers content	FFA content	PV content	P content	SAFV content	B.NTO content	ERIC content
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							

Estoil 3

Estoil 4

There is improvement!

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<http://www.ut.ee/katsekoda/ILC/>

nki

Applied Measurement Science



International master's programme

<http://www.ut.ee/ams>

Programme outline

- Interdisciplinary 3+2 master's degree program
 - Physical measurements
 - Chemical analyses
 - Metrology
 - Quality systems
 - Economic and legal aspects of measurements
- 120 ECTS
- Cross-sectorial
- International: **Tuition in english**

**This
combination of
topics is unique
in Europe!**

Knowledge and skills

- Measurement and analysis methods
 - Physical and chemical basis
 - Hands-on work
- Factors affecting the results
- Calculation methods
- Knowledge necessary for assessment of quality of results
- Economic and legal aspects, quality systems

Programme structure

Obligatory Module (45 ECTS)

Courses: Measuring and Instrumentation, Measurement Data Processing, Lab of Physical Measurements, Practical Chemical Analysis Methods, Lab of Chemical Analysis Methods, Fundamentals of Metrology, Metrology in Chemistry, Seminar in Measurement Science, Quality management

Elective Module (30 ECTS, courses can be chosen from the list)

Courses: Materials Characterization and Testing, Structural Analysis, Measurements in Biochemistry, Measurements and the Law, Economic Aspects of Measurements, Signal Processing, Chemometrics, Environment and Measurement, Electrochemical Measurement and Analysis Methods, Nanometrology, Quality Systems etc

Optional Subjects

(6 ECTS, any courses can be chosen university-wide)

Internship

(9 ECTS, internship placement in industry or analysis or calibration laboratories)

Master's thesis

(30 ECTS, reasearch project with a topic related to measurement science)

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Measurement Science in Chemistry

www.msc-euromaster.eu



- International
- 8 countries
 - Estonia, Slovenia, Bulgaria, France, Portugal, Poland, Romania, Finland
- 10 universities
 - Coordinator: University of Warsaw
 - Mentor-organization: EC-JRC IRMM



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Measurement Science in Chemistry: Mission

- To contribute to **radical improvement of the education level of analytical chemistry** by being the best international provider of measurement science education in chemistry

"Jointly delivered" programme

- 3+2 **Master's** level programme
- Broad education in the basics of measurement science in chemistry (analytical chemistry)
- "Jointly delivered":
 - Study at home university, according to a local program
 - Added value by international activities
 - Summer school
 - Student and teacher exchange
 - Best practice in teaching

MSC consortium: short history

- 2001 Start of the IRMM  initiative
- 2005  Summer School (Rogaška Slatina)
- 2007  Summer School (Krakow/Wieliczka)
- 2007-... Applied measurement science international master's programme (University of Tartu)



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MSC consortium: short history

- 2008 ECTNA awards to the consortium the **Chemistry Euromaster®** quality label



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MSC consortium: short history Summer schools

- Summer **2008 Celje** (Slovenia)

- 35 participants
- 8 countries



- Summer **2009 Blagoevgrad** (Bulgaria)

- 43 participants
- 9 countries



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Summer schools

- Summer **2010 Lепanina** (Estonia)

- 39 participants
- 9 countries



- Summer **2011 Poznań** (Poland)

- 43 participants
- 13 countries



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Programme: generic structure

Year 1

Fundamentals of Measurement Science (incl MS in Chemistry) (8-12 ECTS)

Data evaluation and management (8-12 ECTS)

Instrumental methods (8-12 ECTS)

Sampling, sample preparation and separation methods (5-8 ECTS)

Applications of analysis (16-24 ECTS)

Summer

Summer School (30 ECTS)

Year 2

Other subjects required by the home university
(Subject to decision at university level)

Master's thesis (30 ECTS)
(research project with a topic related to measurement science)

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Programme Structure

- The structure on the previous slide is generic
 - At every university teaching follows a local program
 - Local differences exist between universities
- An important unifying link is the Summer school

Volume in ECTS

- The overall program volume is 120 ECTS
- 30 ECTS of the Summer school can either partially or fully replace some local courses at universities
 - This is to be decided at university level (the student, the local coordinator at the university and the university officials)

Enrollment

- Student first enrolls to one of the consortium universities as a master student
- Then separately applies for a place in the MSC program

**Selection is based on
academic excellence!**

What comes in addition to local university programme?

- Summer school
- Homework during the following autumn semester
- Scrutiny of the master's thesis

This is the minimum requirement for the EDS!



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Summer School

1. The Actual Summer School
 - Lectures, seminars
 - Group work
 - Student contest
 - Learning evaluation
 2. Additional homework during autumn semester following the summer
- Final mark (a combination of 1 and 2) and ECTS points

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Summer school content

- Validation of chemical analysis procedures
- Basic statistics, Statistical basis of calibration
- Traceability in chemical analysis
- Alternative Approaches for the Quantification of Measurement Uncertainty
- ISO 17025, Accreditation visit to real lab
- Sampling and sample preparation in food and environmental analysis
- Customer-analyst interactions
- Importance of reliable measurements to implement EU legislation

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Master's Thesis

3. Scrutiny of the master's thesis

- Extended English summary has to be presented
- PPT presentation in English has to be prepared (to be put on the web)
- The thesis will be scrutinized by the local coordinator at the home university (and if necessary by the MSC management committee)

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Novel teaching approaches

“Learning by involvement”

- Contest of student teams
- Accreditation visits to ISO 17025 accredited laboratories



Metrology in chemistry on the move!



<http://www.msc-euromaster.eu/>