A proof-of-concept CdTe detector for in-situ measurement of strontium-90 in groundwater

G. Turkington[1,*], K. A. A. Gamage[1], J. Graham[2]

[1]School of Engineering, University of Glasgow, G12 8QQ, UK

[2]National Nuclear Laboratory, Sellafield, CA20 1PG, UK

*corresponding author contact: g.turkington.1@research.gla.ac.uk

Background

- Strontium-90, one of the primary beta emitting radionuclides produced during nuclear fission, has contaminated groundwater at nuclear decommissioning sites after leaks and spills of nuclear waste [1].

- The baseline method for monitoring ^{90}Sr in groundwater is by sampling of boreholes installed in the groundwater table and submission of the samples for laboratory analysis.

- This approach generates high-quality results, but is expensive, time consuming, produces chemical wastes and may expose both samplers and analysts to elevated levels of radiation.

- By taking a direct approach to detection, through deploying a mobile detector directly into groundwater, sample collection and treatment can be eliminated, thereby reducing chemical waste, labour, and time requirements.

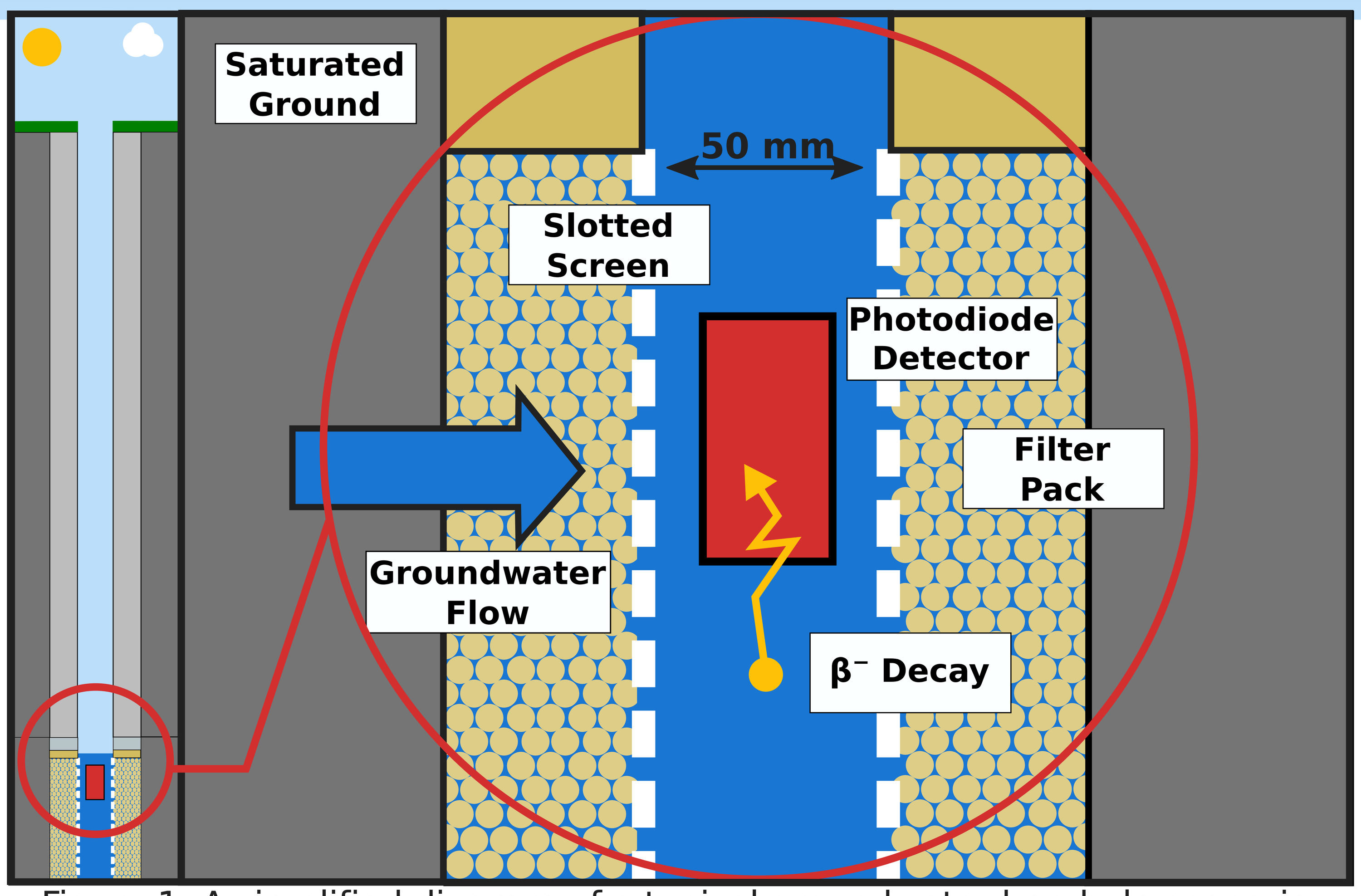

Figure 1: A simplified diagram of a typical groundwater borehole scenario, and the prospective deployment of an in situ semiconductor detector.

Detector Testing

- A 10 x 10 x 1 mm CdTe detector was mounted with a charge sensitive preamplifier, shaping amplifier and compact 85 V digital power supply unit. This sensor was housed in a 120 x 89 x 38 mm plastic box, wrapped in two layers of low density polyethylene

- The detector was tested in two scenarios, one where the temperature of the water had an average value of 14.3 °C and in another scenario where the temperature was 4.1 °C on average. Figure 5 plots the internal temperature of the detector over time in each scenario. In the warmer water condition, the internal temperature of the detector was less stable, and was raised by 2.1 °C over the duration of the 120 minute period. Heat is generated inside the detector by the electronic components with the primary source of heat being the 80 V power supply used to bias the CdTe sensor.

- The counts incident on the detector were recorded in both tap water and synthetic ground water scenarios. In each scenario the temperature of the water was maintained at 14.4 °C. The average number of counts in the tap water scenario was 7.127 x 10^5 +/- 844 and in the synthetic groundwater scenario was 7.129 x 10^5 +/- 844 showing no significant difference in results.

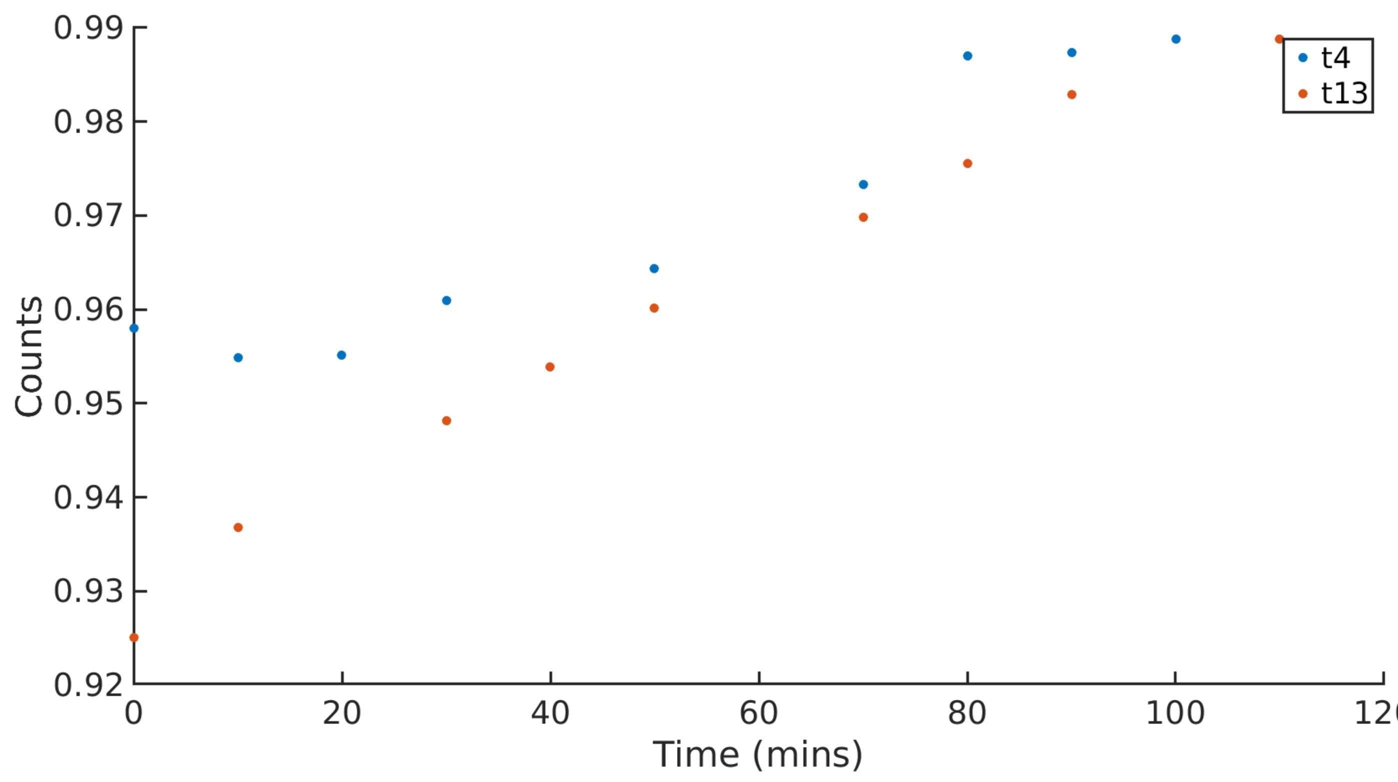

Figure 4: The internal temperature of the detector over time..

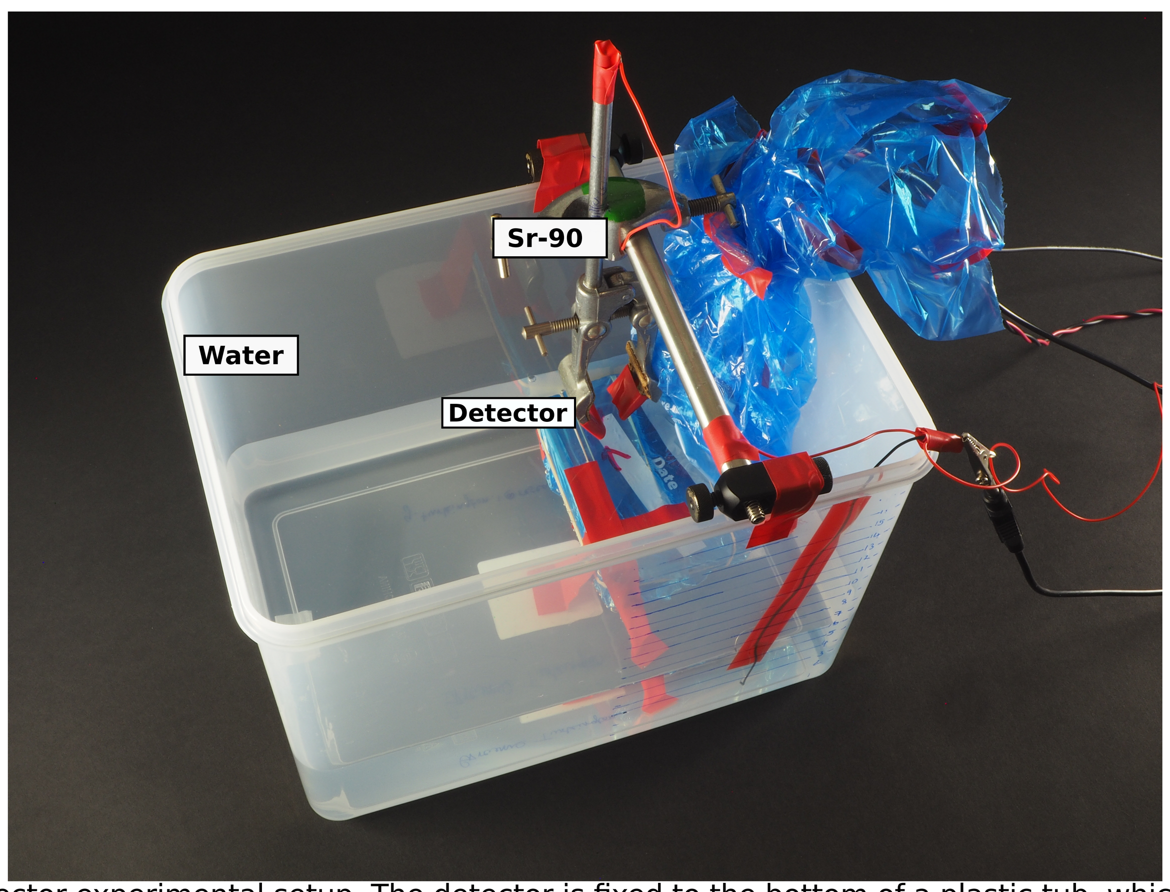

Figure 3: The detector experimental setup. The detector is fixed to the bottom of a plastic tub, which is filled with water, and a ^{90}Sr source was clamped at increasing distances from the detector.

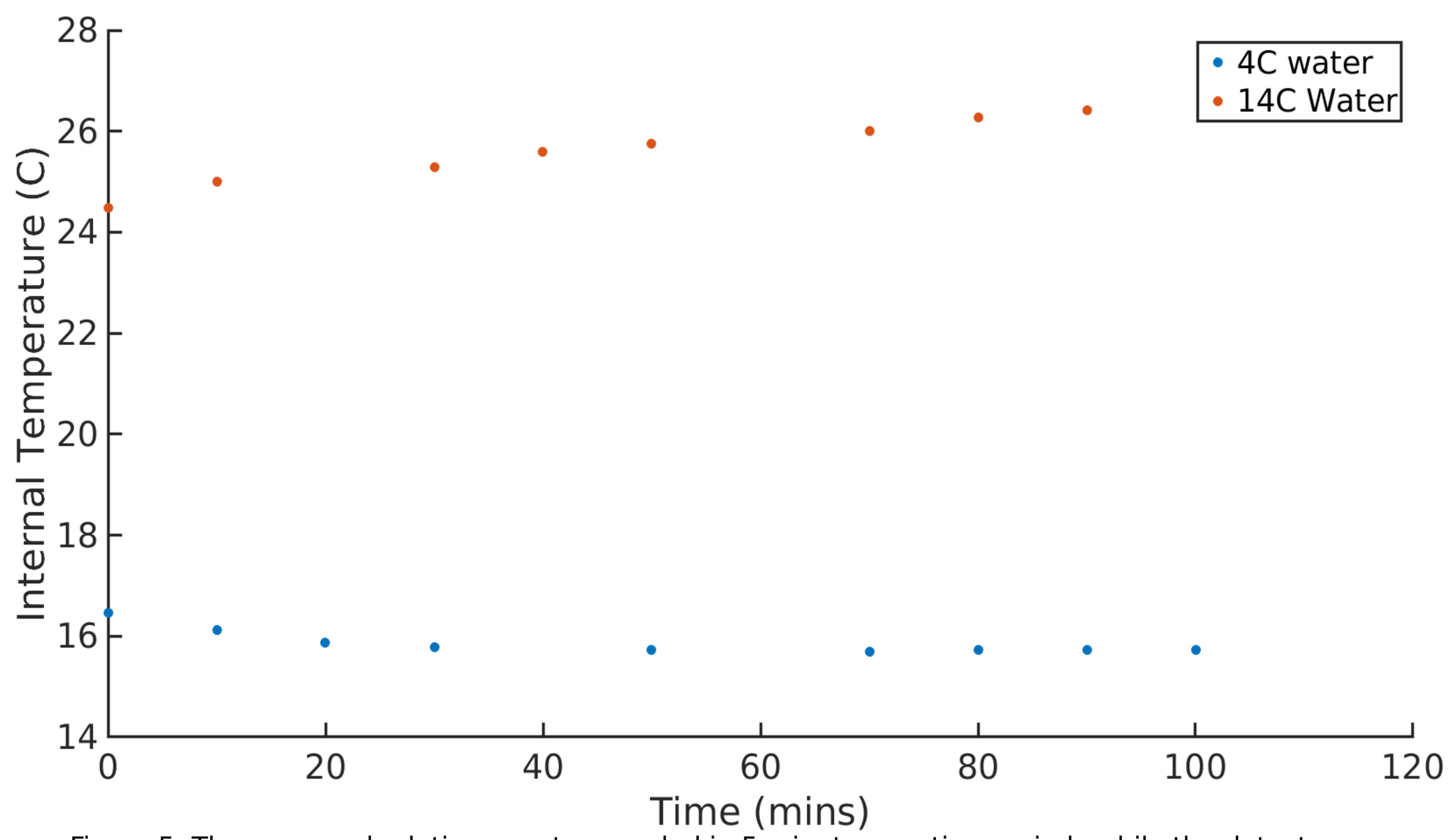

Figure 5: The averaged relative counts recorded in 5 minute counting periods while the detector was submerged in 4.1 °C water and 14.3 °C.

- The deployment of CdTe sensors into groundwater boreholes must account for variations in environmental conditions and, given the sensitivity of the detector to temperature, a key factor will be the temperature of the groundwater. The stability of a CdTe detector in likely groundwater temperatures has been investigated and it has been demonstrated that the detector's performance was most stable at a water temperature of 4.1 °C.

Groundwater Simulations

- Some of the pure beta emitting radionuclides found at Sellafield are ^{90}Sr, ^{90}Y, ^{14}C, and naturally occurring ^{40}K. It's important to establish the detector's sensitivity to these radionuclides to establish whether they contribute to the detector's response function. This will give insight into the viability of this detector in the real world, and give insight into the difficulty of examining ^{90}Sr decay in the presence of other radionuclides.

- It is expected that when the detector is deployed into groundwater it will not be sensitive to weak beta emitters such as ^{14}C, but has sensitivity to strong betas like ^{90}Sr, ^{90}Y, ^{40}K and ^{137}Cs.

- The limit of detector for the CdTe sensor and ^{90}Sr decay was found to be 323 BqL^{-1} after a 1 hour measurement and 66 BqL^{-1} after a 24 hour measurement. Meanwhile, the GaAs sensor had a lower limit of detection of 91 BqL^{-1} and 18 BqL^{-1} in 1 and 24 hours respectively. Existing techniques are capable of examining ^{90}Sr decay below the World Health Organisations safe drinking water limit of 10 BqL^{-1}. This has the benefit of allowing decommissioning sites to examine the data quickly to determine whether beta activity is present or not, and rapidly respond to unexpected spikes in groundwater activity resulting from new leaks. This could be used to compliment existing techniques and allow for a selective approach with existing techniques such as liquid scintillation counting for closer examination of ^{90}Sr activity. Additionally this would allow for rapid scanning of large areas of land and be used to pinpoint locations of peak activity.

Table 3. The limit of measurement for ^{90}Sr in the CdTe detector for increasing lengths of measurement.

Length of Measurement	Limit of Detection (BqL^{-1})
10 minutes	799
1 hour	323
24 hours	66
48 hours	46
168 hours	25

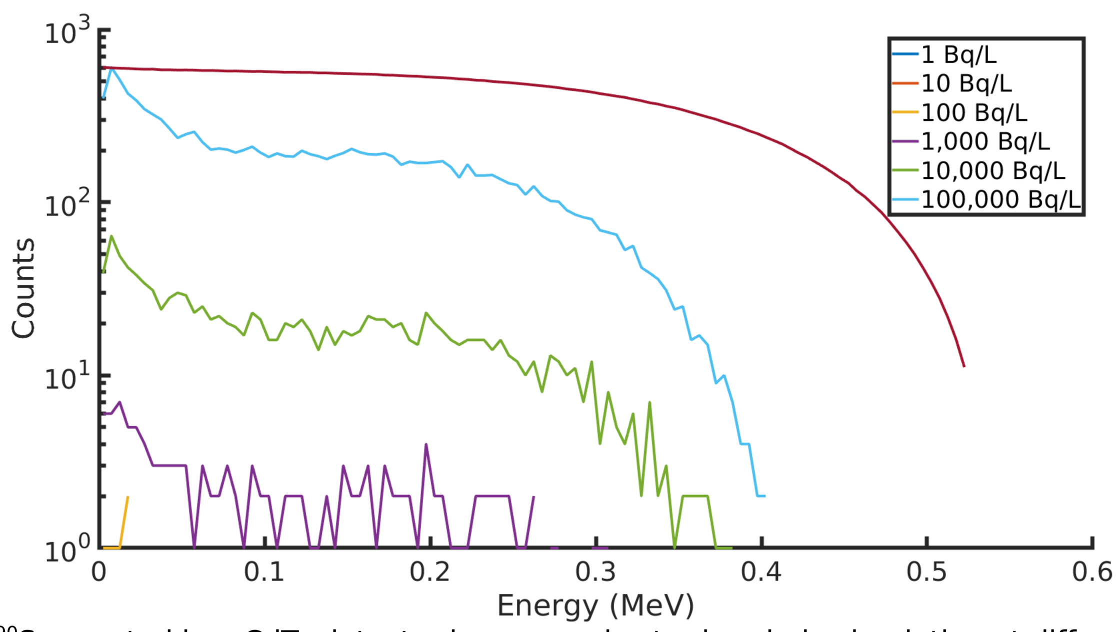

Figure 6: ^{90}Sr counted in a CdTe detector in a groundwater borehole simulation at different activities..

Acknowledgments

The authors would like to acknowledge the Nuclear Decommissioning Authority and the University of Glasgow for funding support.

References

[1] G. Turkington, K. A. A. Gamage and J. Graham, Beta detection of strontium-90 and the potential for direct in situ beta detection for nuclear decommissioning applications, NIM: A **911** (Dec., 2018) 55–65.

[2] G. Turkington, K. A. A. Gamage and J. Graham, Direct measurement of strontium 90 in groundwater: geometry optimisation of a photodiode based detector, J. Inst. **14** (Oct., 2019)