# REFERENCE MATERIALS FOR NUCLEAR FORENSICS

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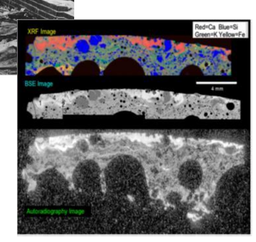
## Background

The discipline of nuclear forensics was developed because of an increasing concern nuclear or radiological material will be used in a terrorist attack. Nuclear forensics is the thorough collection, analysis and evaluation of radiological and nuclear material in pre-detonation and post-detonation scenarios resulting from a nuclear detonation. Conclusions drawn from this collected data coupled with law enforcement and intelligence information, may support nuclear attribution – the identification of those responsible for planned and actual attacks. The development of reference materials (RMs) for the improvement of traceability, accuracy, and precision of nuclear forensic measurements is currently being pursued by NIST as well as the USDOE New Brunswick Laboratory (NBL) and partner organizations (DHS DNDO NTNFC, FBI, DOD, DOE National Laboratories, and international partners), with support from DHS National Technical Nuclear Forensic Center and the FBI. Using a proper RM standard to constrain measurement accuracy and uncertainty bolsters the veracity of measurement results and provides a strong base to stand up to legal scrutiny.



## Reference Material Projects

## $^{229}$Th Isotope Dilution Mass Spectrometry Tracer Reference Material

**Purpose**
For accurate $^{230}$Th assay for $^{234}$U-$^{230}$Th age-dating.

**Project Description**
- Production of ~160 $^{229}$Th IDMS tracer units (prepared from existing NIST Stock $^{229}$Th Solution).
- Production of ~ 80 $^{232}$Th calibration units (prepared from existing NIST stock $^{232}$Th Solution).
- Primary: Certification of $^{229}$Th tracer material for assay & isotopic composition.
- Secondary: Higher accuracy determination of $^{229}$Th half-life.

**Current Efforts**
- Unit production completed (NIST).
- Samples prepared (NIST & NBL).
- Sample assay and isotopic analysis complete (LANL, LLNL, CEA).
- Preliminary data evaluation complete (NBL & NIST) (Figure 1).

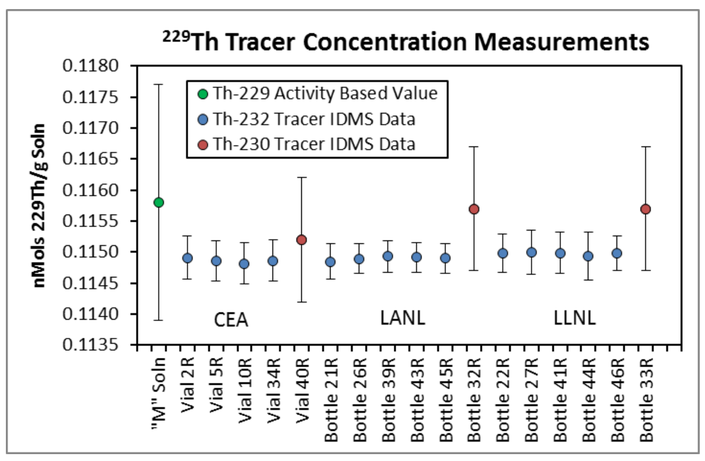



**Figure 1.** The $^{229}$Th Tracer solution concentration data from the 3 labs. It is clear that the measured concentration is consistent with the concentration determined from $^{229}$Th activity (green circle) and IDMS concentration determinations using the SRM 4342A ($^{230}$Th) solution as a tracer (red circles). A systematic bias, however, appears to exist between the assay values determined using the $^{232}$Th calibrant versus the $^{229}$Th activity determination and the $^{230}$Th calibrant. Error bars are expanded uncertainties (k=2).

**Future Efforts (Verification Analyses)**
- Verification Analysis.
  - Production of Th Metal IDMS Solutions.
  - IDMS sample Production and Analysis.
- Data evaluation and production report.
- Completion of Certification Report.

## $^{134}$Ba Isotope Dilution Mass Spectrometry Tracer Reference Material

**Purpose**
Tracer for accurate $^{137}$Ba assay for $^{137}$Cs-$^{137}$Ba age-dating.

**Project Description**
- Production of enriched $^{134}$Ba (>99 %) isotopic tracer.
- Units of tracer to be ampouled in high purity quartz.
- Certification of $^{134}$Ba tracer material for assay & isotopic composition.

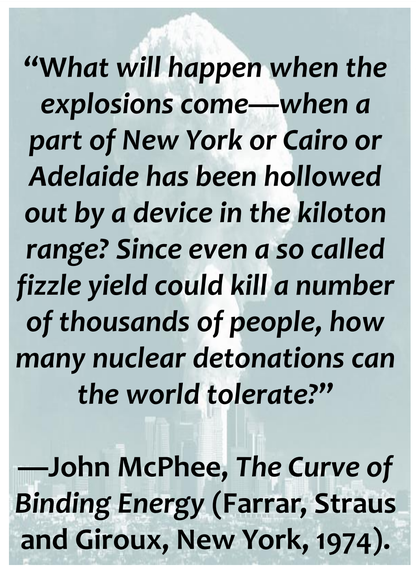
**Current Efforts**
- Completing production of $^{134}$Ba material.
- Production of tracer material sample units.
- Evaluation of test samples for isotopics complete (Table 1).

| | NIST Iso % | INL Iso% |
|---|---|---|
| $^{130}$Ba | 1.2005 | <0.05 |
| $^{132}$Ba | 0.0421 | <0.08 |
| $^{134}$Ba | 90.287 | 93.6 |
| $^{135}$Ba | 1.5527 | 1.87 |
| $^{136}$Ba | 0.2875 | 0.591 |
| $^{137}$Ba | 5.9751 | 0.625 |
| $^{138}$Ba | 0.6552 | 3.45 |

**Table 1.** The isotopic abundance results from NIST and Idaho National Laboratory (INL) for the Ba isotopes are listed. One concern with producing highly-enriched materials is natural Ba contamination, in this case contamination from natural Ba which is dominated by $^{138}$Ba. INL requested NIST assess whether natural Ba had contaminated the purified material. In this case we did not find an issue with natural contamination but we did find contamination at the $^{137}$Ba isotope.

**Future Efforts**
- Analysis of additional test samples to assess potential contamination.
- Production of purified tracer material sample units.
- Assay & isotopic characterization (true) of units.
- Data evaluation, report, CRM certificate.

## Surrogate Post-Detonation Urban Debris Standard Reference Material

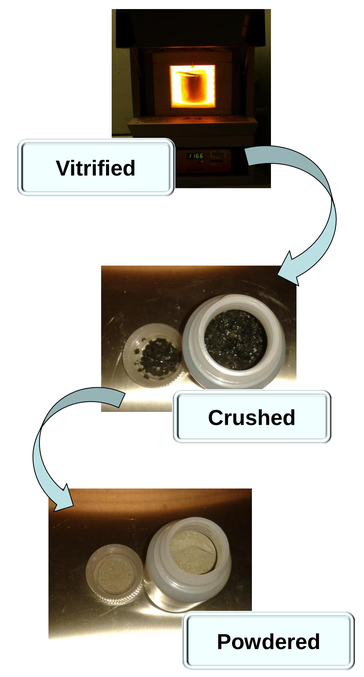


***"What will happen when the explosions come—when a part of New York or Cairo or Adelaide has been hollowed out by a device in the kiloton range? Since even a so called fizzle yield could kill a number of thousands of people, how many nuclear detonations can the world tolerate?"***

**—John McPhee, *The Curve of Binding Energy* (Farrar, Straus and Giroux, New York, 1974).**

**Purpose**
To test post-detonation nuclear forensic measurement capability by providing a surrogate post-detonation material to enable:
- method development and validation,
- testing and readiness,
- and enable labs to legally and scientifically demonstrate the efficacy, accuracy, and precision of analysis methods and establish traceability.

**What Is It?** Surrogate debris urban material with fresh fission products that mimics "rubble" of a blown up city after an Improvised Nuclear Device detonation.




- vitrified mixture of cement/concrete/steel material (CaAlFeSi) doped with HEU ($^{235}$U-22%) and major, minor & trace elements
- Particle size 150-300 microns,100 units of 25g each

**How Would It Work?**
- Known starting material (known chemical concentrations and isotope composition)
- Expose to known neutron energy & fluence (reactor)
- Predict "known" activation and fission product yields

| Certification Stages | Lab | Analysis Method | Funding Source | Status |
|---|---|---|---|---|
| Production | NPL | | FBI | Complete |
| Homogeneity Characterization | DoD, FBI, NIST | INAA, µXRF | NIST | In progress |
| Dissolution Procedures | FBI, NIST | Microwave digestion, Parr bomb | FBI, NIST | In Progress |
| Elemental/Actinide Assay, U Isotopics | NIST | INAA, HR-ICP-MS | NIST (?), Other | Scoping |
| Modelling | NIST | | NIST | Scoping |
| Certification & Release | NIST | | NIST | No Activity |

## SUMMARY

The projects highlighted here are some of the first reference materials to be developed for the field of nuclear forensics. Demonstrating the validity of nuclear forensic data is critical as this data could be an important component of the attribution process resulting in prosecution in a court of law or development of actionable intelligence. Thus, using a proper reference material to constrain measurement accuracy and uncertainty bolsters the veracity of measurement results and provides a strong base to stand up to legal scrutiny.