

Liquid scintillation counting in decommissioning studies

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What does LSC offer ?

- ❑ Highly versatile technique
- ❑ Capable of measuring beta emitting radionuclides over a large energy range
- ❑ High counting efficiencies for low energy beta emitters and alpha emitters (~100%)
- ❑ Simultaneous measurement of alpha and beta emitting radionuclides
- ❑ Can also be used for Cerenkov counting
- ❑ Capable of measuring to < 0.1 Bq/g with realistic sample sizes

Case studies

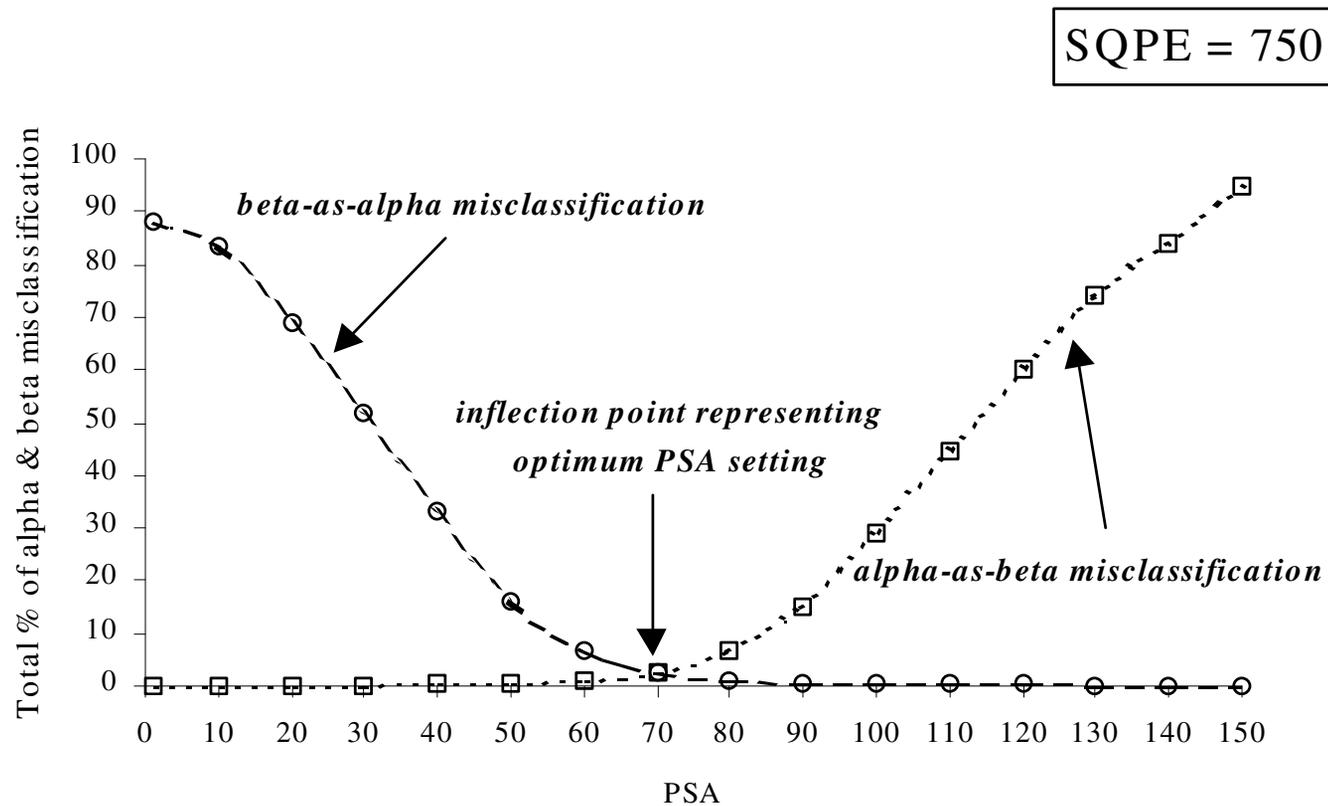
- Gross screening techniques
 - ^3H
 - ^{55}Fe
 - Cerenkov counting
-
- All measurements performed on the Quantulus liquid scintillation counter

Gross alpha / beta

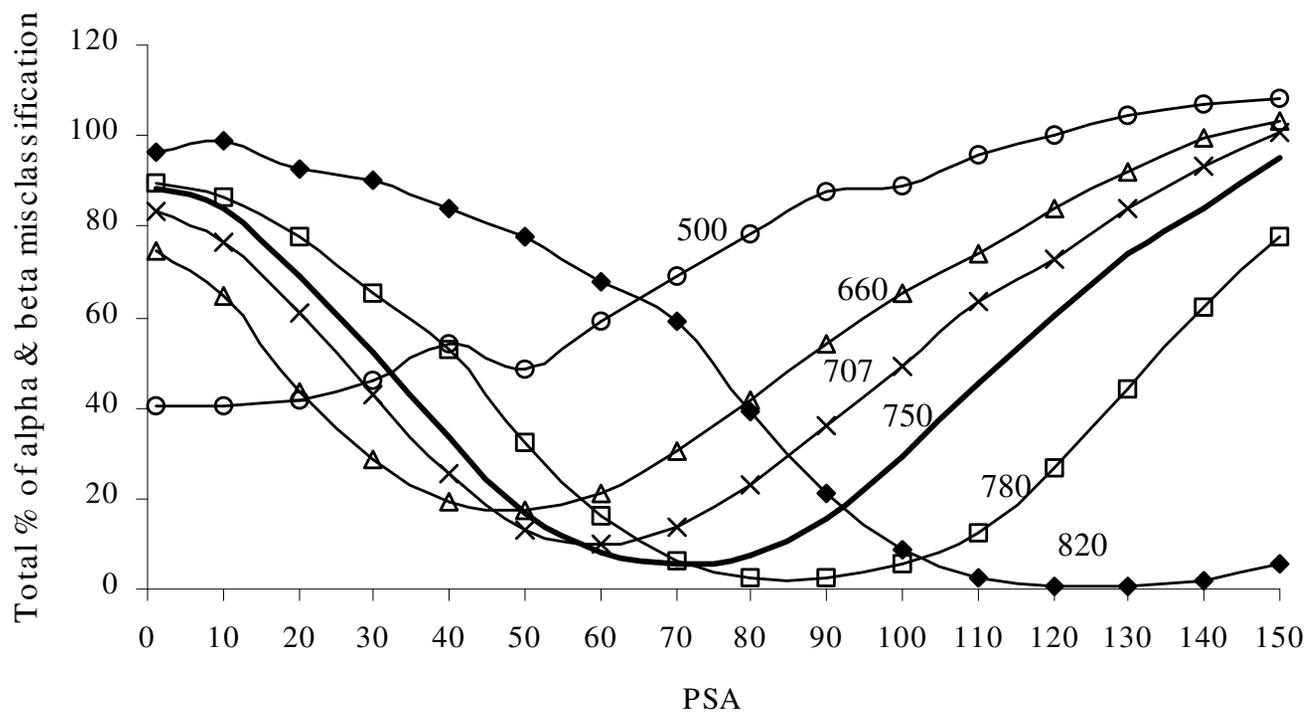
The benefits of LSC

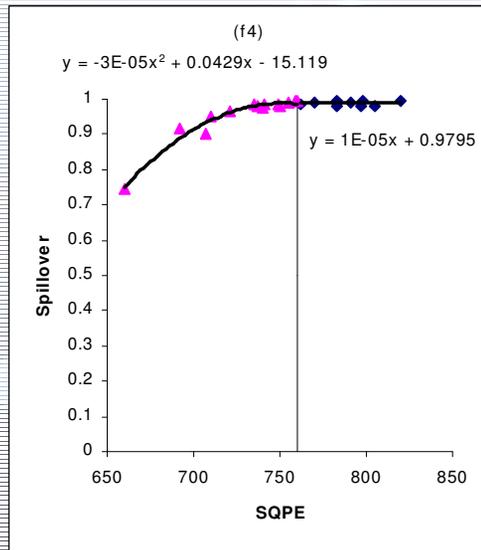
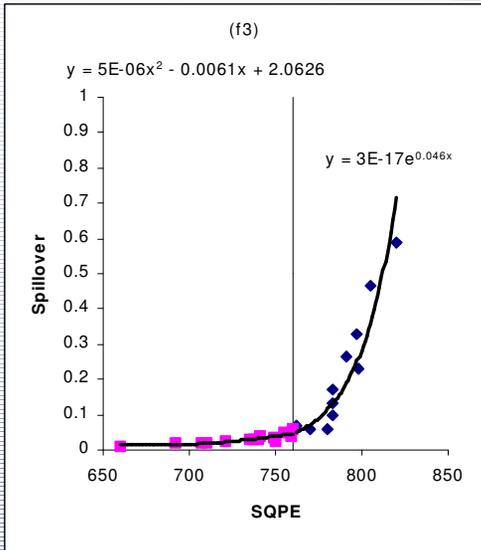
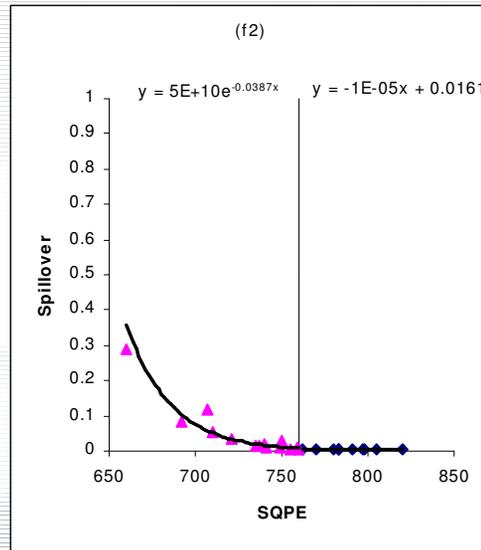
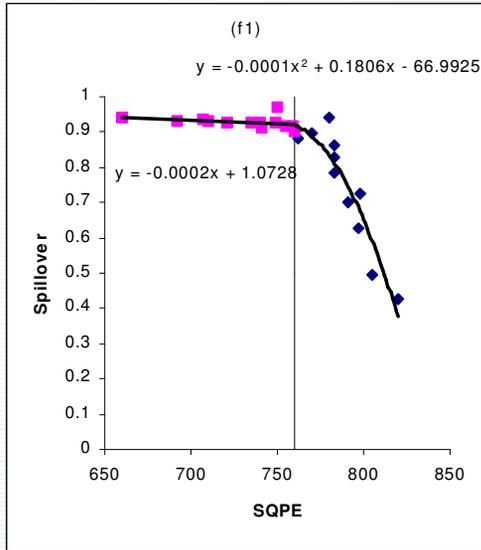
- Can detect a larger range of beta emitters with higher efficiencies
- Can provide information on low energy beta levels
- Will provide beta spectrometric information
- High alpha counting efficiencies
- Permits screening of a wide range of sample types

Alpha / beta spillover



Effect of quench on spillover





Calibration factors

$f_1 = \text{beta in beta}$

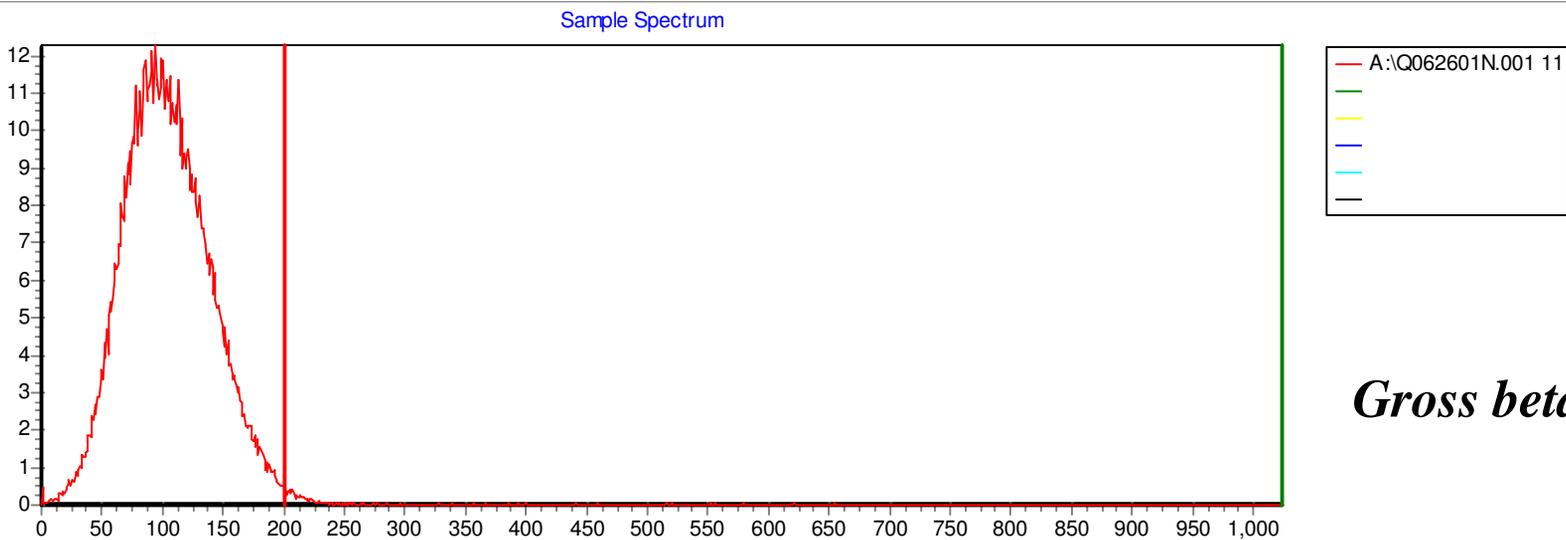
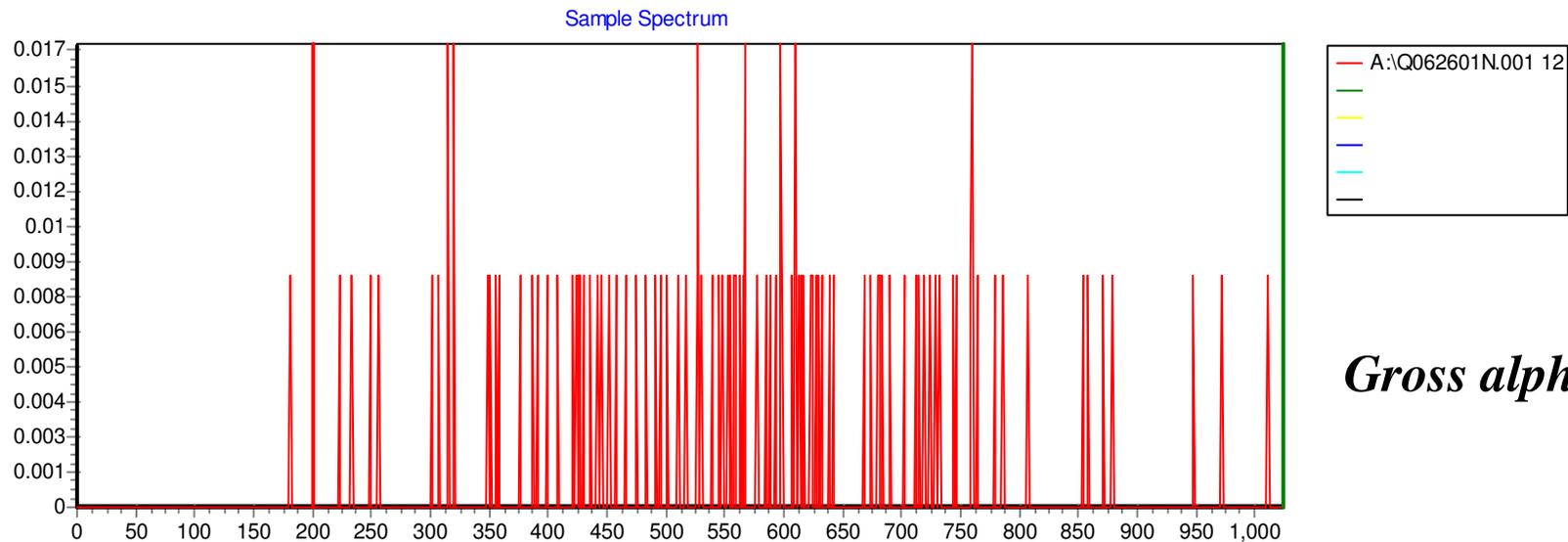
$f_2 = \text{alpha in beta}$

$f_3 = \text{beta in alpha}$

$f_4 = \text{alpha in alpha}$

PSA = 70

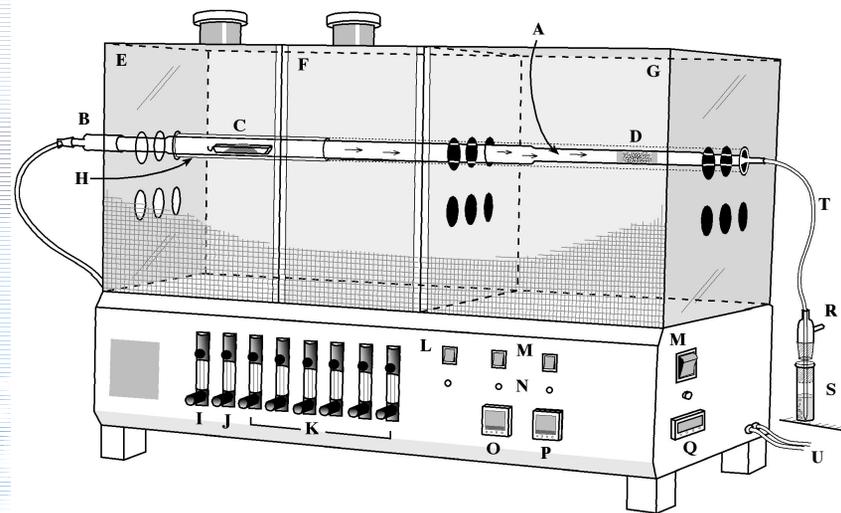
Calibrations performed
using spiked concrete
leachates



Tritium

- In liquids following distillation
- In solids following leaching or combustion

Combustion of samples



Key

- | | | |
|--------------------------------|-----------------------------------|-------------------------------------------------------|
| A. Silica glass work tube | H. Alumina tube liner | O. Sample zone furnace temperature controller |
| B. Borosilicate glass end cap | I. Primary air flow control | P. Catalyst zone furnace temperature controller |
| C. Silica glass sample boat | J. Primary oxygen flow control | Q. Mid zone furnace temperature controller (optional) |
| D. Pt-alumina catalyst | K. Flow controllers for tubes 1-6 | R. Bubbler head (borosilicate) |
| E. Sample zone furnace | L. Sample furnace cooling switch | S. Bubbler bottle (borosilicate) |
| F. Mid-zone furnace (optional) | M. Elements isolated switch | T. Silicone tube connector |
| G. Catalyst zone furnace | N. Element isolated indicators | U. Compressed air/oxygen inlet connectors |

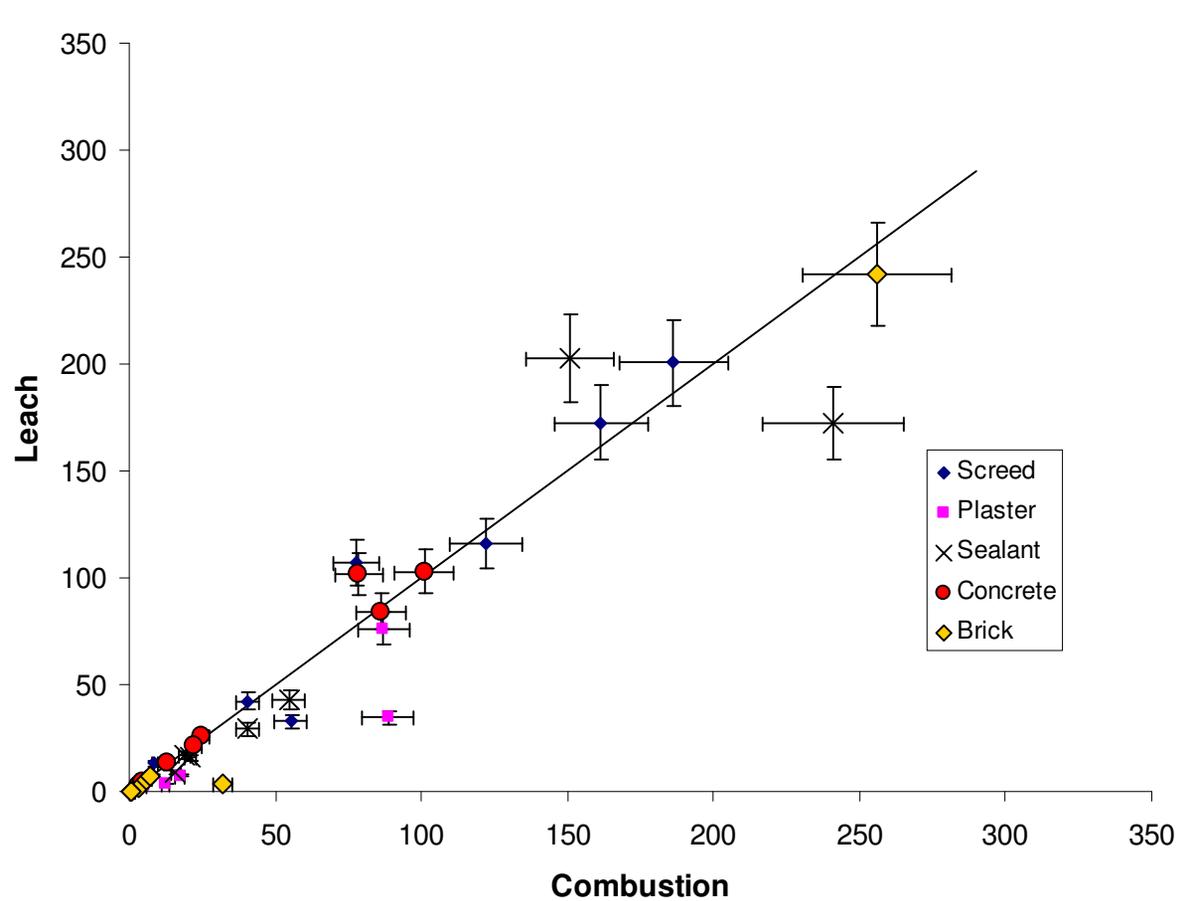


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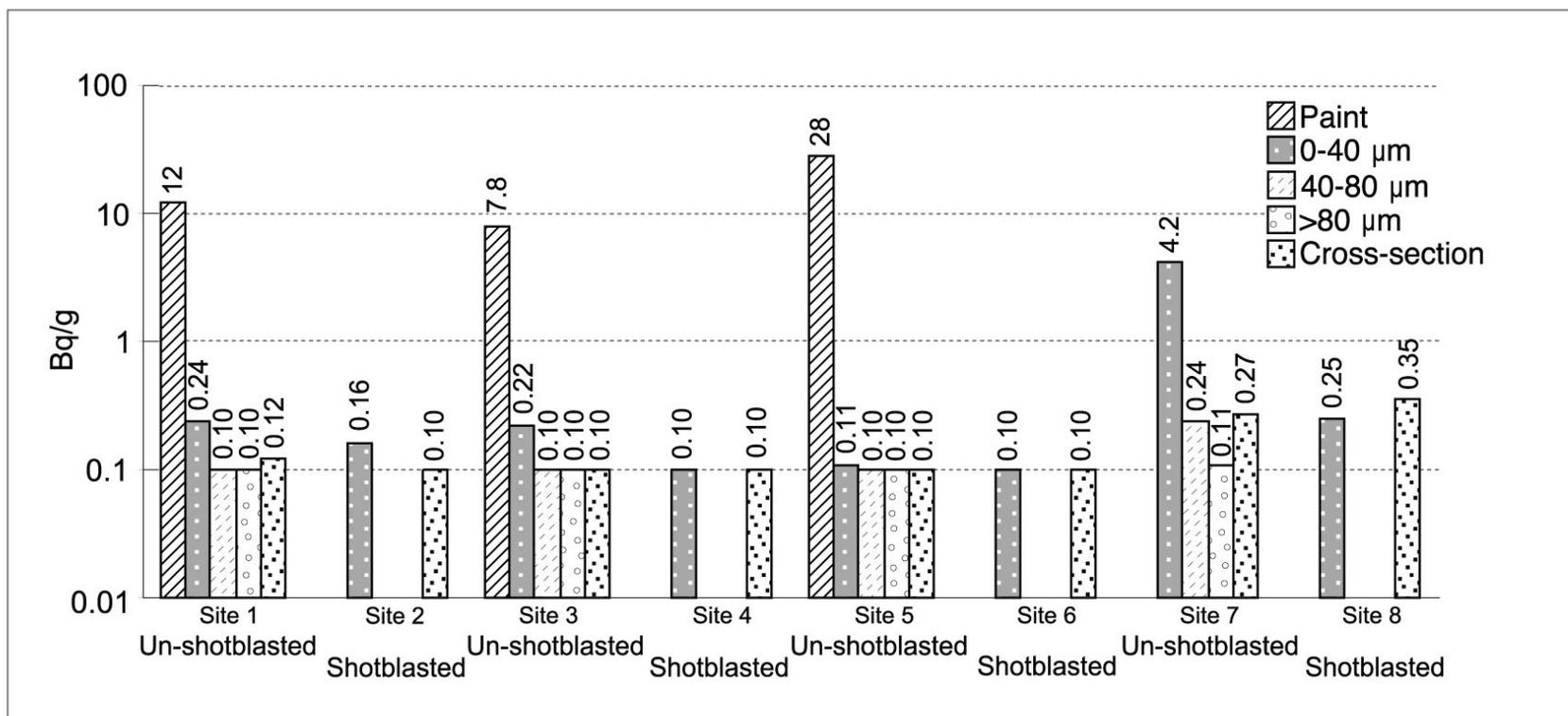


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Comparison of leaching versus combustion



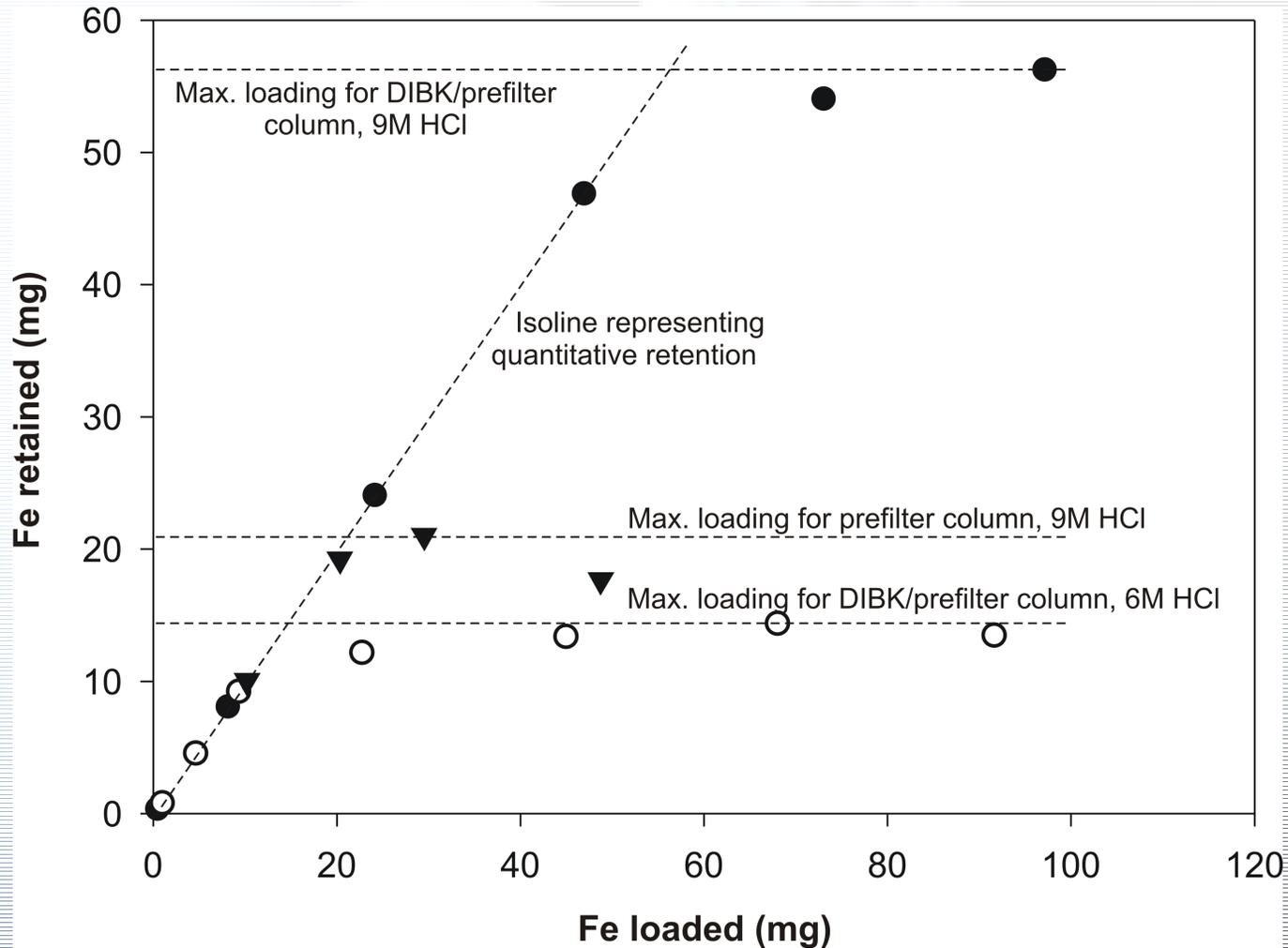
^3H in metal profiling



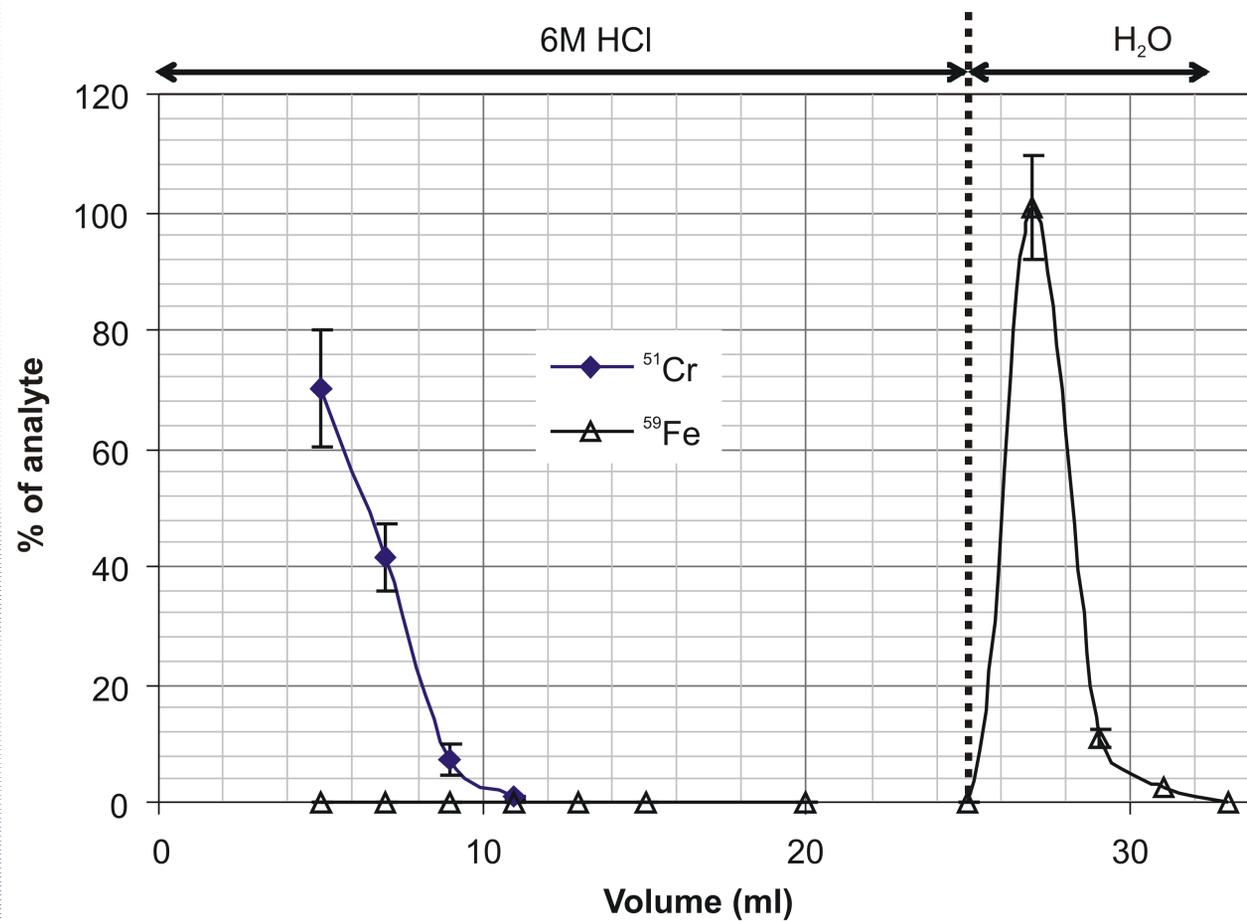
^{55}Fe & ^{59}Fe

- ❑ ^{55}Fe may be measured via its X-ray emission (5.9 keV) but the technique is not that sensitive
- ❑ Liquid scintillation counting of ^{55}Fe following radiochemical separation is more sensitive but relies heavily on effective chemical separation from other radionuclides

Chromatographic separation

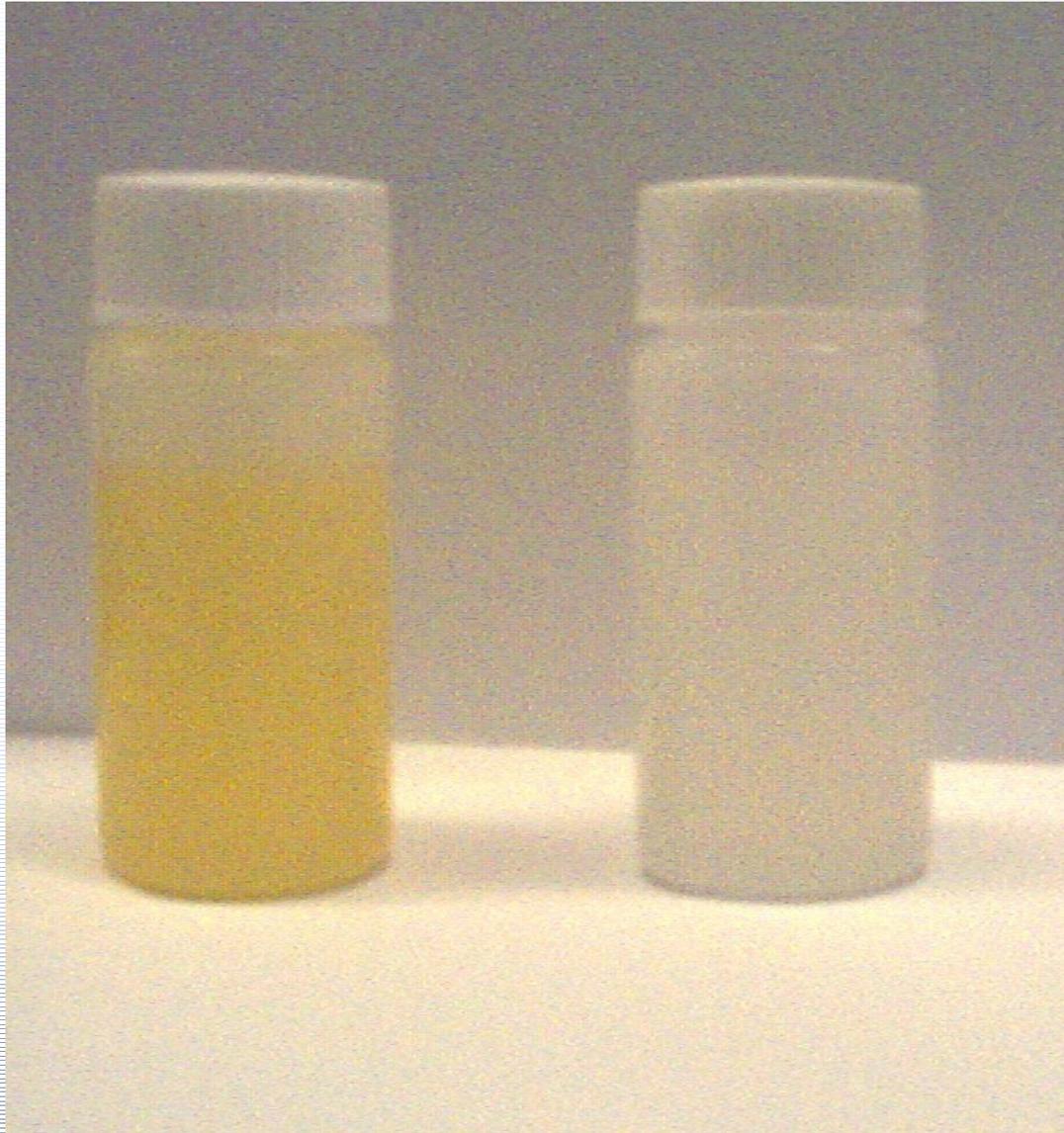


Separation from other activation products

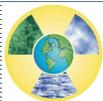


Source preparation

- ❑ Yellow of Fe leads to severe colour quench and low counting efficiencies
- ❑ Overcome by dissolving Fe in 2M H_3PO_4 to produce a colourless solution
- ❑ Ultima Gold AB used due to its high loading capacity for acidic solutions



Both vials contain
4mg Fe in scintillant

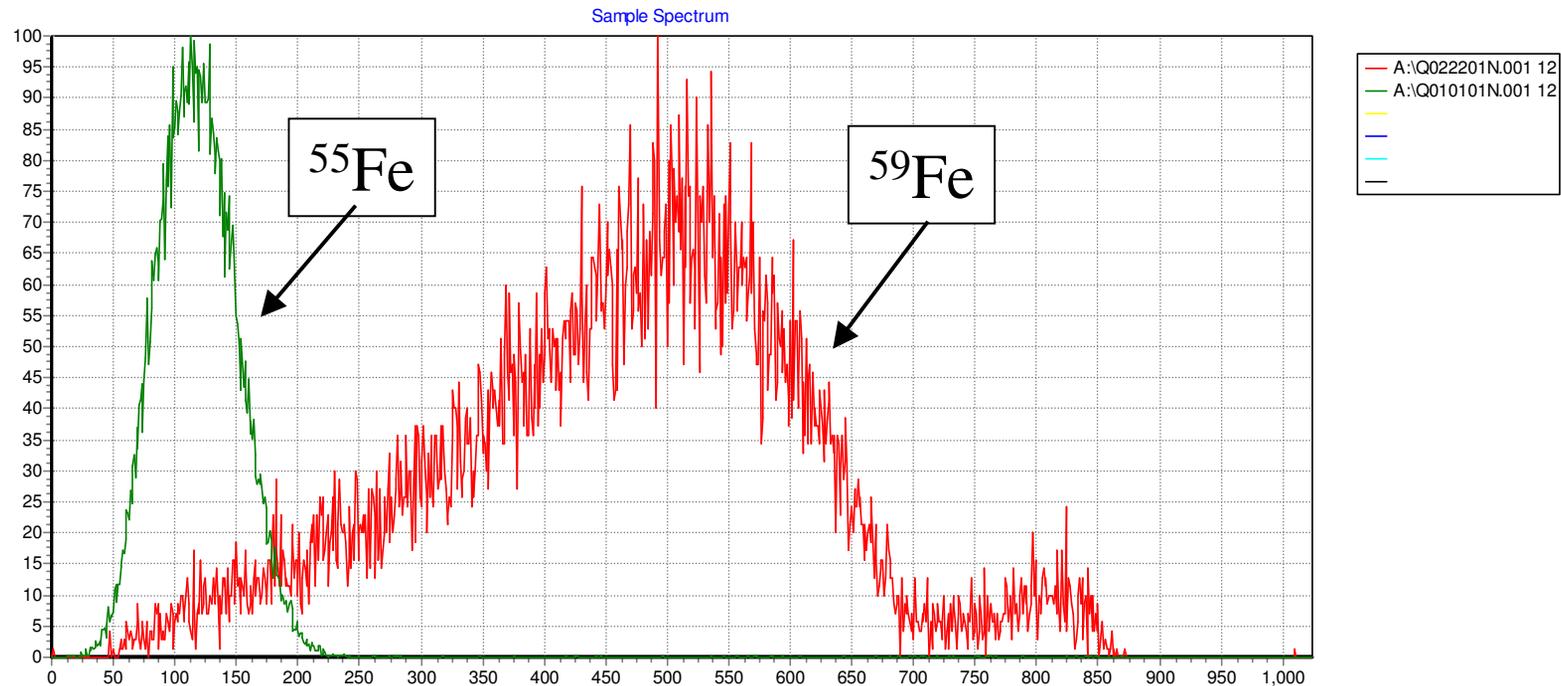


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Deconvolution of ^{55}Fe & ^{59}Fe



Cerenkov counting

- ❑ Very useful approach for measuring high energy beta emitters (> 300 keV)
- ❑ Low backgrounds
- ❑ No chemiluminescence
- ❑ No chemical quench
- ❑ Routinely used for measuring ^{90}Sr via ^{90}Y daughter
($E_{\text{max}} = 2279 \text{ keV}$)

^{89}Sr & ^{90}Sr measurement

At any given time after $^{90}\text{Sr}/^{90}\text{Y}$ separation, the activity in the Sr fraction will be

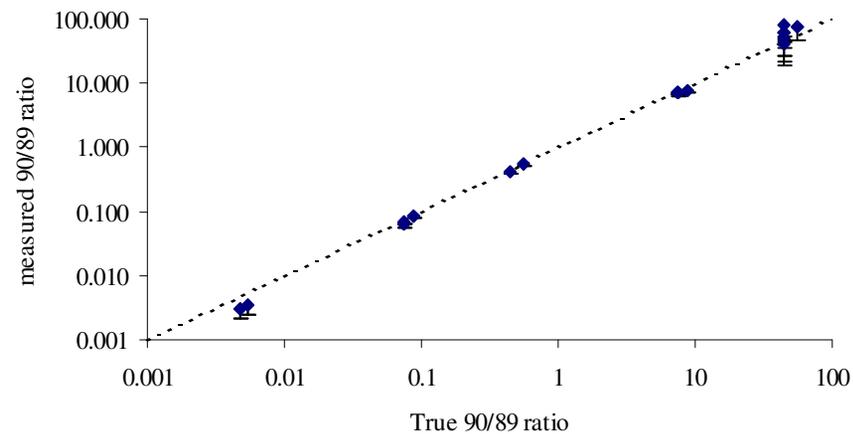
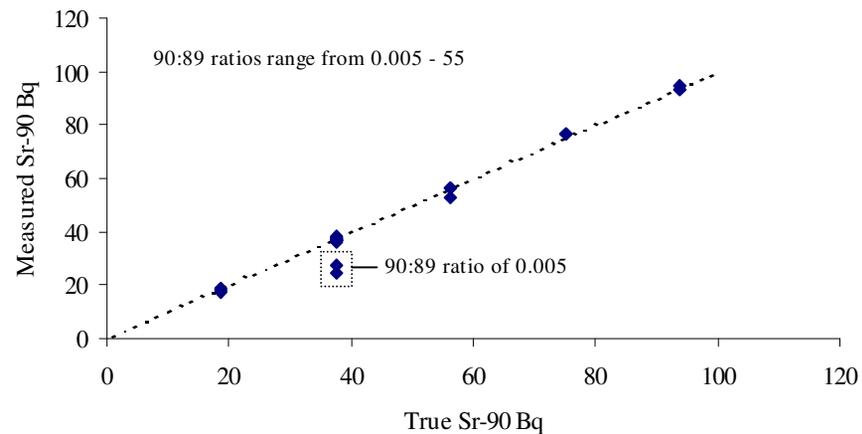
$$CPS = (A_{90} \times E_{90}) + \left[(1 - e^{-\lambda_1 t_1}) A_{90} E_Y \right] + (e^{-\lambda_2 t_1} A_{89} E_{89})$$

Which simplifies to

$$CPS = k_1 A_{90} + k_2 A_{89}$$

By measuring the sample activity twice at different times and solving a simultaneous equation, the activities of both ^{89}Sr and ^{90}Sr can be determined

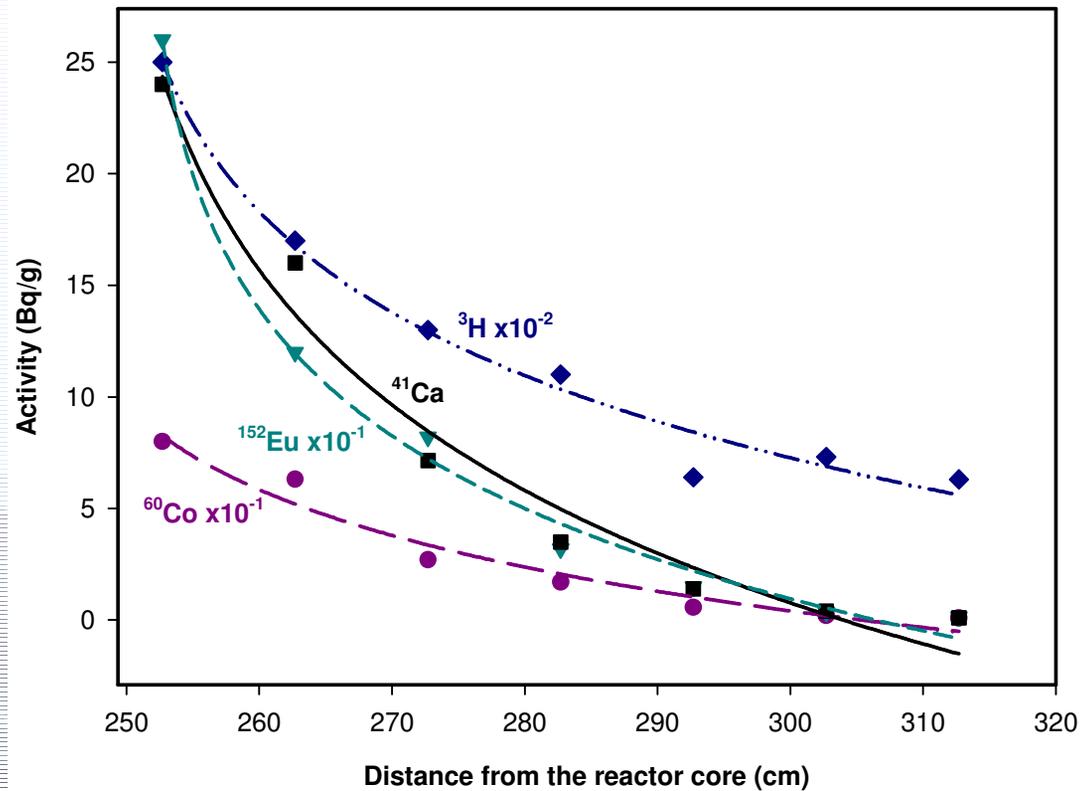
Simultaneous ^{89}Sr + ^{90}Sr



Air luminescence

- First radioanalytical application reported in 1979.
- Alpha particles travelling through air result in excitation of N_2 ultimately leading to light emission.
- Counting efficiencies of 10 – 20% reported.
- Could provide an interesting alternative for alpha measurement.

Concrete characterisation



What next ?

- Novel and rapid radioanalytical separations
- Counter calibration for unusual nuclides
- Dual label counting
- Rapid data processing