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GammaWorkshops Proceedings

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Abstract

Due to a sparse interaction during the last years between practioners in gamma ray spectrometry in the Nordic countries, a NKS activity was started in 2009. This GammaSem was focused on seminars relevant to gamma spectrometry. A follow up seminar was held in 2010. As an outcome of these activities it was suggested that the 2011 meeting should be focused on practical issues, e.g. different corrections needed in gamma spectrometric measurements. This three day's meeting, GammaWorkshops, was held in September at Risø-DTU.

Experts on different topics relevant for gamma spectrometric measurements were invited to the GammaWorkshops. The topics included efficiency transfer, true coincidence summing corrections, self-attenuation corrections, measurement of natural radionuclides (natural decay series), combined measurement uncertainty calculations, and detection limits. These topics covered both lectures and practical sessions. The practical sessions included demonstrations of tools for e.g. corrections and calculations of the above meantioned topics.

Key words

Gamma spectrometry, Efficiency transfer, self-absorption correction, true coincidence correction, natural radioactivity, uncertainty, detection limit

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Nordic Workshops for users of gamma ray spectrometry

Risø-DTU 26-28 September 2011

Henrik Ramebäck (ed), Elisabeth Strålberg, Seppo Klemola,
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Summary

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Introduction

Due to a sparse interaction during the last years between practioners in gamma ray spectrometry in the Nordic countries, a NKS activity was started in 2009. This GammaSem was focused on seminars relevant to gamma spectrometry. A follow up seminar was held in 2010. As an outcome of these activities it was suggested that the 2011 meeting should be focused on practical issues, e.g. different corrections needed in gamma spectrometric measurements. This three day's meeting, GammaWorkshops, was held in September at Risø-DTU.

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GammaWorkshops 2011

About 50 persons from about 20 organisations in the Nordic and Baltic countries attended the GammaWorkshops. Most of the persons were young scientists who work with gamma spectrometry. Invited lecturers were

- Dr. Tim Vidmar from SCK CEN in Belgium who talked about efficiency transfer and self-absorption corrections in gamma ray spectrometry. He also provided a version of the program EFFTRAN in which efficiency transfer, self-absorption correction as well as true coincidence corrections (TCC) can be done. Dr. Vidmar also held a session about TCC in the gamma spectrometry software Genie-2000.
- Dr. Menno Blaauw from Delft University of Technology in the Nederlands. He gave a lecture regarding true coincidence summing and also had a practical session on TCC for GammaVision users.
- Dr. Tuukka Turtiainen, who gave a lecture on gamma spectrometric measurements of natural radionuclides.
- Dr. Kaj Heydorn who gave a lecture on detection limits and the ISO-standard ISO-11929:2010

- There were also lectures, and practical sessions, given by persons from the GammaWorkshops project board (the authors of this report):
    - Sigurður Emil Pálsson gave a presentation on *Dealing with radioactive decay series as compartmental models (without solving the Bateman equations)*. This was demonstrated using a freeware mathematical software, SMath which was made available to the participants as well as the source code for the solution. The solution is important in e.g. measurements of radionuclides in the natural decay series
    - Elisabeth Strålberg gave a lecture on an empirical correction method for self-absorption
    - Dr. Henrik Ramebäck gave a lecture on the combined uncertainty calculation according to GUM (Guide to the expression of Uncertainty in Measurements) and its application to gamma ray spectrometry.

Almost all of the presentations and computer codes, where applicable, were made available to the participants at a special web site (for participants only). One presentation was only distributed in paper form. The available presentations can be downloaded from the NKS website.

Various references relevant for gamma spectrometry have been compiled at a special wiki web site:
https://www.gr.is/wiki/GammaWiki/
Some of the references there were provided by lecturers at the GammaWorkshops and by participants. Presentations from the seminar are also available there as well.

Response by participants

At the end of the GammaWorkshops a survey was conducted amongst the participants and all delivered written comments.

It was appreciated that the focus was on practical issues and teaching. The selection of speakers was also appreciated. The overall opinion about both the lectures and practical sessions was very positive. Some examples of feedback:

- *"I liked that the lectures were were focused on teaching rather than on presenting results."*
- *"The speekers were very good."*
- *"I liked the practical approach."*
- *"The workshops were very useful in increasing knowledge in gamma spectrometry."*
- *"It was a very interesting and useful workshop."*
- *"It was the most useful and interesting workshop I ever attended."*

All participants are looking forward to a second GammaWorkshop in which issues not covered in the 2011 workshop could be included.

Reports from previous related activities are available from the NKS web site:

1. Elisabeth Strålberg (ed.) et al: GammaSem Proceedings - A Nordic seminar for users of gamma spectrometry - Kjeller 28-29 September 2010 – Report NKS-224
2. Paula Nunez (ed.) et al: GammaSem Proceedings - A Nordic seminar for users of gamma spectrometry - Oslo 15-16 September 2009 – Report NKS-212

A summary of these activities follows.

GammaSem 2009

During the first GammaSem seminar several key issues for follow-up were identified and working groups for addressing the identified problems were established. At the seminar it was decided that the topics for the working groups should form the basis for the seminar in 2010 where the groups should be invited to present the results of their work and ideas/solutions to the problems. This was thought to ensure that the identified key issues were not forgotten but followed up, and hopefully lead to solutions that will increase the performance of the individual laboratories. Working groups established at GammaSem 2009 included:

- Uncertainties and detections limits
- True coincidence summing corrections
- Monte Carlo simulations and efficiency transfer
- Absorption (density corrections and geometries)
- Mobile gamma spectrometry systems
- Nuclear forensics (on special samples and special parts of the spectra)

At the seminar in 2009 it was also decided that the participants of the GammaSem activity should organise web sites for posting relevant information and discussion forums. This would make it easier to contact Nordic colleagues on issues related to gamma spectrometry. At this seminar Gordon Gilmore was invited as a speaker.

GammaSem 2010

Beside presentations given by the participants, the plan was to include presentations from all six working groups to the agenda. However, only two out of six working groups gave presentations of the work accomplished during the last year:

- Working group on uncertainties and detections limits
- True coincidence summing corrections

However, as an outcome from the second GammaSem it was suggested to organise a third meeting with a focus on how to solve practical issues in quantitative gamma ray spectrometry. A list of possible issues was made which included:

- True coincidence summing corrections
- Self-absorption corrections
- In situ gamma ray spectrometry
- Combined measurement uncertainty calculation and budgeting

- Characterization of nuclear materials using gamma spectrometry (*nuclear forensics*)
- Detection limits
- Measurements of radionuclides in the natural decay series
- Databases
- Tuning of libraries

This seminar started with an invited lecture given by Lars-Erik De Geer.

Concluding remarks

There is a need for more cooperation and interaction as well as for training within the field of gamma spectrometry. This fact has been proved through the two seminars GammaSem 2009 and 2010, and now through the GammaWorkshops in 2011.

The participants to all these events agreed that the seminars and workshops have been extremely successful in providing a forum not otherwise present to practitioners in gamma ray spectrometry in the Nordic as well as in neighbouring countries (e.g. the Baltic States and even Germany). Moreover, all participants found the teaching and practical sessions very useful in learning how to deal with difficult issues relevant to gamma spectrometry. This fact is very important since a very limited number of students choose to study e.g. nuclear sciences at a university level. Instead many young people have to learn their professional skills within their employment. Events like the GammaSem and GammaWorkshops will therefore help to boost up the general knowledge regarding important issues in measurements of gamma emitting radionuclides.

Short resumes of the lectures

The following section gives short resumes of the lectures given at the workshop. The available presentations can be downloaded from the NKS website.

The lectures and various supportive material can also be found on the Gamma Wiki web:
https://www.gr.is/wiki/GammaWiki/

-Methods for characterisation of detectors and samples and efficiency transfer

Tim Vidmar

Characterisation of germanium detectors and samples are important for e.g. the calculation of measurement efficiencies in gamma spectrometry. If the composition of the sample matrix is known the linear attenuation coefficient can be calculated. Otherwise it has to be determined experimentally, (*cf. the lecture given by E. Strålberg*). The detector geometry is either given by the manufacturer, or measured by means of X-ray radiography. For low energy gamma spectrometry, the dead layer thickness becomes important. Having a sample and a detector characterised, any other geometry using the same detector can be calibrated via a computational approach: The efficiency transfer method. The advantage with this approach is that it requires only a few empirical calibrations (ultimately only one). After the introduction to the efficiency transfer method, the lecturer presented some computer codes available for the calculations. One of these codes, EFFTRAN, was available free of charge for download for the participants. This program was also demonstrated by the lecturer.

-Self-absorption corrections in gamma spectrometry: direct method-external source

Elisabeth Strålberg

Corrections for self-absorption in samples that are not consistent, from a matrix point-of-view, with the calibration source is often done with respect to density differences. However, for high-Z elements this will not give satisfactory corrections, in particular for low energy gamma rays. The lecture started with the fundamental basis of gamma ray interactions and attenuation, resulting in an equation for self-absorption correction using an external source. In this method, the observed count rate for the sample with the external source, containing a radionuclide emitting a gamma ray with a relevant energy, placed on top of the beaker is compared to the count rate observed when the external source is placed on top of the calibration source (or a sample with a matrix consistent with the matrix of the calibration source). The lecturer also presented the result from a validation of the method. It showed that self-absorption may occur well above 100 keV, which is often stated as the higher energy for which the Z-dependence of the self-absorption may be negligible. The lecturer also provided a spreadsheet model for the calculation of the correction factors using the presented method.

-Treatment of the Marinelli beaker geometry (Sima method)

Sigurður Emil Pálsson

This presentation was linked to the previous one, but focussed on a specific problem, self-absorption corrections for a Marinelli beaker. This can be dealt with by a relatively simple method by Octavian Sima, whereby the average thickness of the Marinelli beaker is calculated, this thickness can then be used in calculations assuming simple geometries. Sima's original paper was presented and a free-of-charge mathematical package (S-Math) was distributed to the participants, with an example worksheet using the same example as was in Sima's paper.

-General introduction to TCS

Menno Blaauw

The lecturer started with the essence of true coincidence summing. Often forgotten is that even single-photon emitting radionuclides may suffer from TCS, e.g. a radionuclide which decay via electron capture always emit, from the daughter, an X-ray in coincidence with the gamma ray. However, classic TCS cases are ^{60}Co and ^{88}Y, which are commonly used for empirical calibration of gamma spectrometric systems, and ^{134}Cs. Thereafter the coincidence summing based detector calibration was presented. Four different methods were mentioned of which one was presented more in detail. This method is incorporated in the GammaVision software for TCS based calibration. Finally, the lecturer gave a presentation on true peak areas and TCS for voluminous sources.

-Natural radioactivity and gamma spectrometry

Tuukka Turtiainen

This lecture gave the basis for measuring radionuclides in the natural decay series: the uranium series, the thorium series and the actinium series. In these measurements, the radionuclides of interest are often measured via their daughters. Moreover, depending on the activity ratio many gamma ray energies suffers from interferences from at least one radionuclide in the same or in a different series. For example, for a 100 times higher activity of ^{228}Th compared to ^{238}U,the 1001 keV peak of ^{234m}Pa is interfered by ^{228}Ac, and about 37% of the counts originates from ^{228}Ac. The lecturer gave recommendations of useful peaks in these measurements, and on common pitfalls in the analysis of spectra on samples containing these radionuclides. The lecturer also stressed the importance of not assuming radioactive equilibrium. For example, soil samples do not normally exhibit radioactive equilibrium for the natural decay series.

- Dealing with radioactive decay series as compartmental models (without using the Bateman equations)

Sigurður Emil Pálsson

Understanding of radioactive decay series is essential for interpretation of some gamma spectrometric results, for example when measuring many natural radionuclides. Tuukka Turtiainen gave some vivid examples of mistakes made when corrections had not been properly applied. The in-growth and decay of radionuclides in a decay series are traditionally dealt with by solving the Bateman equations. But this becomes rapidly tedious as the decay chain grows longer and more complex (e.g. due to branching). There are commercial software packages available for solving the equations and during discussions it was pointed out that one expert had made such a package free-of-charge. The presentation focused on how serial decay could be expressed as a compartmental model, simplifications that could be done and how the compartmental model could be solved with a simple numerical procedure. A free-of-charge mathematical package (S-Math) was distributed to the participants with example worksheets using the presented algorithm. The worksheets can be used to solve any problem involving serial decay, but they are mainly meant for educational purposes. For routine work, a dedicated software package is recommended.

-Uncertainty assessment according to GUM applied to gamma spectrometric measurements

Henrik Ramebäck

The lecture started with some important issues like the definition of metrological traceability and why combined uncertainty calculations are important. Since most measurements are done as a basis for decision making, no or irrelevant uncertainty estimates may result in wrong decisions. For e.g. radiological emergencies this may lead to wrong actions taken in order to mitigate consequences. However, the main part of the lecture was on the GUM process for estimation of measurement uncertainties. This process involves eight steps, from the definition of the measurand to reporting the measurement result. A tool for propagation uncertainties was also presented (the Kragten spreadsheet approach). This tool can easily be implemented in spreadsheet programs for the calculation of combined uncertainties as well as for uncertainty budgeting. At the end of the lecture an example of uncertainty propagation in gamma spectrometric measurements was given.

-Uncertainties and detection limits. A critical review of ISO 11929:2010

Kaj Heydorn

This lecture started with the concept of detection limit given by L.A. Currie in his classical Analytical Chemistry paper from 1968. Some concepts defined in different ISO/IEC Guides were presented. It was e.g. shown that in different ISO documents some of these concepts have discrepant definitions. The lecturer also presented uncertainty evaluations according to ISO documents: Type A, Type B and Poisson. Furthermore, the calculation of the detection limit according to ISO 11929:2010 was presented as well as an approach for verification of uncertainty estimates. Finally, recommendation on reporting was given.

Appendix 1 - Agenda of the NKS-B Gamma Workshops

Monday, September 26

- 10:00-11:30: Registration
- 11:30-13:00: Lunch
- 13:00-13:10: Welcome and practical information: **Matrix and absorption corrections**
- 13:10-13:30: **Methods for characterizing detectors and samples** (Tim Vidmar)
- 13:30-14:00: **External source method** (Elisabeth Strålberg)
- 14:00-14:30: **Efficiency method – general introduction** (Tim Vidmar)
- 14:30-14:45: Coffee
- 14:45-14:55: **Proof-of-principle** (Tim Vidmar)
- 14:55-15:05: **Description of a study testifying to the equivalence of the available efficiency transfer codes** (Tim Vidmar)
- 15:05-15:25: **Demonstration of the EFFTRAN code and its application to self-absorption** (Tim Vidmar)
- 15:25-15:35: **Treatment of the Marinelli beaker geometry (Sima method)** (Sigurður Emil Pálsson)
- 15:35-15:45: Coffee
- 15:45-17:00: **Practical computer work**, three exercises (Tim Vidmar), including short descriptions of the codes:
  -Density and composition correction – same geometry of sample and standard
  -Full extended-source-to-extended source transfer
  -Point source to extended source transfer
- 17:00-17:30: Discussions and questions
- 19:30: Dinner in Roskilde

Tuesday, September 27

- 09:00-09:45: **General introduction to TCS** – (Menno Blaauw)
- 10:00-10:45: **General introduction to TCS** (cont.)
- 11:00-11:45: **General introduction to TCS** (cont.)
- 11:45-12:30: Lunch
- 12:30-13:15: **Introduction to other softwares for TCS corrections** (Tim Vidmar)
- 13:30-14:15: **Parallel sessions - software specific** – Genie (Gerhard Fritz) and GammaVision (Menno Blaauw)

- 14:30-15:15: **Parallel sessions - software specific**, practical work (all lecturers)
- 15:30-17:30: End of Tuesday's workshop – summing up, and last chance for questions

Wednesday, September 28

- 09:00-10:30: **Natural radioactivity and gamma spectroscopy** (Tuukka Turtiainen)
  -Short recap: Decays series and interesting photopeaks
  -Often measured matrices, special characteristics of: Uranium, Thorium-232, Radium-226, Thorium-228, Pb-210 and Po-210
  -Exercise 1: Review of some recent articles
- 10:30-10:45: Coffee
- 10:45-12:15: **Radioactive decay series and a simple procedure for solving the Bateman equations** (Sigurður Emil Pálsson)
  -Radioactive decay series, the Bateman equations
  -Compartmental models - setting up problems involving radioactive decay series as compartmental models
  -An effective procedure for solving compartmental models (presented in SMath Studio, freeware similar to MathCad)
  -Exercise 2 (from presentation on Natural radioactivity): *Calculating decay and in-growth in environmental samples*
  12:15-12:30: Summing up of morning's workshops, questions
- 12:30-13:30: Lunch
- 13:30-16:00: **Uncertainties and detection limits** (including GUM and ISO-11929:2010) (Henrik Ramebäck)
  -Some small remarks: The GUM method: from definition of the measurand to reporting measurement results
  -The model equation in gamma spectrometry, and a tool for uncertainty propagation
  -Workshop example: Calculating combined uncertainty in gamma ray spectrometry
- 16:15:17:00: *Characteristic limits, ISO 11929* (Kaj Heydorn)

Appendix 2: List of participants

Gro Elisabeth Hjellum	Algeta ASA
Toon Meeuwsen	Canberra
Carsten Israelson	CBRN Instituttet
Bente Lauridsen	Danish Decommissioning
Jens Søgaard-Hansen	Danish Decommissioning
Thommy Ingemann Larsen	Danish Decommissioning
Anna Vesterlund	FOI
Annika Tovedal	FOI
Henrik Ramebäck	FOI
Neda Tooloutalaie	FOI
Heidi Lampén	Fortum, Loviisa Nuclear Power Plant
Laura Togneri	Fortum, Loviisa Nuclear Power Plant
Miia Pehkonen	Fortum, Loviisa Nuclear Power Plant
Stefan Isaksson	Gammadata Instrument AB
Stefan Mårtensson	Gammadata Instrument AB
Óskar Halldórsson	Geislavarnir ríkisins / IRSA
Sigurður Emil Pálsson	Geislavarnir ríkisins / IRSA
Kaj Heydorn	IBX International Consulting
Camilla Nordhei	IFE-Halden
Elisabeth Strålberg	IFE-Kjeller
Paula Nunez	IFE-Kjeller
Rajdeep Sidhu	IFE-Kjeller
Trygve Bjerk	IFE-Kjeller
Ingrid Sværen	Institute of Marine Research
Peder Kock	Lunds Universitet
Alexander Mauring	NRPA
Johannes Nilssen	NRPA
Juan Mantero Cabrera	NRPA
Thomas Bandur Aleksandersen	NRPA
Anna Nalbandyan	NRPA Tromsø
Laima Pilkyte	Radiation Protection Centre
Haijun Dang	Risø-DTU
Keliang Shi	Risø-DTU
Per Roos	Risø-DTU
Sven P. Nielsen	Risø-DTU
Violeta Hansen	Risø-DTU
Xiaolin Hou	Risø-DTU
Tim Vidmar	SCK-CEN
Asser Nyander Poulsen	SIS
Henrik Roed	SIS
Katrine Berg	SIS
Inger Östergren	SSM

Seppo Klemola	STUK
Tuukka Turtiainen	STUK
Irene Borén	Svensk Kärnbränslehantering AB
Moa Eriksson Örtengren	Svensk Kärnbränslehantering AB
Daniela Pittauerová	University of Bremen, IUP
Susanne Ulbrich	University of Bremen, IUP
Menno Blaauw	University of Delft
Kerttuli Helariutta	University of Helsinki

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