Rapid screening of radionuclides using test-stick technology

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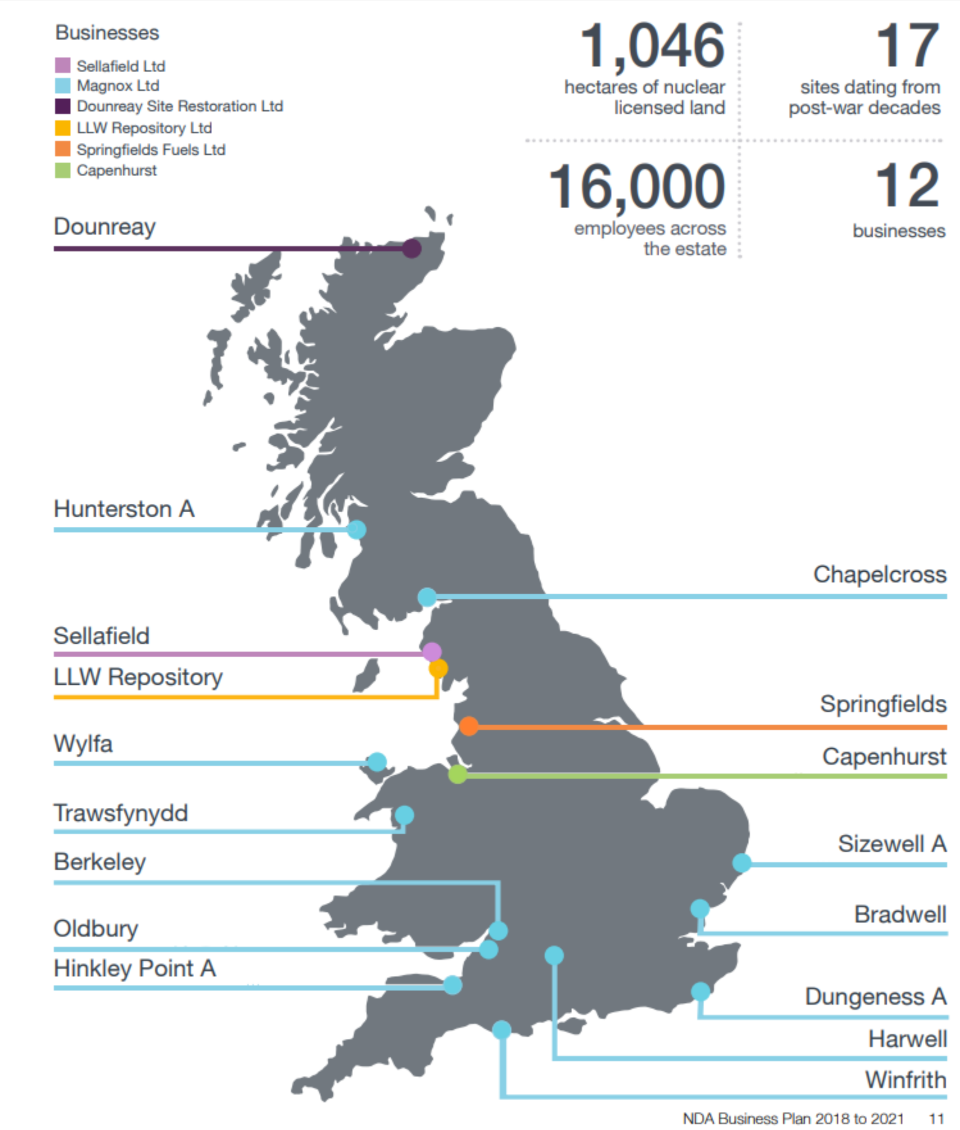
Nuclear Decommissioning Challenge

- UK undergoing large scale decommissioning process led by the Nuclear Decommissioning Authority (NDA)
- Site Licensed Companies (SLCs) have been contracted to tackle decommissioning in 17 different sites
- Legacy waste and site complexity challenges
- Radionuclides such as ^{90}Sr, ^{99}Tc and ^{137}Cs are some of the most commonly found contaminants



NDA: Call For Help

- NDA has identified and promoted the development of rapid screening techniques to streamline the decommissioning process at VLLW (Very Low Level Waste) and below.

Real time measurement with ease of data manipulation is preferred[1]

Promoting timely characterisation and segregation of waste[2]

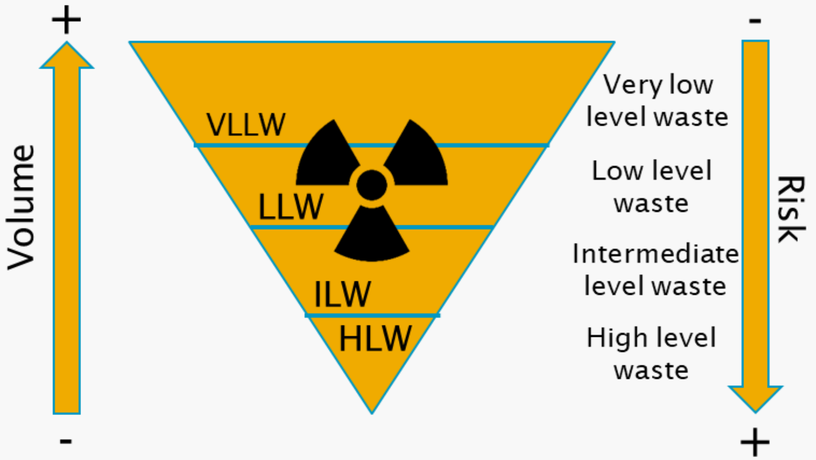
Portable versions of existing characterisation techniques and non-destructive evaluation technologies[2]

[1]Technical Memorandum, National Nuclear Laboratory, 2017
[2]NDA Technical Baseline, Nuclear Decommissioning Authority, 2016

Test-stick Technology: Reply For Help

- Test-stick technology looks to offer a rapid screening method to determine the presence of major radionuclide contaminants.

- Would be a readily deployable on-site technique and act as a first response on samples.

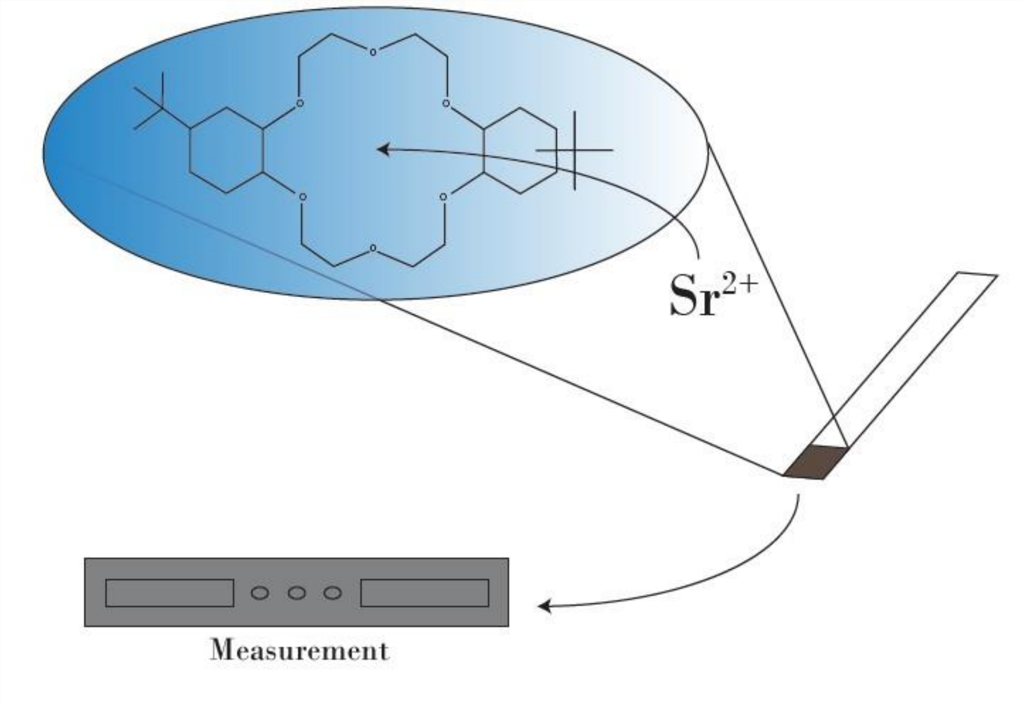


- This would support waste sentencing by distinguishing whether activity of a specific radionuclide is above or below a legislative threshold.

Test-stick Technology: Overview

- A technique designed to be utilised on-site for rapid screening of radionuclides of nuclear decommissioning importance.

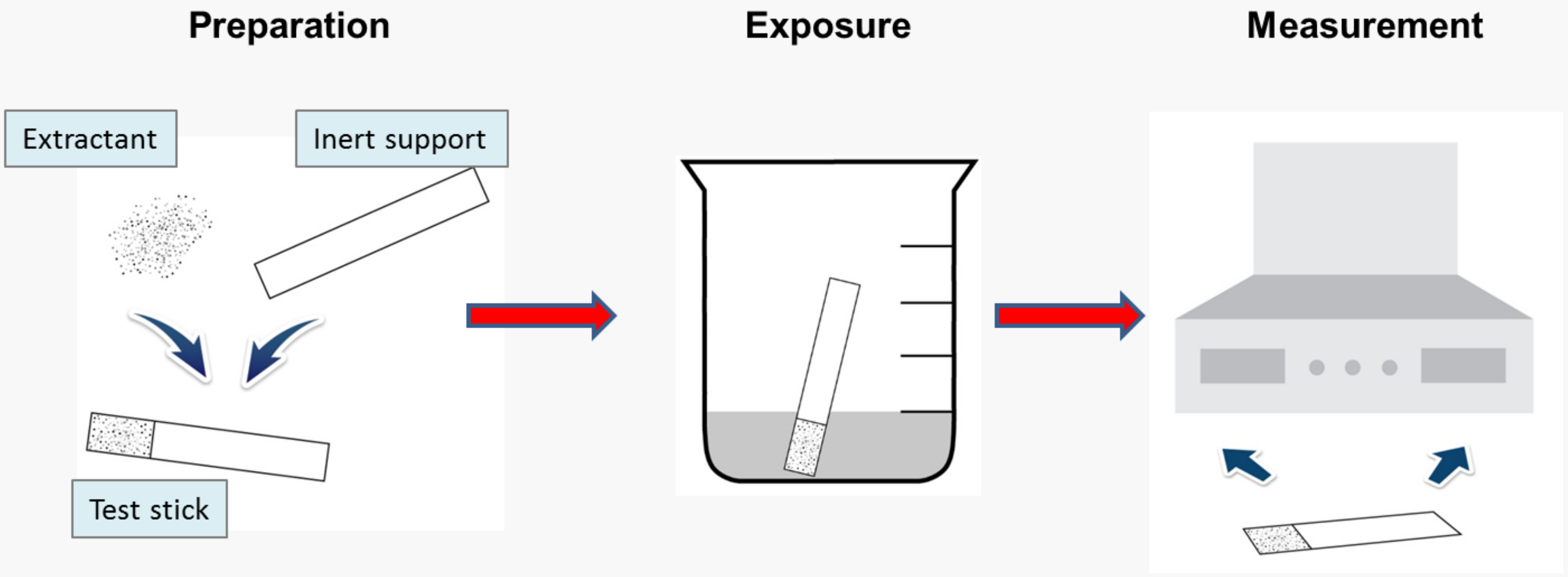
- In this case the radionuclide of interest is ^{90}Sr due to its:



- High fission yield (~5.071%)
- Being a pure β-emitter
- Bone seeker properties
- Half-life of 28.8 years

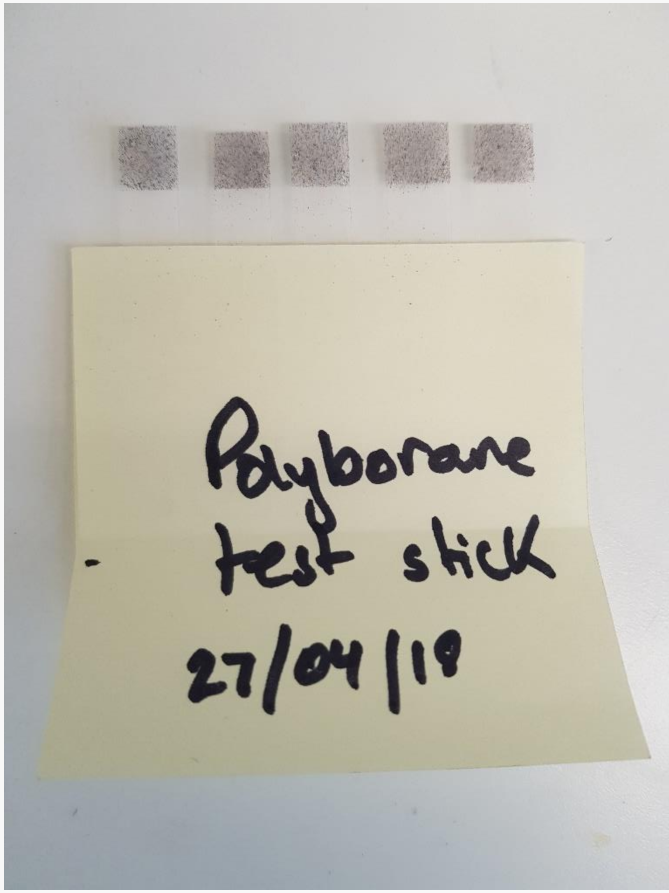
Test-stick Technology: Methodology

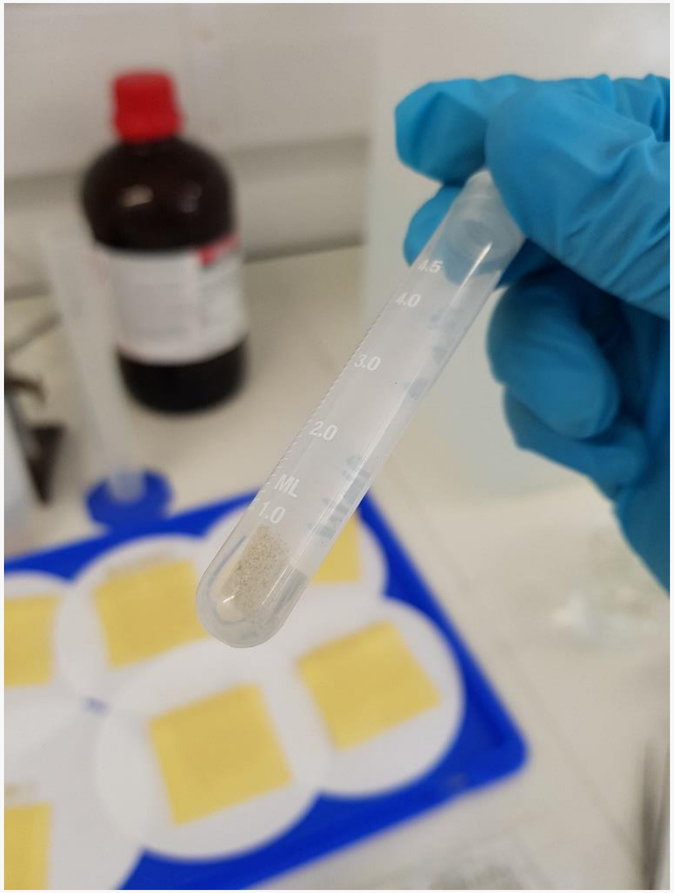
- Test-stick technology can be organised into 3 phases – preparation, sample exposure and measurement.



- The active site consisting of 1 cm^2 area at the tip of the test-stick is the focal point as this is where ^{90}Sr uptake will occur.

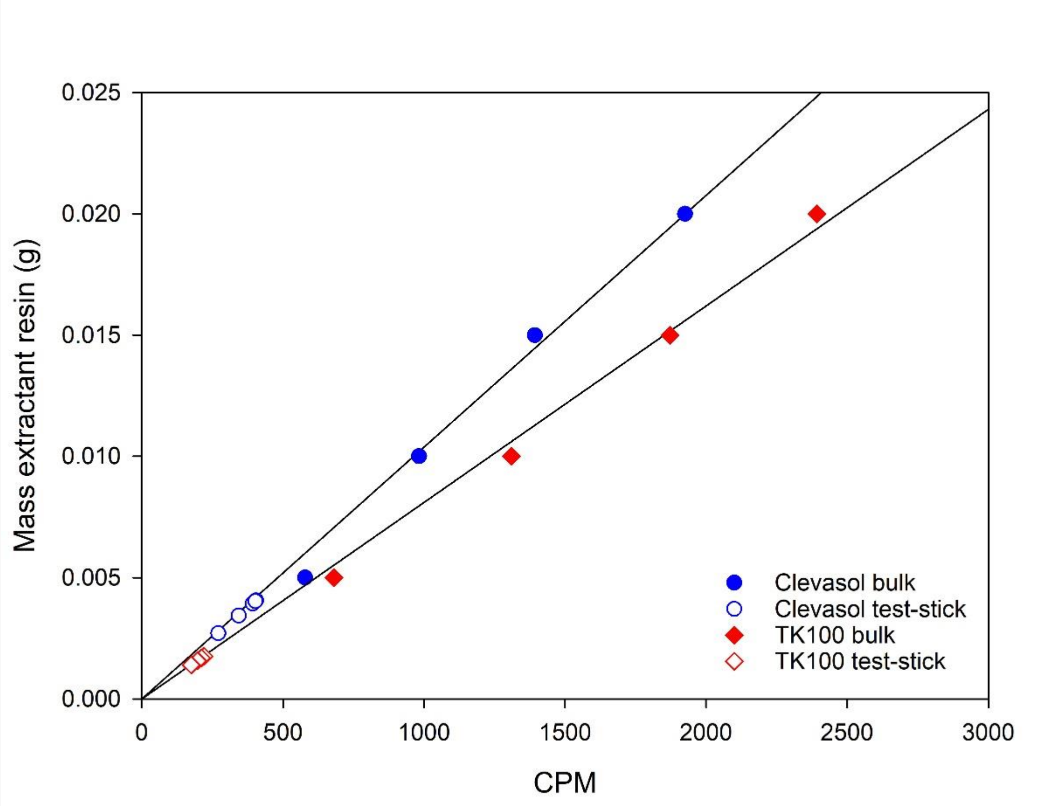
Test-stick Technology





Results: Mass Loadings

- Mass loading experiments involving tagging extractants with ^{90}Sr showed average mass loadings of:
- **3.6 ± 1.2 mg** (2σ, *n* = 5) for Clevasol™
- **1.6 ± 0.4 mg** (2σ, *n* = 4) for TK100™
- Low extractant mass loadings required.
- This information is important for future test-stick k_d calculations



Results: Proportionality Mechanism

- Effectiveness of test-stick technology is dependent on the proportionality of uptake.

$$A_{stick} \propto A_{aq}$$

- This means that with increasing activity of ^{90}Sr in the aqueous phase (groundwater), the uptake of ^{90}Sr onto the test-stick will also increase…

…proportionally, hopefully.

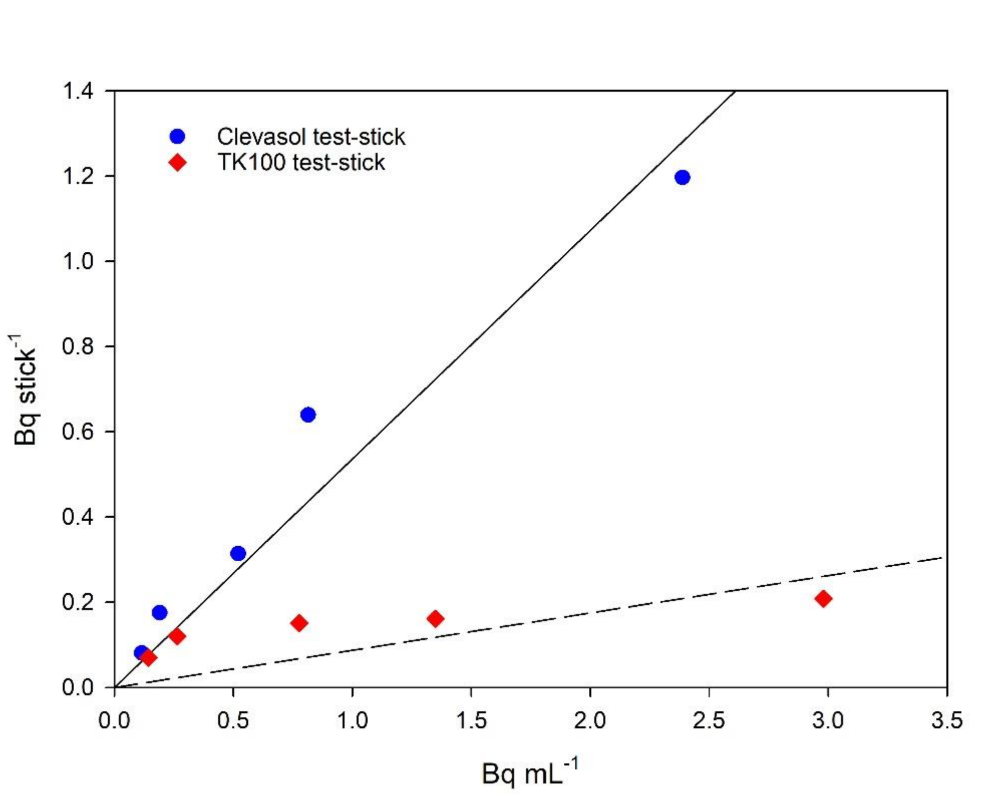
$$A_{stick} = b_t \cdot [A_{aq}]_0$$

Results: Mechanism in Practice

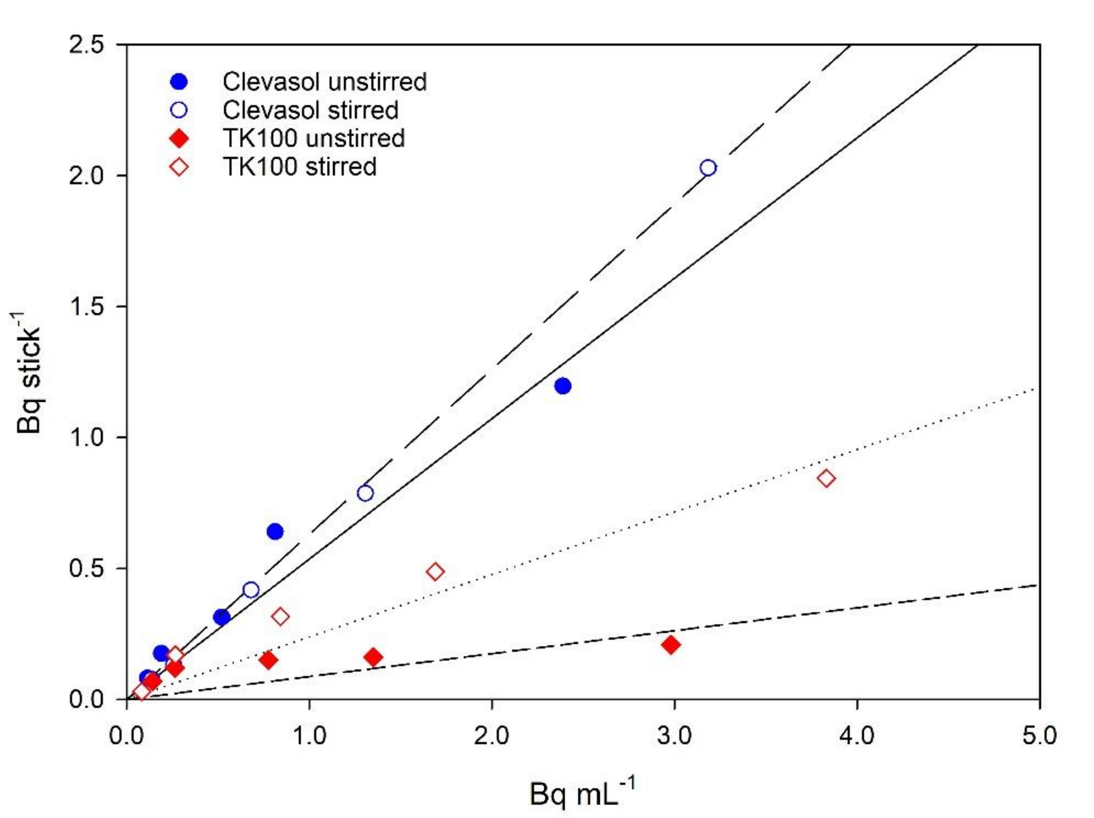
- Linearity observed for Clevasol™ test-sticks demonstrating proportional mechanism present.

- Clevasol™ test-stick $R^2 = 0.93$

- No R^2 value obtained for TK100™ test-sticks meaning no linear relationship is observed. No proportional mechanism present.

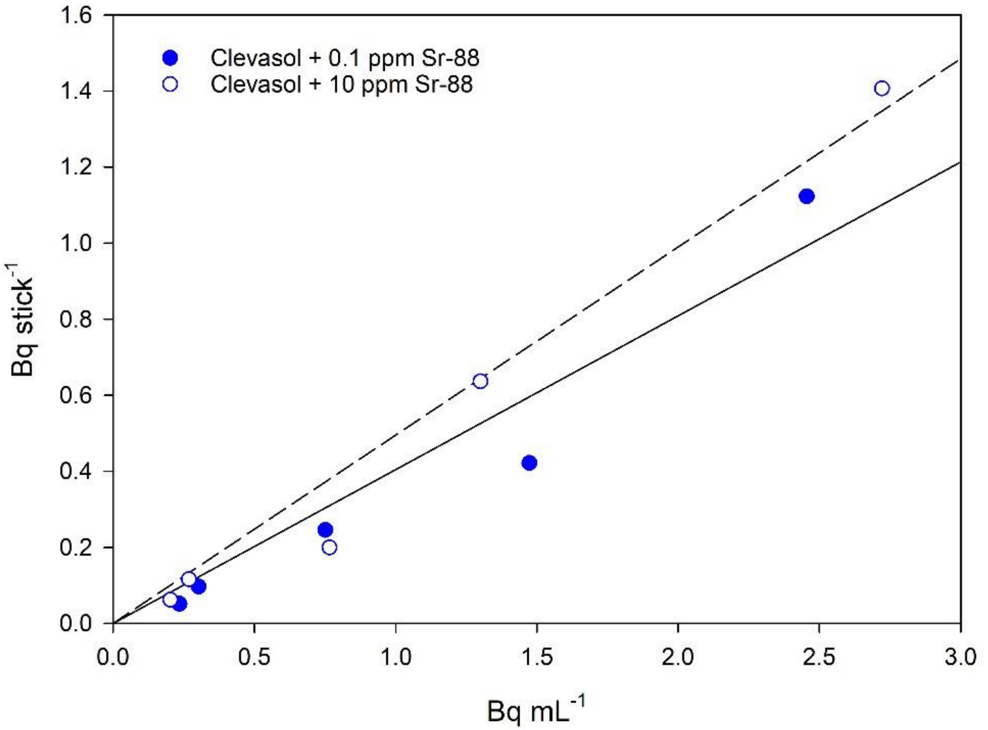


Results: Diffusion Control



- Agitating the test-sticks is found to generally improve the linearity of both Clevasol™ and TK100™ test-sticks.
- This improved linearity is reflected in improved R^2 values and b_t constants.

Results: Diffusion Control

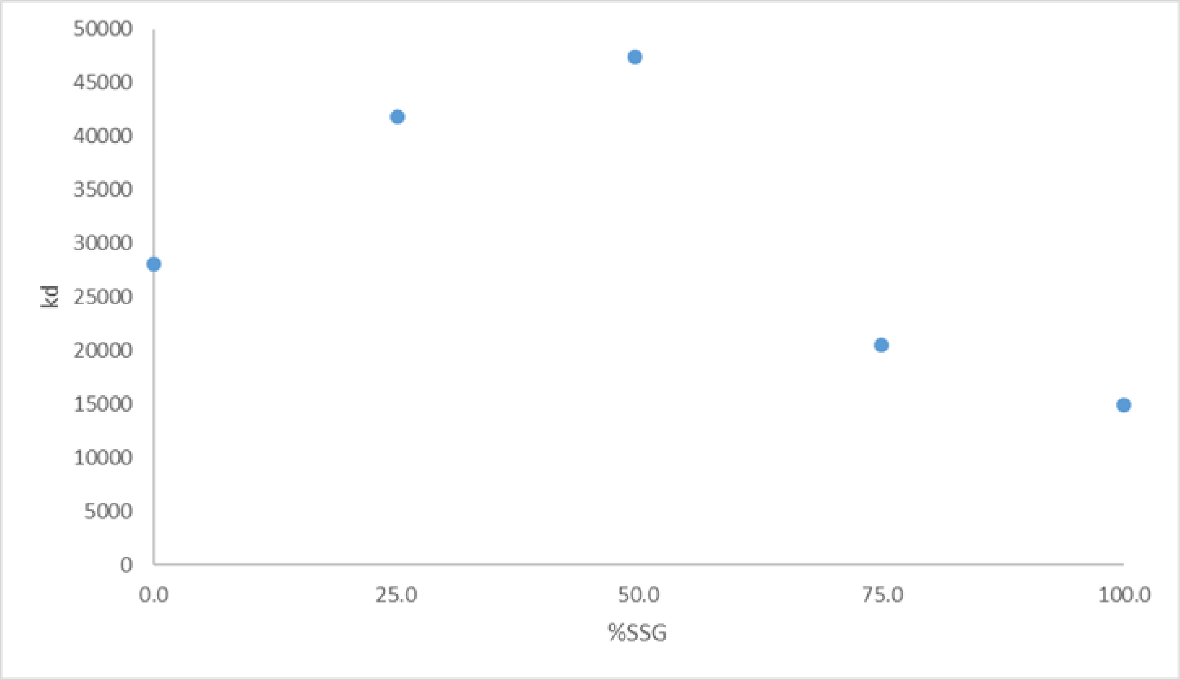


	R^2	Proportionality constant, b_t
TK100™ unstirred	N.c.	0.0875
TK100™ stirred	0.9070	0.2387
Clevasol™ unstirred	0.9324	0.5360
Clevasol™ stirred	0.9988	0.6304
Clevasol™ + 10 ppm ^{88}Sr	0.9704	0.4951
Clevasol™ + 0.1 ppm ^{88}Sr	0.9300	0.4045

N.c. = No correlation

Results: Ionic Interferences

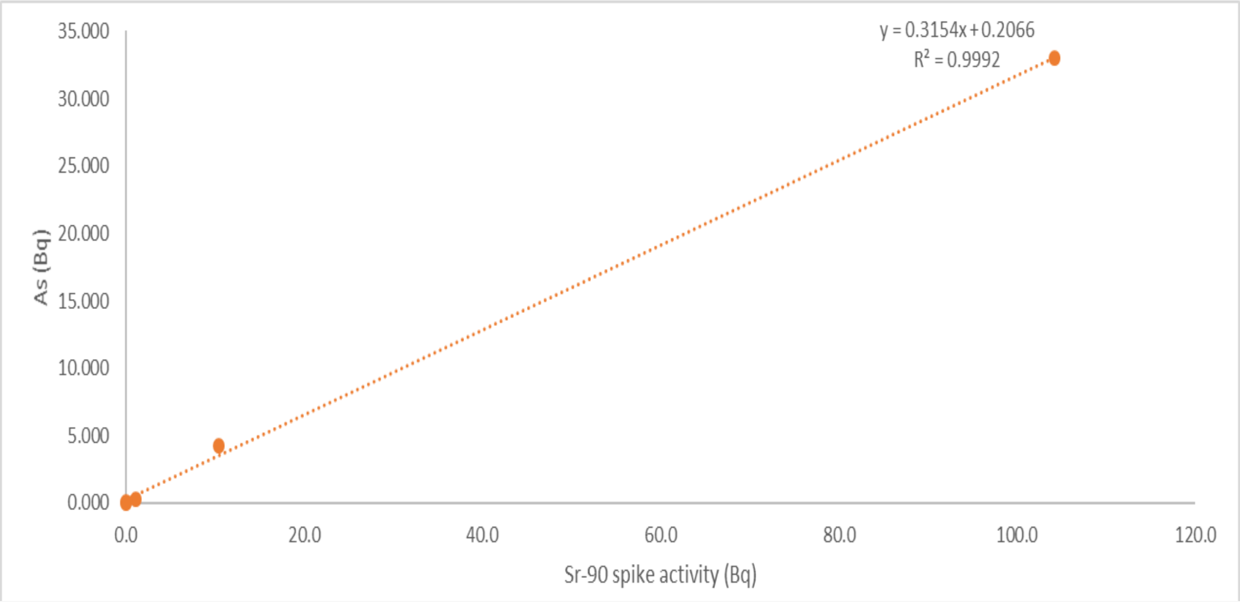
- Experimental work was carried out looking at the effect of increasing the aqueous phase with simulated Sellafield groundwater (SGS).



- Test-sticks showed increasing uptake performance with increasing SGS composition up to 50%SSG before sharply declining.

- This shows that test-sticks can withstand presence of interferences up to a specific limit.

Results: Test-stick Response



- Test-stick response control in SGS matrix was also looked into.
- SGS provided conditions including the presence of competing ions and species for the test-sticks to operate under.
- Test-stick response was maintained with variable ^{90}Sr activity; from 0 Bq to 100 Bq.

On-going Work

- Currently working on a theory model for test-sticks including accounting for, and predicting, uptake performance of test-sticks with different extractants and/or for different radionuclides.

- Use of embedded scintillator extractants to improve the detection process of test-stick technology and streamline the process further.

- Real world application of test-sticks to demonstrate the technique being applied in real world scenarios.

Conclusion

- Test-stick technology offers a rapid method of screening for specific radionuclides and determining whether activity is above or below a threshold.

- Low mass loadings required for test-sticks to function.

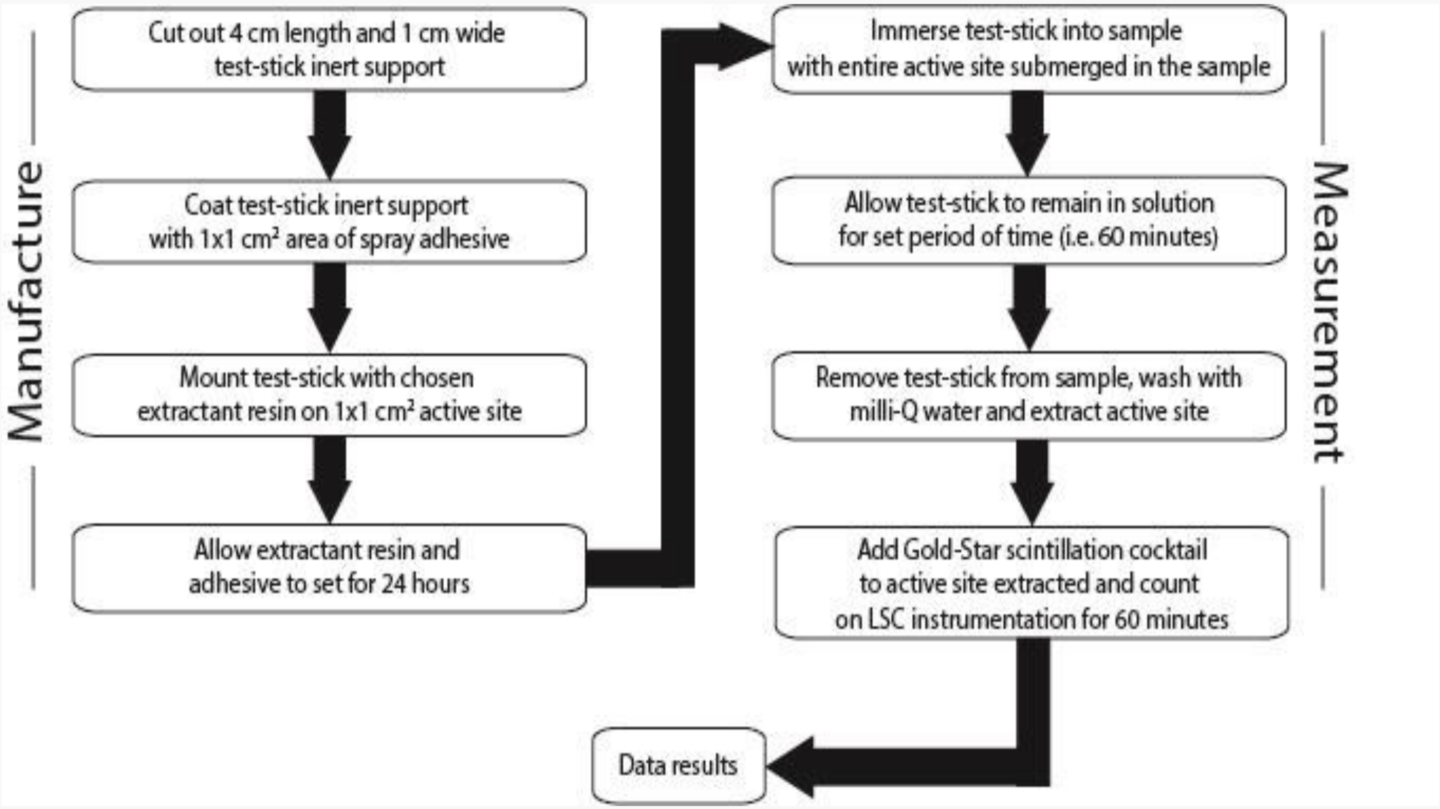
- Proportional uptake is the dominant uptake pathway for test-sticks. This was more pronounced when introducing agitation to the test-stick procedure.

- Test-sticks showed strong ^{90}Sr uptake performance even in SGS conditions.

Thank You For Listening

Any questions?

Test-stick Technology: Methodology



- Flow chart demonstrating the methodology of test-stick technology from manufacture to data acquisition.