UNCERTAINTY QUANTIFICATION FOR NUCLEAR SAFEGUARDS AND NON-DESTRUCTIVE ASSAY

Point of Contact:
Stephen Croft
crofts@ornl.gov
(865) 241-2834

Project Manager:
Arden Dougan, NNSA DNN R&D
arden.dougan@nnsa.doe.gov
(202) 586-5118

Benefit

Improve Uncertainty Quantification (UQ) in nuclear safeguards

- Improve identification of trends in material balances, which will help inspectors assess the need for investigation
- Enable more cost efficient assay systems
- Reduce material unaccounted for (MUF)
- Increase consistency with the State Level Approach

Applications

Nuclear Safeguards

- Accountancy reports
- Process monitoring decision-making

Consensus best practice standards & guides

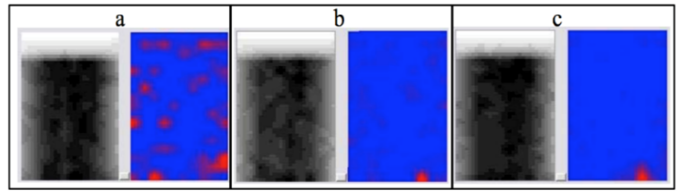
Project Description

UQ is the scientific art of generating confidence statements. Without defensible UQ physical measurements and calculations have no meaning. UQ in non-destructive assay for materials control and accountancy has been essentially dormant for the last two decades, while computing resources have increased and the formal approach to uncertainty has matured. The engrained approaches used today no longer represent good practice and often do not provide the information needed. This project showcases modern UQ methods applied to nuclear safeguards though a series of relevant case studies which can be adapted by others.

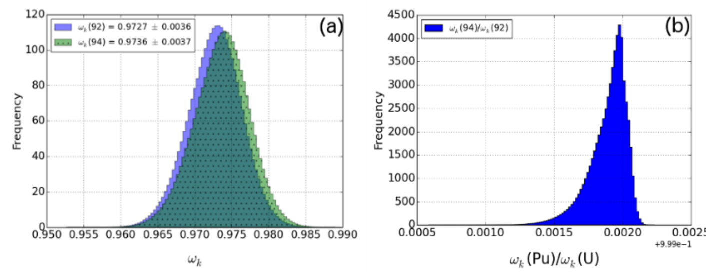
Accomplishments

The UQ team performed a series of case studies with the following results:

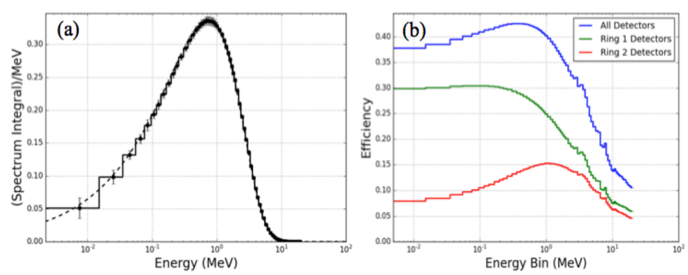
- Minimum detectable activity of a Tomographic Gamma-Ray Scanning system was determined using the Currie formalism (top figure)
- Bootstrapping method was used to generate fluorescence yield parameters and uncertainties (middle figure). For Hybrid K-Edge Densitometry (HKED) measurements, these parameters can be used to predict the concentration of plutonium and quantify uncertainty in HKED models for nuclear safeguards measurements.
- Detection efficiency was determined for a coincidence counter using covariance data (bottom figure). The use of covariance information drastically reduced the total uncertainty in the average detection efficiency.



Transmission (left) and passive (right) Tomographic Gamma-Ray Scanner images for (a) 0.24 µCi, (b) 0.48 µCi, and (c) 0.68 µCi point source strengths [1]. The transmission measurement improves detection efficiency while passive measurement detects sources. The sources with strengths above the 0.46 µCi Currie formalism predicted minimum (b and c) are easy to spot.



Fluorescence yield fit parameter histograms (a) and fluorescence yield ratio (b) to be used in Hybrid K-Edge Densitometry models. Data was developed using a Monte Carlo bootstrapping method [2]



Mannhart (1986) ^{252}Cf spontaneous energy fission spectrum and covariance matrix (a) used to determine detection efficiency (b) of the Large-Volume Active Well Coincidence Counter [3]

Anticipated Final Capabilities

- Strengthened consensus standards and guide with realistic and consistent bias and error treatments
- Workshop, publications, case study templates, and promotion of findings to give direction and provide leadership
- Improved neutron calibrations through ^{252}Cf metrology challenge (using ^{252}Cf as a calibration surrogate for Pu)
- Virtual On-Line Enrichment Monitor software used to develop an uncertainty budget
- Bayesian methods applied to neutron counting experiments to improve Pu mass inferences

Further Reading

[1] R. Venkataraman et al, *Minimum detectable activity for tomographic gamma scanning system*, WM2015 Waste Management Conference

[2] A. Nicholson et al., *K-Shell Fluorescence Yields and Their Uncertainties for Use in Hybrid K-Edge Densitometry*, DOI 10.1007/s10967-015-4543-1

[3] A. Nicholson et al., *Sensitivity Analysis of the Large-Volume Active Well Coincidence Counter to the ^{252}Cf Spectrum, 2015 INMM* Conference

Oak Ridge National Laboratory

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