

PhD Course

Representative Sampling of solids

Characterization and analysis



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The course will introduce **Theory of Sampling** – TOS – as developed by *Pierre Gy*, and applied to solids and in analytical chemistry

August 27 -31, 2007 Technical University of Denmark Lyngby, Denmark

Apply to: 3R@dtu.dk before June 15, 2007

For further information: www.RECETO.dk or www.3R.er.dtu.dk

REPRESENTATIVE SAMPLING OF HETEROGENEOUS SYSTEMS AND PROCESSES

- 5 ECTS Points
- 5 Full Days of Lectures
- Series of Exercises
- 70 Hours of Reading
- Participation Diploma

Fee: Free of Charge

100 Euros for Course Material

Lunches & Refreshments Provided
by 3R / Receto

Travel & Accommodation
Not Included

Room 011, Building 115/113

Deadline for Registration
15 June 2007

*Download the Course Outline
and Register Your Interest Here*

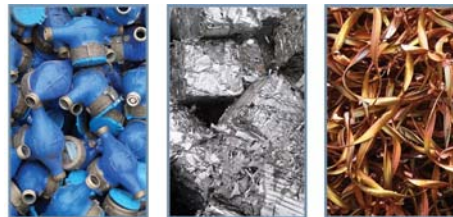
<http://www.3r.er.dtu.dk>

Non-PhD students can attend the
course paying a fee of 1000€. Details
about payment will be provided upon
acceptance as a course participant.

In Collaboration with



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3R Residual
Resources
Research

A PhD research school on integrated resource and waste management

PhD Course
Technical University of
Denmark, Copenhagen

REPRESENTATIVE
SAMPLING OF SOLIDS

27 August – 31 August 2007



CHARACTERIZATION
AND
ANALYSIS

In Collaboration with



Institute of Environment & Resources
Technical University of Denmark



Solid Sampling PhD Course
27/08/07 – 31/08/07
Copenhagen, Denmark

Background

This course gives a full introduction to all principles and practical procedures involved in the Theory of Sampling (TOS), in the form of seven Sampling Unit Operations (SUO). Incorrect sampling represents the dominating error source in all analysis of complex scientific, laboratory, technological and industrial systems, often contributing by a factor of 50 to 100 times higher than all analytical errors combined. Specific case stories and experience from science, technology and industry, with a special focus on solid waste sampling are presented, but TOS' generic principles apply to all types of heterogeneous systems, such as soil sampling, biotechnology and environmental engineering.

Learning objectives

This course will give participants a robust understanding of all principles of representative sampling. Skills for analysis of sampling procedures/campaigns will be developed. Participants will be able to focus on how to plan a representative sampling campaign, by mastering the heterogeneity characterization imperative.

Participants will become familiar with the most practical relevant tools used for representative sampling and - mass reduction and how to use them correctly, i.e. how to make sure their use always follows the principles of TOS.

Participants will obtain a first experience regarding sampling in practice and will be able to analyze their own sampling problems correctly.

Outline Content of the Course

- Introduction to solid characterization
- Introduction to the sampling process (Representative Sampling, Sampling correctness)
- Introduction to representative mass reduction
- Introduction to TOS concepts, terminology and principles
- Differences between laboratory sampling and field sampling
- Introduction to the minimum set of specific TOS terms needed: lot, sample, sub-sample (increment), composite sampling, fragment, group, critical component
- Representativity expressed as a quantitative characteristic using Gy's formula
- Lot dimensionalities - and how they can be reduced (autocorrelation, discrete sampling model, continuous sampling model)
- Description and reduction of sampling errors
- Concept of heterogeneity (Quantitative heterogeneity, heterogeneity type, practical measurement)
- ACAB's seven sampling unit operations
- Correct mass reduction (Methods, devices, tools and hardware)
- Introduction to data analysis and error analysis (Statistical characterization of heterogeneity and variography)
- Computer software tool for statistical analysis in the TOS context



- Sampling case stories and examples
- A series of exercises for developing analytical, planning and practical sampling skills

Lecturers



Kim H. Esbensen, Professor, Aalborg University (Esbjerg)

Bo Svendsmark, Associate Professor, Dept. of Chemistry, Univ. of Copenhagen

Lars Petersen, Assoc. Prof. Aalborg University (Esbjerg)

Thomas H. Christensen, Professor, E&R, DTU

Christian Riber, Ph.D. student, E&R, DTU

Alessio Boldrin, Ph.D. student, E&R, DTU

Getting here...

- By Road: Direction to Lyngby (See directions [here](#))
- By Rail: S Trains from Main Railway station to Lyngby, 5 min taxi or bus to university
- By Air: Kastrup Airport 35 minutes by S Train and Bus 150S.
- By bus: Take bus S150 from Nørreport to Lyngby DTU
- Location map of the university
http://www.dtu.dk/English/About_DTU/DTU%20Directory.aspx

Title: REPRESENTATIVE SAMPLING OF SOLIDS- CHARACTERIZATION AND ANALYSIS

Organizer: A collaboration between the research schools **Residual Resources Research (DTU)**, **Receto (KU)** and **ACABS research Group (AAUE)**

Lectures: Kim H. Esbensen, Professor, Aalborg University (Esbjerg)
Bo Svensmark, Associate Professor, Dept. of Chemistry, Univ. of Copenhagen
Lars Petersen, Assoc. Prof. Aalborg University (Esbjerg)
Thomas H. Christensen, Professor, E&R, DTU
Christian Riber, Ph.D. student, E&R, DTU
Alessio Boldrin, Ph.D. student, E&R, DTU

ECTS: 5 ECTS. Five full days of lectures and exercises + 70 hours of reading and preparation of report on student's own sampling problem(s), corresponding to a total of 130 workhours

Date: Monday August 27 – Friday August 31, 2007

Place: Institute of Environment & Resources (E&R), Room 011, Building 115/113, Technical University of Denmark, 2800 Kongens Lyngby, Denmark

Deadline: The application form can be downloaded from www.3r.er.dtu.dk. It has to be submitted by e-mail to 3R@er.dtu.dk before June 15, 2007

Participants: A maximum of 30 PhD students

Fee: EU PhD students participate free of charge except a fee of 100 Euro for the purchase of the book provided. PhD students pay their own travel and accommodation (Hotel in the vicinity is about 130 Euro per night including breakfast and taxes). Lunches, refreshments and notes are provided by 3R/Receto.

Non-PhD students can attend the course paying a fee of 1000€Details about payment will be provided upon acceptance as a course participant.

Diploma: A diploma is provided as documentation for participation

Introduction

Sampling is the first, necessary step when performing a chemical and/or a physical analysis for characterization of materials or processes, often followed by data analysis such as statistics or chemometrics. Although sampling may be a source of large variation of characterization results, it is often conducted without sufficient scientific rigor and methodology necessary in order to obtain statistically consistent results. Sampling of solid materials, such as waste, is particularly challenging because of its inherent heterogeneity. It is consequently difficult to mix the materials to obtain consistent homogeneity, leading to potentially unreliable and non-repeatable results.

It is therefore critical to use a rigorous sampling method and technique to minimize the degree of uncertainty associated with this first step of material characterization. The "Theory of Sampling" (TOS), developed by **Pierre Gy** during fifty years of experience as a sampling consultant, is an exhaustive methodology addressing the critical issue of representative sampling. TOS covers all types of heterogeneous materials and processes such as aggregate mixtures, powders, slurries, as well as two- and three-phase systems.

By establishing a comprehensive, general theory of heterogeneity, coupled with a systematic analysis of the sampling process in practice, TOS derives and formulates all necessary principles for assessing all characteristics of representative sampling.

This course gives a full introduction to all principles and practical procedures involved in TOS, in the form of seven Sampling Unit Operations (SUO). Incorrect sampling represents the dominating error source in all analysis of complex scientific, laboratory, technological and industrial lots and systems, often contributing by a factor of 50 to 100 times higher than all analytical errors combined. Specific case stories and experience from science, technology and industry, with a special focus on solid waste sampling are presented, but TOS' generic principles apply to all types of heterogeneous systems, such as soil sampling, biotechnology and environmental engineering.

Content of the course

The Theory of Sampling (TOS) includes the following elements, which will be presented and discussed during the course:

- Introduction to solid characterization: Why and what?
- Introduction to the sampling process. Definition of "Representative Sampling". Examples to show whether a sampling procedure can be considered representative or not. Sampling correctness.
- Representative mass reduction is the fundamental cornerstone embedded in all sampling. Mass reduction is not equal to representative sampling, but representative sampling includes representative mass reduction.



- Introduction to TOS concepts, terminology and principles. Comparison between the “old” sampling approach (grab sampling) and TOS, focusing on how to secure both accuracy and precision in the sampling process.
- Demonstration that “differences” between sampling in the lab and in the field is only a matter of scale; TOS’ principles are scale-invariant however.
- Introduction to the minimum set of specific TOS terms needed: lot, sample, sub-sample (increment), composite sampling, fragment, group, critical component.
- Representativity – can be expressed as a quantitative characteristic. Gy’s formula connecting sampling error with a material’s constants and the sampling process.
- Lot dimensionalities - and how they can be reduced. Concept of autocorrelation. Sampling of 0-dimensional lots (discrete sampling model). Sampling of 1-dimensional lots (continuous sampling model).
- Sampling errors: description of the seven sampling errors, how they originate and - most importantly – how they can be reduced/eliminated.
- Concept of heterogeneity. Heterogeneity characterization of lots and materials (theoretical basis for all TOS). Quantitative heterogeneity characterization (IHL). Different types of heterogeneity. Practical measurement of heterogeneity.
- Sampling as a multistage operation. Practical sampling: the ACAB’s seven sampling unit operations (3 principles and 4 practical procedures).
- The critical role of a correct mass reduction. Methods for mass reduction. Devices, tools and hardware for correct mass reduction procedures.
- Introduction to data analysis and error analysis. Statistical characterization of heterogeneity and variography (heterogeneity characterization of 1-dimensional material streams & bodies). The variogram and information about process variability. The “nugget effect” as the Minimum Practical Error. Variographic experiments.
- Computer software tool for statistical analysis in the TOS contest.
- Sampling case histories and examples on representative sampling. “Sampling’s “Hall of fame/Hall of Shame” - examples of good/bad sampling practice.
- Exercises for developing analytical, planning and practical sampling skills.
- Solid waste cases: Organic waste, garden waste, bottom ash ...
- Analytical chemistry cases: Soil, biological materials,...

Learning objectives

This course gives participants a robust understanding of all principles of representative sampling. Skills for analysis of sampling procedures/campaigns will be developed. Participants will be able to focus on how to plan a representative sampling campaign, by mastering the heterogeneity characterization imperative.

Participants will have become familiar with the most practical relevant tools used for representative sampling and - mass reduction and how to use them correctly, i.e. how to make sure their use always follows the principles of TOS.

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Program

August 2007		830 - 1200	1300 - 1700	Evening
Sunday	26	Arrival on Sunday		
Monday	27	Introduction/lab visit:	TOS	Ice breaker
Tuesday	28	TOS	TOS	Free evening
Wednesday	29	Solid waste sampling	Anal. Chem. Sampling	Cases
Thursday	30	TOS (1-dim)	Group exercise	Social event
Friday	31	TOS / software / standards	Students' own case discussion	Departure

Course literature / material:

Prior to the course the students read the following notes (they will be sent by email) and prepare a 3 page statement on their own present sampling strategy:

Lars Petersen, P. Minkkinen & Kim H. Esbensen, "Representative Sampling for Reliable Data Analysis: TOS (Theory of Sampling)", Aalborg University Esbjerg.

Lars Petersen, Casper K. Dahl, Kim H. Esbensen, "Representative Mass Reduction in Sampling – a Critical Survey of Techniques and Hardware", ACACSRG, Aalborg University Esbjerg.

At the course the following material is distributed:

Pierre Gy, "Sampling for Analytical Purposes", John Wiley and Sons, 1998

Lars Petersen & Kim H. Esbensen, "Representative Process Sampling for Reliable Data Analysis: A Tutorial", ACABS, Aalborg University Esbjerg.

Esbensen, K.H, H.H.Friis-Petersen, L. Petersen, J.B. Holm-Nielsen & P.P.Mortensen (2006). Representative process sampling – in practise: Variographic analysis and estimation of Total Sampling Errors (TSE). Proceedings 5.th Winter Symposium of Chemometrics (WSC-5), Samara 2006. Chemometrics and Intelligent Laboratory Systems, Special Issue (in print)

Jansen,J.I.C., Spliid,H., Hansen,T.L., Svärd,Å. & Christensen,T.H. (2004): Assessment of sampling and chemical analysis of source-separated organic household waste. Waste Management, 24, 541-549.

Selected material on representative sampling in analytical chemistry.