

Tritium in Concrete

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Tritium in Concrete

- The UK 'nuclear legacy' from Harwell to Sizewell B will need to be decommissioned over the next century
- Total expected cost (2005 prices) ~£50 Billion over the next century (that's ~£10 million *per week*)
- Currently, the boundary between 'free release' and low level radioactive waste is 0.4 Bq/g, summed over all anthropogenic radionuclides, irrespective of radiotoxicity
- In reactor concrete, this effectively means tritium limits the disposal route

Tritium in Concrete

Source term

- Neutron activation:



- Fission:

Fission yields 0.01 to 0.02%

- Contamination

Ingress of water from elsewhere

Tritium in Concrete

- Tritiated cement made by making commercially available cement with tritiated water
- Concrete/cement setting is complex and takes years to complete; water loss is important in this process
- Water is incorporated in two ways:
 - Within pores and channels within the concrete matrix
 - Within Calcium Silicate Hydrate ($\text{Ca}_2\text{SiO}_4 \cdot x\text{H}_2\text{O}$) gel
- Isotopic fractionation is not expected

Tritium in Concrete

- Tritiated cement prepared as a single bulk mixture and set in:
 - Closed polystyrene pots (150 cm³)
 - Open polystyrene pots (150 cm³)
 - Open aluminium pyrolyser boats (~20 cm³)
- Allowed to cure in a sealed glass tank with a water reservoir
- Activity concentration based on mass balance from mixing and any evaporation losses

Tritium in Concrete

- Mass Balance:

$W_1 =$ dry container + dry mixer

$W_2 =$ dry concrete + W_1

$W_3 =$ water + W_2

$W_4 = W_3 - W_1$ (= mass of wet concrete)

$W_5 =$ cured concrete + W_1

$W_6 = W_5 - W_1$ (= mass of cured concrete)

$W_7 = W_6 - (W_2 - W_1)$ (= mass of water in cured concrete)

$P = W_7 / (W_3 - W_2)$ (= proportion of water retained)

Tritium in Concrete

- Activity concentration in cured concrete

$A_1 =$ Bq/g of tritium in mixing water

$A_2 = A_1 \times (W_3 - W_2) / W_4$ (= Bq/g of tritium in wet concrete)

$A_3 = A_1 \times W_7 / W_4$ (= Bq/g of tritium in cured concrete)

- Cannot carry out a meaningful direct measurement
- Have to rely on mass balance data only

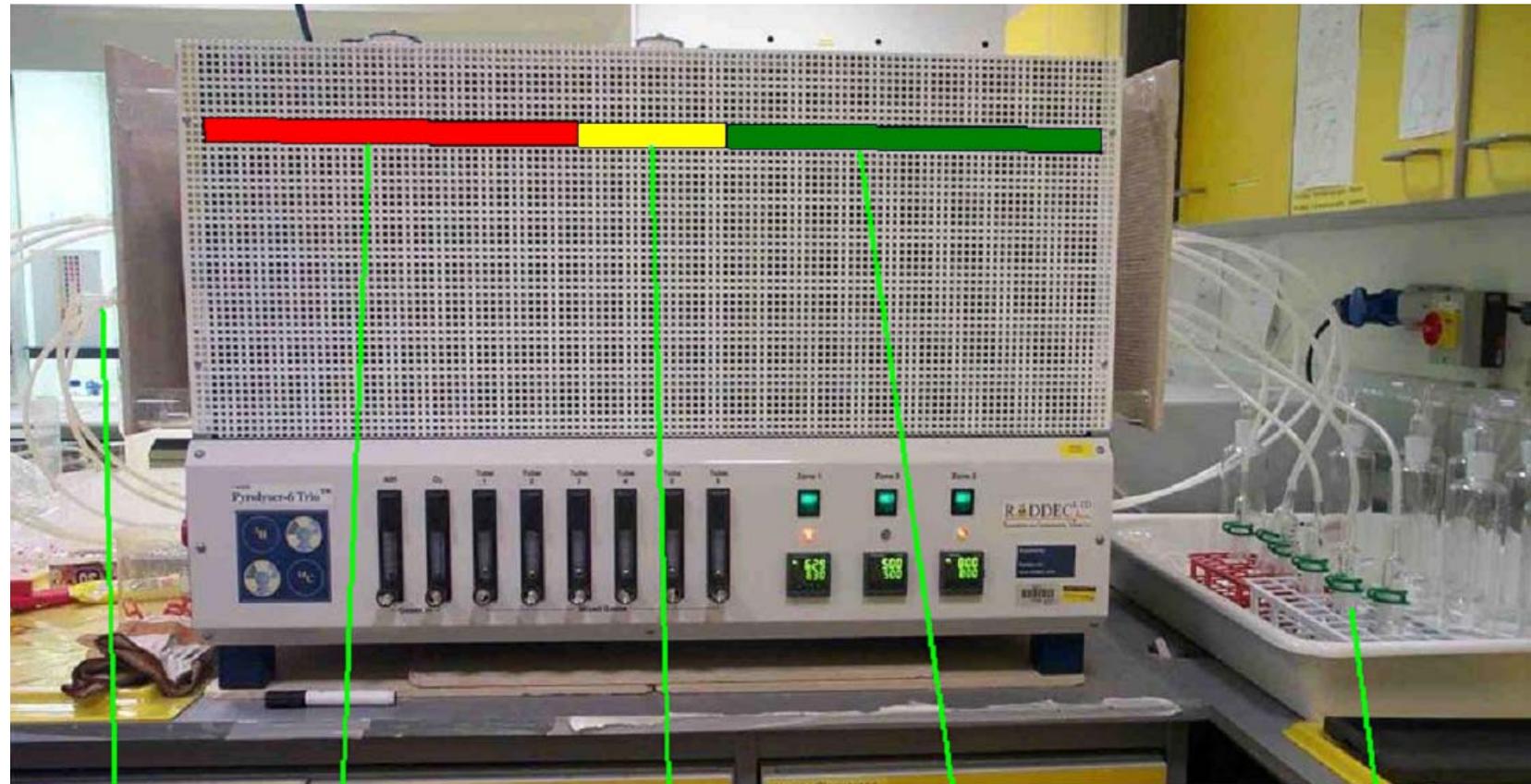
Closed polystyrene pots $1446 \pm 0.70\%$ Bq/g ($k=1$)

Open polystyrene pots $1424 \pm 0.73\%$ Bq/g ($k=1$)

Open aluminium pyrolyser boats $1363 \pm 0.91\%$ Bq/g ($k=1$)

Tritium in Concrete

- Analysed with RADDEC Pyrolysis Furnace
- Six tube furnace for volatile radionuclides



Air/Oxygen Inlet

Combustion Zone

Transfer Zone

Catalysis (Pt on Alumina)

Gas Bubblers

Tritium in Concrete

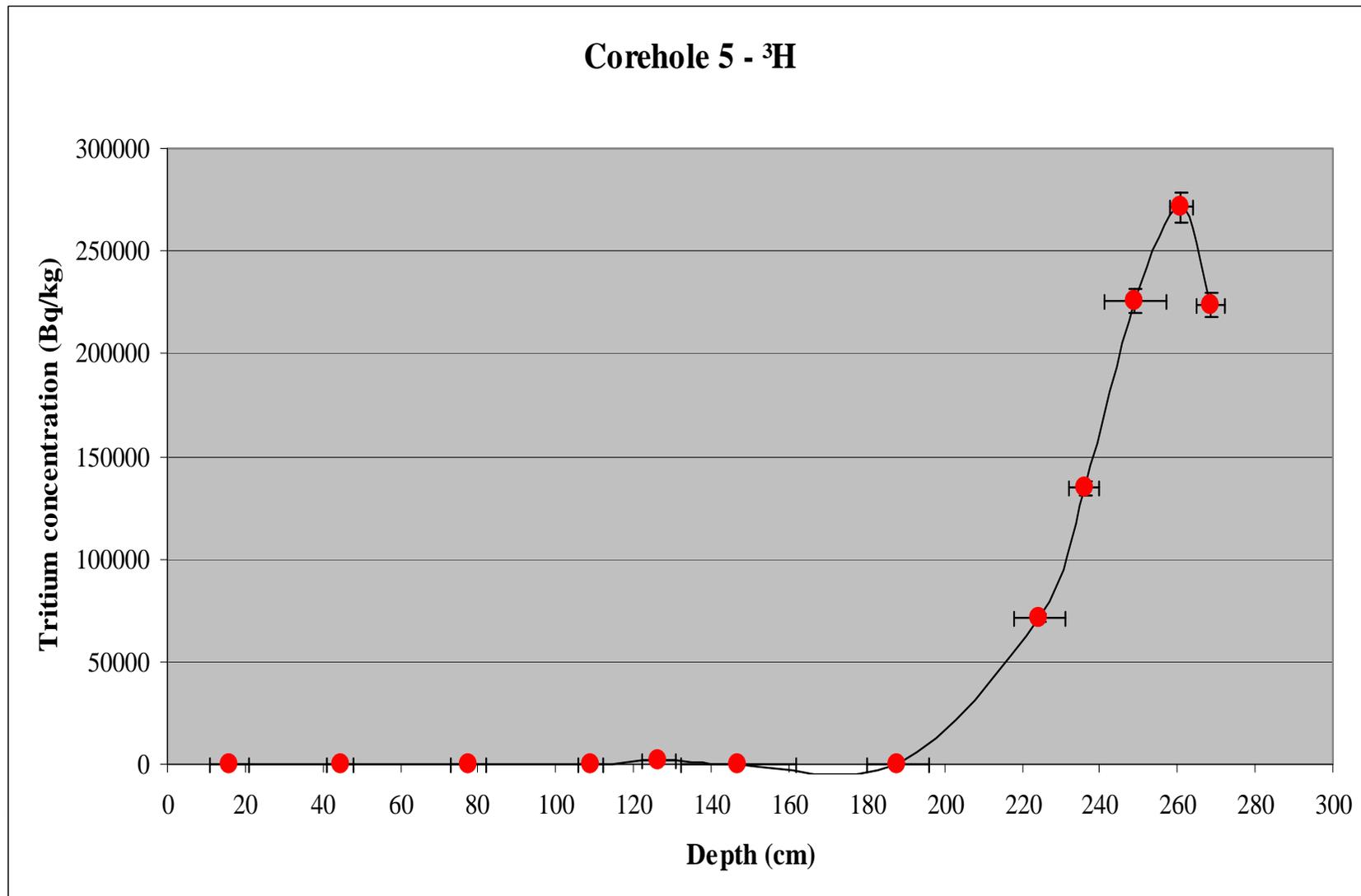
- Samples measured by loading into combustion boats
- Oxygen passed through system
- Off-gas trapped in bubblers
- Ignition by increasing temperature to 900 °C
- Maintain temperature for at least 6 hours
- Weigh and distil water in bubblers
- Mix with Ultima Gold AB
- Measure on suitable counter



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- Initial measurements with combustion at 900 °C gave good recoveries – 69.5 (± 8.5)% ($k=1$)
- Assumed (at this stage) that losses were due to poor gas flow through the system and losses from the gas bubblers
- Temperature profiled release indicated that tritium released at ~200 °C and at ?6-900 °C
- Two releases of tritium indicate that water in concrete pores released at lower temperatures but matrix bound tritium requires more aggressive treatment
- Similar observation made independently by another laboratory

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Tritium in Concrete

- All very successful, but.....
- Combustion yields dropped to very low levels
- Only operational difference was to grind the concrete prior to analysis
- Surface area increased
- Diffusion paths decreased
- May lead to rapid loss of tritium

Tritium in Concrete

- Setting reactions are slow and balance between pore and matrix water may change
- Material may not be stable, depending on the sample pre treatment
- Should it be prepared with low surface to volume ratio
- How is this to be presented to users?
- Many laboratories use crushing/grinding/sieving techniques for sample preparation

Tritium in Concrete

Conclusion

- Tritiated concrete can be prepared and the tritium activity concentration derived from experimental data
- Tritium is present as pore and crystalline water in a dynamic system
- Presenting such material as a powder limits its usefulness
- As with organically bound tritium, certification will need to cover chemical form as well as activity concentration
- Work so far has raised more questions than it has solved
- Compliance with ISO Guide 34 is not yet possible

Any questions?