In-situ Gamma-Ray mapping of Environmental Radioactivity at *i*Themba LABS and associated Risk Assessment

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INTRODUCTION

*i*Themba LABS (*i*TL) produces radioisotopes for use by, amongst others, the local nuclear medicine community. Waste radionuclides are released into two holding ponds on the *i*TL site in a controlled manner. The water from these ponds is also used to irrigate the *i*TL grounds. Since 2004, the Environmental Radioactivity Laboratory (ERL) of *i*TL has performed *in-situ* and *ex-situ* measurements of environmental radioactivity on the *i*TL site. This is done in order to determine the distribution and quantity of radionuclide contamination due to irrigation, and what radiological risks the contamination poses to persons on site. The study focused on measurements done in June 2004, as well as February and July 2005.

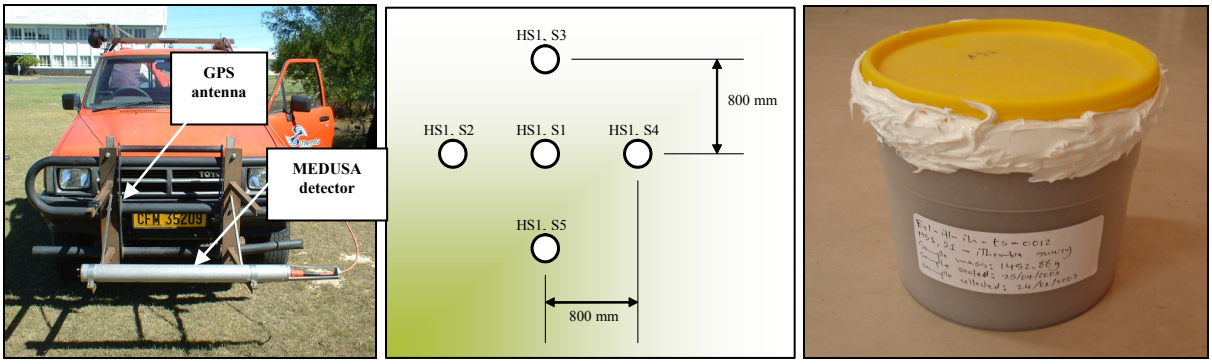
MATERIALS AND METHODS

The ERL used the MEDUSA (De Meijer, 1997) and HPGe detector (low-background) systems to make *in-situ* and *ex-situ* measurements, respectively. The MEDUSA system comprises a CsI(Na) detector which is interfaced with GPS receiver. This detector was mounted ~ 0.5 m above the ground on the front of a 4 x 4 vehicle to traverse (at ~ 2 $m.s^{-1}$) the accessible portions of the *i*TL site. Spatial coordinates (with resolution ~ 3 m) were acquired via the GPS receiver whose antenna was mounted directly above the crystal (see Figure 1.(a)). Maps of detector count rate were produced to show the spatial distribution of radioactivity on the site. Stationary *in-situ* measurements were made and samples, mostly soil, were collected at spots of interest. The activity concentrations of radionuclides were determined by means of full spectrum analyses (FSA) and windows analyses of *in-situ* and *ex-situ* spectra, respectively (Hendriks *et. al*., 2001). The FSA technique involves the spectral deconvolution of the measured MEDUSA spectra (each acquired over a 2 s period) using so-called standard spectra (generated by Monte Carlo simulations). The absorbed and effective doses (from external γ-ray irradiation) were determined using dose conversion factors (UNSCEAR, 2000; Saito and Jacob, 1994; Mohanty, *et. al*. 2004).

Sampling procedures

The types of samples collected were either soil (~10 cm depth) or grass, but most were soil. At the locations where 5 soil samples were taken, the method of sampling used is illustrated by the diagram in Figure 1.(b). The sampling strategy allowed for much representation of the spot by the samples collected. The soil samples were weighed, oven-dried at 105°C temperature overnight. Subsequently they were sieved through a wire mesh to remove organic materials, stones, and lumps (Joseph, 2005) and then poured into the Marinelli beaker up to the 1 litre mark. The beaker was sealed by lining with silicone sealant as shown in Figure 1.(c). After sealing, the sample was kept in the ERL for a minimum of 21 days to allow for secular equilibrium to occur between

^{226}Ra (the parent radionuclide to radon (^{222}Rn)) and its daughter radionuclides in the soil before measuring with the HPGe detector.



(a) (b) (c)

Figure 1. (a) Photograph showing the setup of the MEDUSA detector and GPS antenna on the 4x4 vehicle, (b) Schematic top-view representation of the sampling strategy used at e.g. HS1 (see Figure 2.), where the circles indicate the points of sampling, and (c) Photograph showing the sealed soil sample in a labeled Marinelli beaker.

RESULTS AND CONCLUSION

The count-rate maps showed that there were 6 hotspots where anthropogenic radioactivity was concentrated. The soil activity concentration results (from ~ 26000 acquired MEDUSA spectra in 2005) for primordial radionuclides have ranges of 8 – 39, 6 – 21, and 30 – 63 Bq.kg^{-1} for ^{238}U, ^{232}Th, and ^{40}K, respectively. The absorbed and effective dose ranges associated with this natural radioactivity are 10 – 27 nGy.h^{-1} and 13 – 33 μSv.y^{-1}, respectively. An outdoor occupancy factor of 0.2 was used to determine the effective dose rate. The anthropogenic activity concentrations in soil had the ranges of 1 – 6534, 0 – 101, 0 – 21, 0 – 1, and 0 – 193 Bq.kg^{-1} for ^{68}Ga, ^{65}Zn, ^{22}Na, ^{137}Cs, and ^{54}Mn, respectively. The identities and half-lives of the observed anthropogenic radionuclides were obtained by recognising the γ-ray energy peaks associated with them from the HPGe spectra results. The absorbed and effective doses due to these artificial sources were calculated for two plane source depth locations, namely, 1 and 10 cm. The absorbed and effective dose results had ranges of 0 – 153 nGy.h^{-1} and 0 – 187 μSv.y^{-1}, respectively. The maximum effective dose to a person on the *i*TL site due to external irradiation by γ-rays emanating from primordial and anthropogenic radionuclides is calculated to be well below the regulatory 1 mSv per year per member of public.

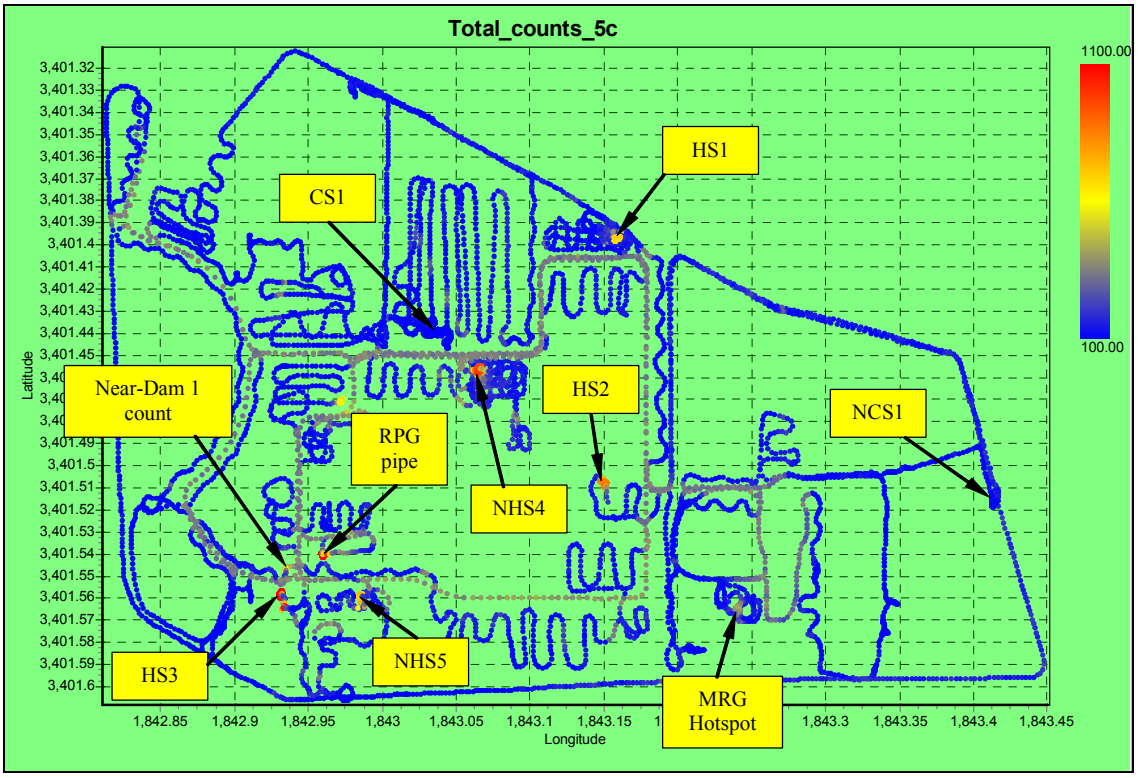


Figure 2. Map showing MEDUSA count rate obtained during the July 2005 survey. The colour-coding range of the count rate is 100 - 1100 counts per second, and is shown on the top-right corner in the map. (Note: The map shows the Latitude and Longitude coordinates in the format x,xyy.yy instead of the usual xx˚yy.yy' where xx and yy.yy correspond to the degrees and minutes, respectively.)

Table 1. Table showing the anthropogenic radionuclides identified at the different hotspots on the site. The red markings indicate enhancement in the activity concentration of the particular radionuclide.

Hotspot location	Identified anthropogenic radionuclides				
	^{68}Ga	^{65}Zn	^{22}Na	^{137}Cs	^{54}Mn
HS1	×	×	×	×	×
HS2	×	×	×	×	×
HS3	×	×	×	×	×
NHS4	×	×	×	×	×
NHS5	×	×	×	×	×
MRG hotspot	×				
Near-Dam 1	×		×		
RPG pipe	×				

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REFERENCES

De Meijer, R. J. (1997). Heavy Minerals: From 'Edelstein' to Einstein. Journal of Geochemical Exploration, 62(1-3): 81-103.

Hendriks, P. H. G. M. *et. al*. (2001). Full-spectrum analysis of γ-ray spectra. Journal of Environmental Radioactivity, 53 (2001): 365-380.

Joseph, A. D. (2005). Radiometric Study of Soil: The Systematic Effects. Unpublished Master's thesis. Cape Town: University of the Western Cape.

Mohanty, A. K. *et. al*. (2004). Natural radioactivity and radiation exposure in the high background area at Chhatrapur beach placer deposit of Orissa, India. Journal of Environmental Radioactivity 75 (2004), 15-33.

Saito, K. & Jacob P. (1994). Gamma ray fields in the air due to sources in the ground. Radiation Protection Dosimetry 58 (1995), 29-45.

UNSCEAR. (2000). Sources and Effects of Ionizing Radiation. United Nations Scientific Committee on the Effect of Atomic Radiation, United Nations, New York. [Online]. Available www.unscear.org/docs/reports/annexb.pdf