Assessing the Bioavailability of Radionuclides in Contaminated Soils Using the Diffusive Gradients in Thin Films (DGT) Technique

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(1) DGT TECHNIQUE

DGT is an in-situ technique used to quantitatively determine the concentration and fluxes of kinetically-labile species in soils, sediments and solutions (Davison and Zhang, 2012). Small, plastic DGT devices (Figure 1A) are deployed in the soil which passively accumulate the target species from the soil solution. Numerous studies have demonstrated a significant linear relationship between the DGT measured concentration and plant uptake for a range of trace elements, implying that the technique can be used as a surrogate for trace element uptake by plants (e.g. Zhang et al., 2001).

The target species undergo molecular diffusion across the filter membrane and diffusive hydrogel layer before bring immobilised by a selective binding agent (e.g. Chelex ion-exchange resin) within the binding layer. This binding establishes a steep concentration gradient across the diffusion layer which promotes sustained diffusion of the species from the soil solution (Zhang and Davison, 1995). Only species that undergo rapid dissociation from complexes and those that are readily resupplied from the soil solid phase are accumulated by DGT.

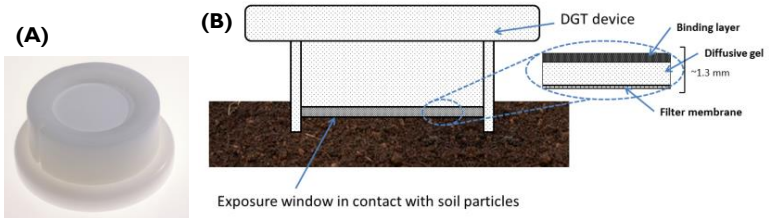


Figure 1. ***(A)*** *An individual DGT device.* ***(B)*** *Schematic cross-sectional diagram of DGT deployment in soil.*

(2) OBJECTIVES & RATIONALE

- *Can short-term (2-3 years) DGT measurements of radionuclide availability in laboratory-spiked soils be used to predict their long-term availability on a timescale relevant to nuclear waste disposal?*
- *Is DGT a reliable indicator of plant available Se, Tc and U in contaminated soils?*

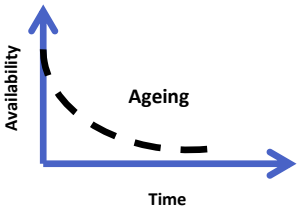
This project specifically considers the radionuclides ^{79}Se, ^{99}Tc and U isotopes. ^{79}Se and ^{99}Tc are long-lived (half-life $\geq 10^5$ years) fission products whilst U is a primordial, with all three having been identified as being of particular importance in long-term safety assessments of nuclear waste disposal.

Understanding the availability of these radionuclides is crucial in ascertaining their potential transfer from the soil and their incorporation into the biosphere as a result of plant uptake should mobilisation within the soil environment occur following disposal of nuclear waste in deep geological repositories. Once taken up by plants then there is significant potential for redistribution throughout the food chain which can ultimately lead to human consumption of contaminated agricultural produce and livestock.

(3) APPROACH

(1) 3-year controlled laboratory soil incubation

- Monitor and model the radionuclide 'ageing' process within the soil matrix.
- 20 different soils encompassing a range of pH values, textural classifications and land use types: 16 from the UK and 4 from the Chernobyl Exclusion Zone.



- A known quantity ('spike') of ^{77}Se, ^{99}Tc and ^{238}U was added to each soil, with subsequent DGT deployments made at progressively-increasing time intervals to assess the availability of each radionuclide for uptake over the course of the incubation period.

Figure 2. *Ageing curve to illustrate the expected decrease in availability over time as the radionuclides are progressively incorporated into less-exchangeable soil fractions.*

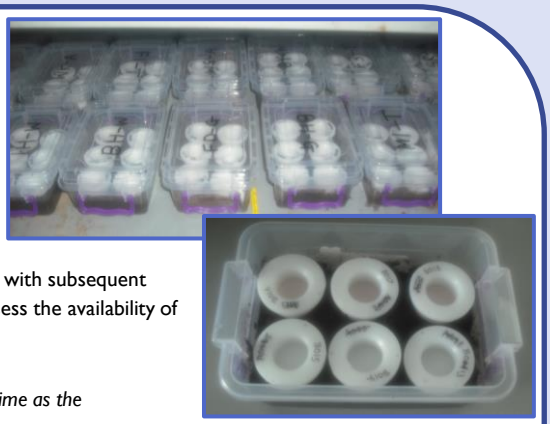


Figure 3. *DGT deployments in incubated soils.*

(2) Plant uptake experiments

- Plants grown in spiked soils in conjunction with simultaneous DGT deployments in the same spiked soil to enable comparison between the radionuclide concentrations accumulated by both DGT and plants.

(3) Verify 'ageing' models

- DGT deployments will be made in 'aged' soils which have received inputs of radionuclides from several years ago in order to test/complement models parameterised from laboratory incubations. E.g. lysimeter soils from Public Health England and potentially soils from the Chernobyl Exclusion Zone.

(4) REFERENCES

DAVISON, W. & ZHANG, H. 2012. *Environmental Chemistry,* 9(1), 1-13.

ZHANG, H. & DAVISON, W. 1995. *Analytical Chemistry,* 67(19), 3391-3400.

ZHANG, H., ZHAO, F., SUN, B., DAVISON, W. & MCGRATH, S. 2001. *Environmental Science & Technology,* 35(12), 2602-2607.