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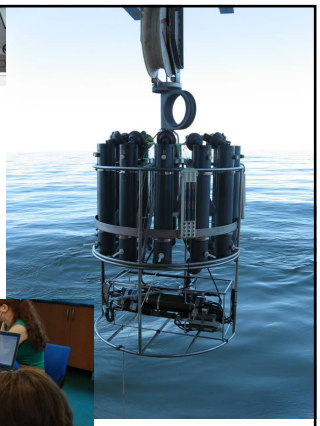
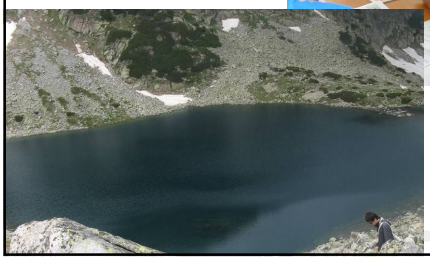
On-site/on-line measurements:
Part of analytical chemistry education?





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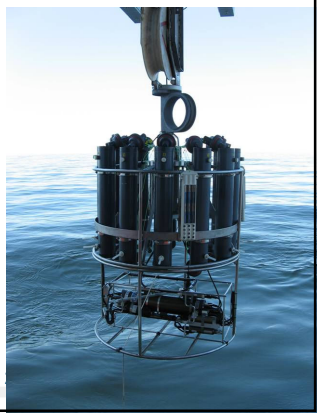
Sensor-based on-line/on-site measurements

- A vast and rapidly expanding area
  - Market growth: 7-10% annually
- Several breakthroughs recently
  - Nano
  - Trace-level potentiometric
  - SPR
  - Wireless data transfer
  - Remote sensing
  - …



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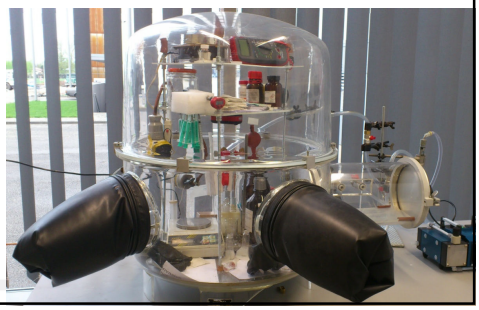
Benefits

- Fast response, immediate feedback possible
- Reduced costs
- Remote areas, aggressive environments
- Unstable samples
- Continuous monitoring as opposed to limited number of samples
  - Detection of “spikes”
  - Early spotting of problems



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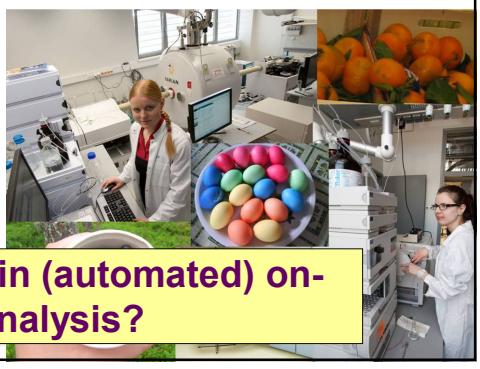
Teaching analytical chemistry

- An established discipline
- Established core concepts:
  - Sampling and sample
    - Representativeness of sample
    - Separation of the analyte from the sample
  - Selectivity
  - Calibration
  - Validation



Does anything change in (automated) on-line/on-site analysis?

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Sample

Part of the analysis object in contact with the sensor at a given moment in time

- Sample
  - generally cannot be stored
  - can be unique: impossible to ever repeat
  - Analyte is not separated

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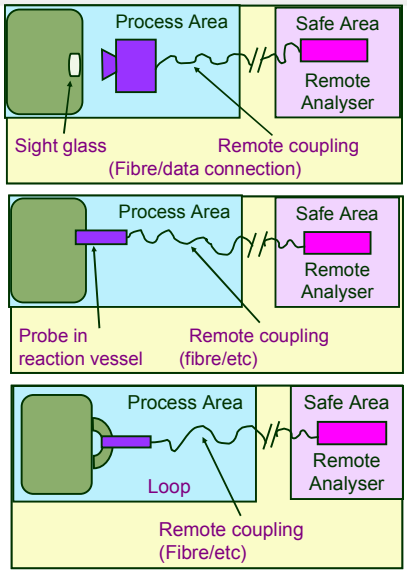
Sampling

- Can look very different from traditional sampling



J. Andrews, P. Dallin, *Spectroscopy Europe* 2003, *15(4)*, 23-26

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Calibration

Can be very challenging in remote areas or when the sensing system is monitoringa continuously running process

Often impossible to do that under the same conditions

Long-term stability is often the most critical parameter of the system

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Example: the ARGO observation system

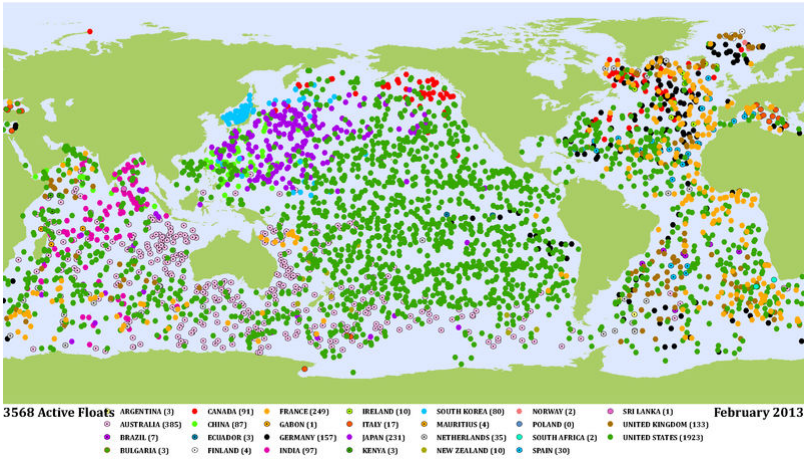

Image: Wikipedia

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Selectivity

A limited number of approaches are available (sensor arrays, ratio/difference approcahes, …)

- Selectivity is another critical parameter of an on-line/on-site analysis system
- Often instead of a concrete analyte a more general parameter is determined

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Validation

Possibility of experimenting and changing the conditions can be very limited (remote analysis, process analysis, …)

- Validation can be done in the lab
- Care is necessary to extend the results to actual operation

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How to introduce it into teaching?

Danger:
Make the core concepts initially too wide – students get lost

- Two-stage approach:
  - General analytical chemistry course defines the traditional concepts
    - But has a short section briefly mentioning that it can be different
  - A dedicated course on on-line/on-site analysis

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Course outline

- Main concepts, differences from conventional chemical analysis
- Sensors
  - electrochemical, optical, combined, …
  - Measurement approaches: differential, ratiometric, arrays, …
  - Sensor design and practical operation
  - Data analysis
- Metrology/quality aspects
  - Traceability, calibration, validation, …
- Application examples
  - Industrial process analysis, oceanographic floats, …

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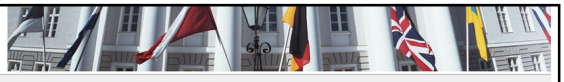

Applied Measurement Science

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

Program 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, On-line/on-site measurements, Seminar in Measurement Science, Quality Systems

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

Possible 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, etc

Optional Subjects

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

Practical Placement

(**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)

See www.ut.ee/ams

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Thank you for your attention!