UNIVERSITY of the WESTERN CAPE

Radon escape from mine tailings dams

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What is the radon problem in South Africa?

Not in houses – well ventilated

due to temperate climate.

UNDERGROUND MINING– 200 000

miners with

Radon >(typically)>1000 Bq.m^{-3}

Gold ⇨ U ➡ Ra ➡ Radon

TENORM at e.g. mining sites and mine dumps

People relocated because of radiation (Timeslive.co.za)

Sapa 18 February, 2011 19:38

People living in the Tudor Shaft informal settlement on Johannesburg's West Rand will be relocated because of the levels of radiation in the area, Mogale City Municipality said.

CANVAS Life

'We have failed our teachers'

P13

Saturday Star January 8 2011

Living in SA's own Chernobyl

Hundreds of shacks have been erected on a toxic and radioactive mine dump, experts warn

SHEREE BEGA

WITH a look of pride, David Ncwana shows off his vegetable garden. The beans, he announces, have started to grow and the onions are getting along nicely, but the potatoes are taking longer than usual to emerge from the toxic earth beneath his feet.

The 51-year-old Ncwana, who once worked as a security guard, understands the flaming orange soil on which his prized vegetable crop slowly grows may pose a danger, but business is improving and people need to eat.

He tends his vegetables on a forlorn patch of land on the edge of the Tudor Shaft informal settlement in Krugersdorp, west of Joburg, where hundreds of shacks have been erected on a toxic and radioactive mine dump.

Last month, British Professor Chris Busby, a world expert in uranium, revealed that one of the shacks he tested here, located a few steps from Ncwana's garden, had showed radiation levels 15 times higher than regulatory limits, and advised the community be urgently relocated.

"This soil is not all right for planting because it contains the chemicals from the mine, which is bad," says Ncwana, barefoot and clad in a faded T-shirt, in his beloved garden.

"But I try to make a living from selling my vegetables and the people are coming from all over to buy them. It's food, after all, and it's giving energy."

He does his best to bypass the contamination. Using wheelbarrows, and when he can get it, he carts in fresh soil from a nearby site, and mixes it with the orange sludge in Tudor Shaft to act as fertiliser.

"Look at the difference. There, I mixed the soil and you can see the mealies are green and fat. But over there," he says, pointing to the corner of his garden, "where I didn't mix the soil, the mealies are a yellow colour and small."

In a Chinese-style dress and her trademark high heels – this time a fiery red pair – local environmental campaigner Mariette Liefferink gestures to the vegetable gardens like Ncwana's, which are interspersed throughout the neat rows of shacks.

"The problem is these crops are not edible," she explains. "You can-

GARDENING WITH PRIDE: David Ncwana, 51, tends the vegetable garden that he created next to his shack at the Tudor Shaft informal settlement in the West Rand – but the soil is polluted. PICTURES: PABALLO THEKISO

woman living on uranium-rich radioactive grounds, when one knows that toxic metals, particularly the radioactive ones, are destructive to human development, Germans appear as a bunch of whining and spoiled children."

The toxic effects are all around but most people are blind to them, she believes. "To point out problems is easy. To solve them takes awareness and financial commitment. Of course, it's easy for me to say relocate these people but can it be done?

"Pollution will get worse, which means disease will rise. Neurological diseases will affect people at an early age and the poor will be affected the worst, because they have many factors against them."

Toxic environments create toxic

Mine Tailings Dumps

- **BIG!**
- **Also many legacy sites**
- **How do we measure the radon exhalation?**
    - **Many methods – all labour intensive and not suitable for large areas**
    - **Try something simpler**

Solution tried in this work

Rather than measuring the radon – measure gamma rays

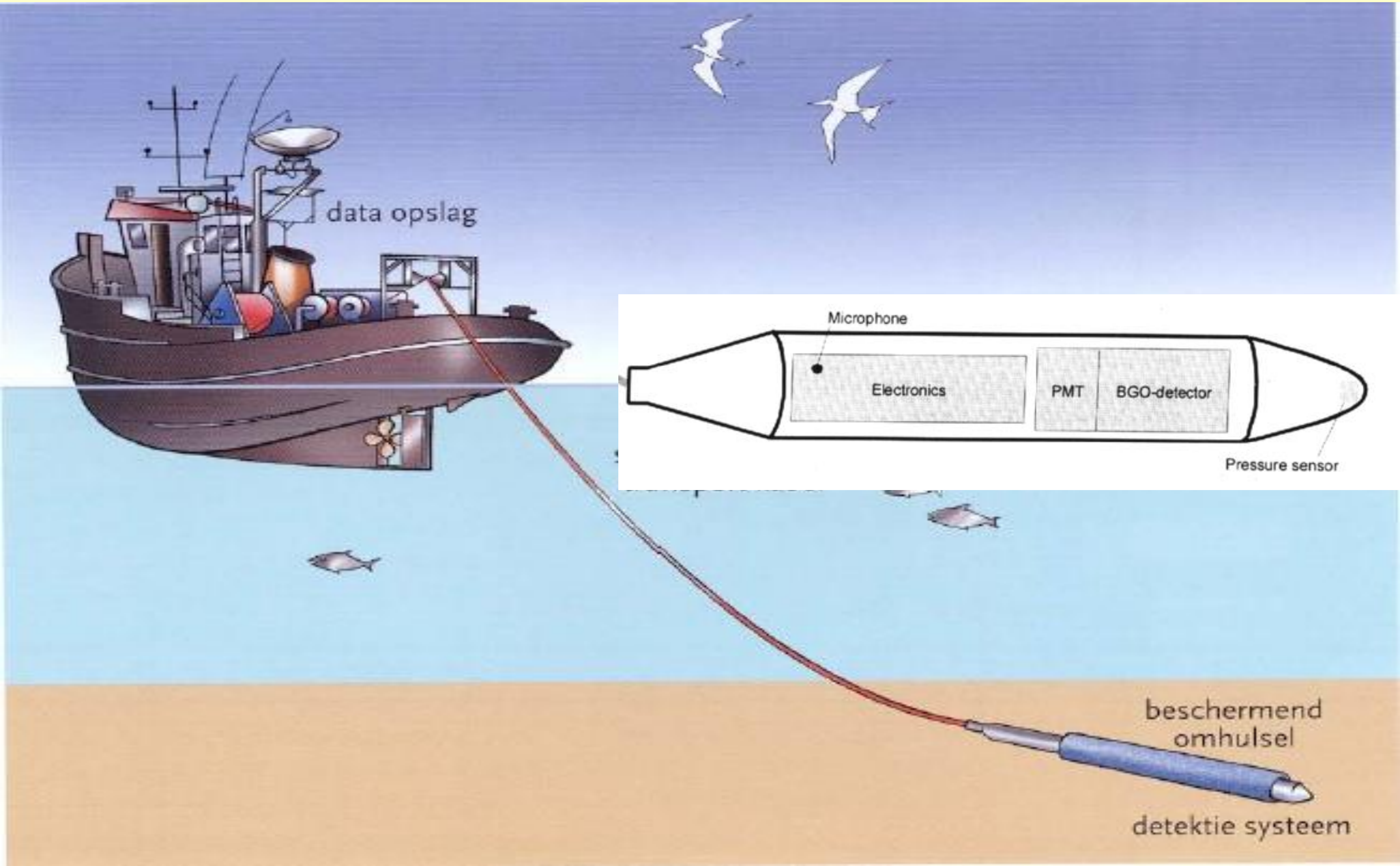
Common to measure natural radioactivity namely: ^{238}U ^{40}K and ^{232}Th – even by flying with large NaI detectors

We have used the MEDUSA detector system (Multi-Element Detector for Underwater Sediment Activity) (De Meijer, 1998) which is a gamma ray detection system to try to quantitatively assess the radon flux from the mine dumps.

Not straightforward!

Multi-**E**lement **D**etector for **U**nderwater **S**ediment **A**ctivity (De Meijer, 1998)

- MEDUSA technology patented by University of Groningen, Netherlands

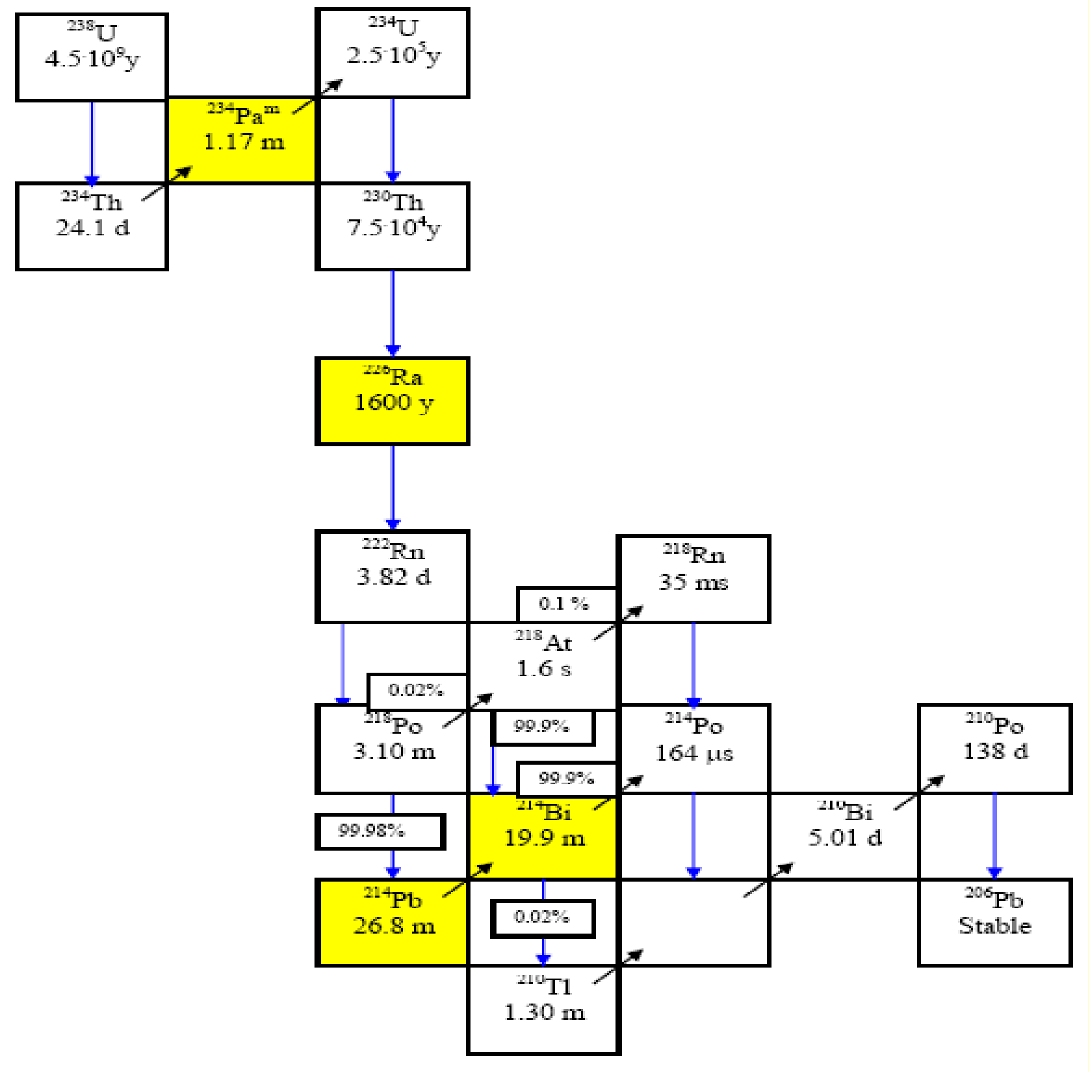


Any other gamma detector will work – NaI…

Kloof at Goldfields mine (Westonaria)

-Dam is approximately 2 square kilometers in area and has been vegetaded.

Problems – Gammas mainly from radionuclides AFTER the radon formation



Arrows pointing down indicate alpha decay.

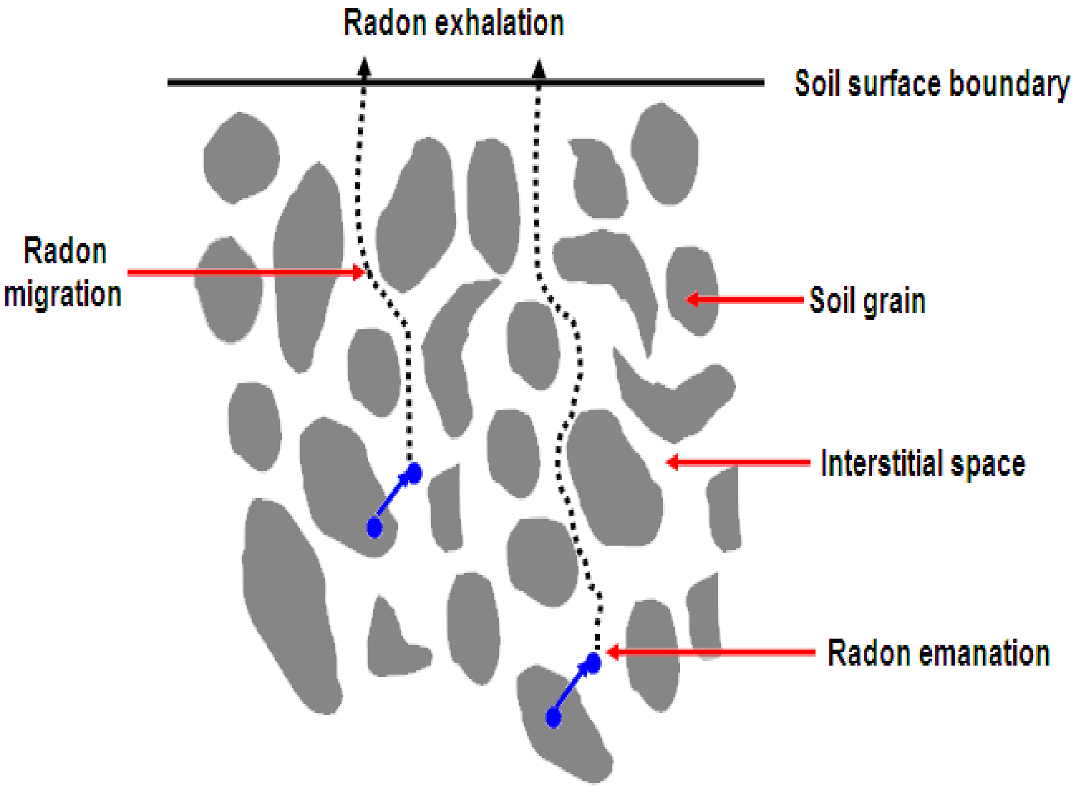
Diagonal arrows indicate beta decay.

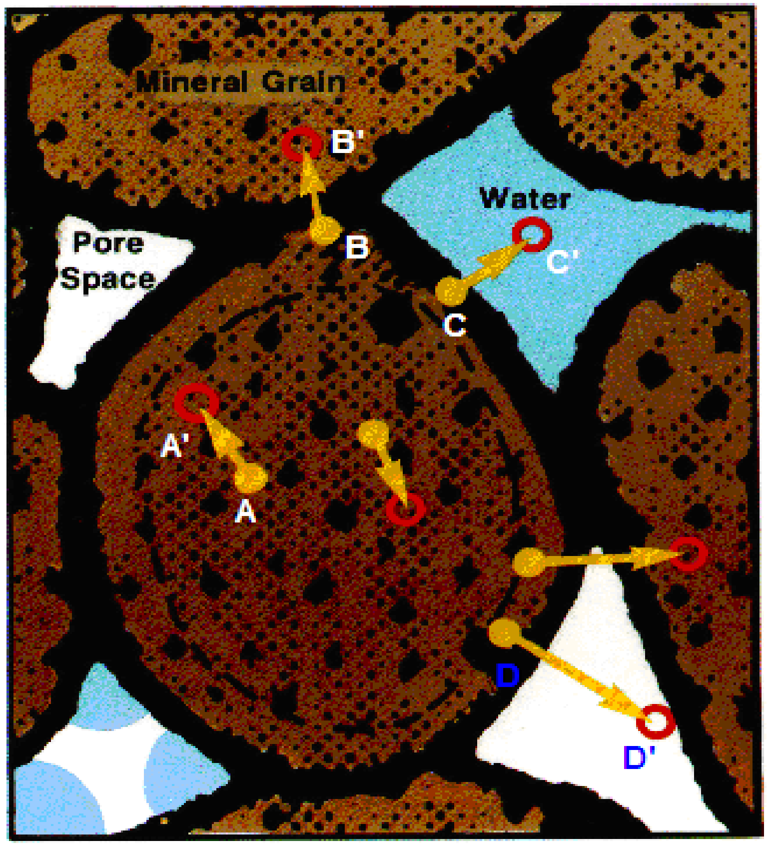
The yellow boxes indicate those radionuclides which decay via significant gamma-ray emission.

Radon flux measurements

- Radon is released to the atmosphere after being transported by diffusion and advection from pore spaces.
- Radon releases are measured by radon flux F (Bq m^{-2} s^{-1}).

-Possible hazard to residents in vicinity



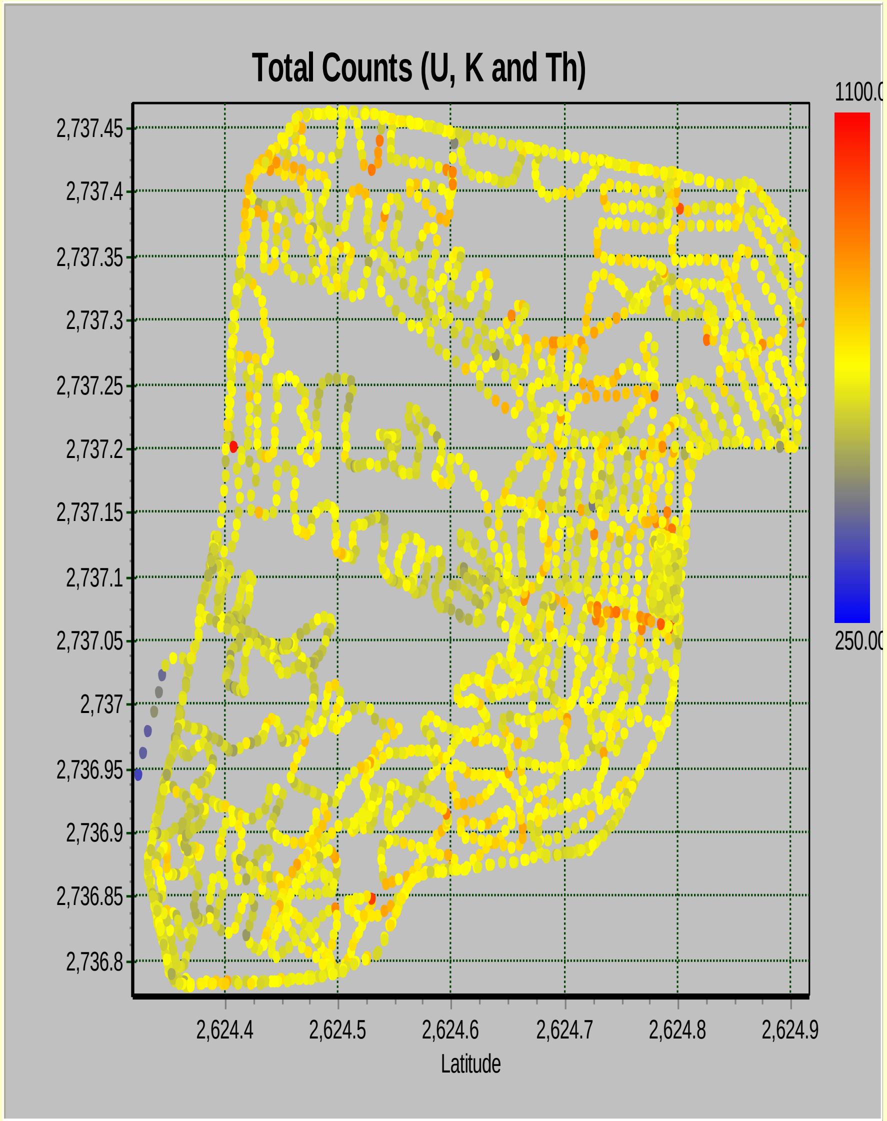


Field measurements

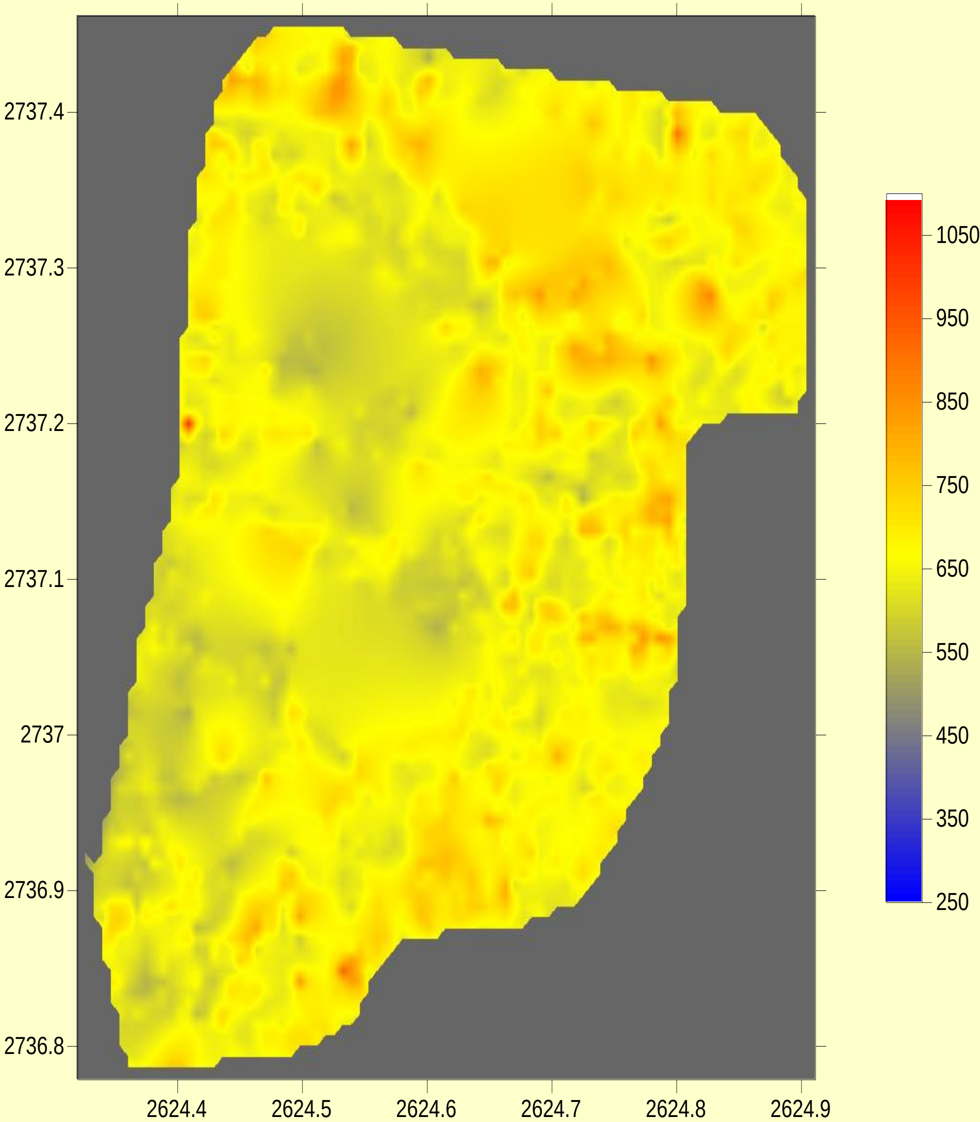
- MEDUSA detector system mounted approximately 60 cm off the ground.
- Total counts and their location recorded – FAST and SIMPLE
- Stationary measurements and mobile measurements are obtained
- Samples collected at a few spots for calibration

Analysing MEDUSA mobile measurements

Obtain total counts first using Full Spectrum Analysis (Hendriks 2001)



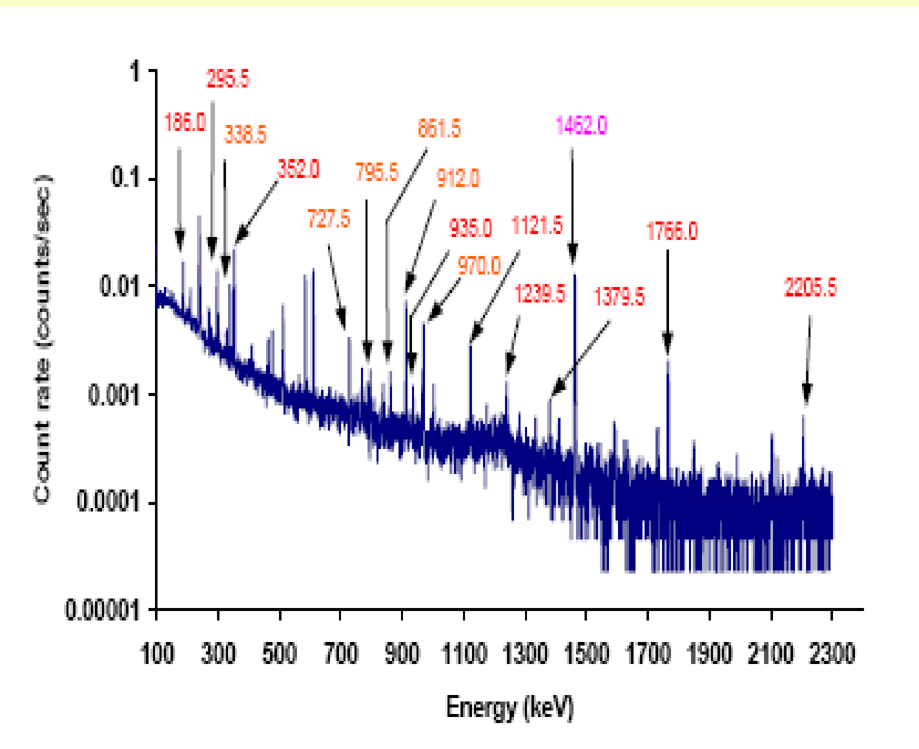
Corresponding interpolated map of total counts using Surfer 8



Calibrate by normalising with Activity concentration determination in the Laboratory at a few spots.

Sample preparation

- Samples were dried, crushed, sieved and sealed in Marrinelli beakers
- Stored for 3 weeks for secular equilibrium to be attained
- HPGe (Hyper Pure Germanium) detector used to analyse spectrum below



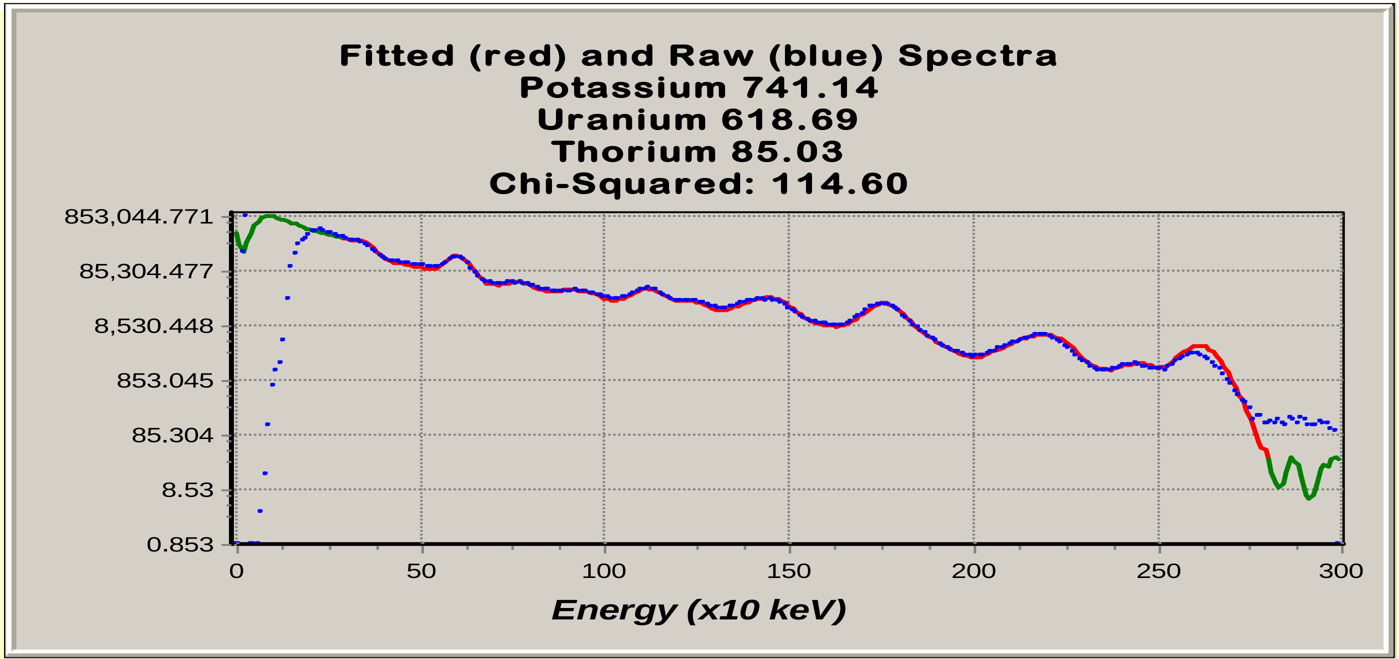
Location of peaks in soil sample for the radionuclides ^{238}U, ^{232}Th and ^{40}K

Relationship between HPGe and MEDUSA

Link between HPGe and MEDUSA has to be established using stationary measurements

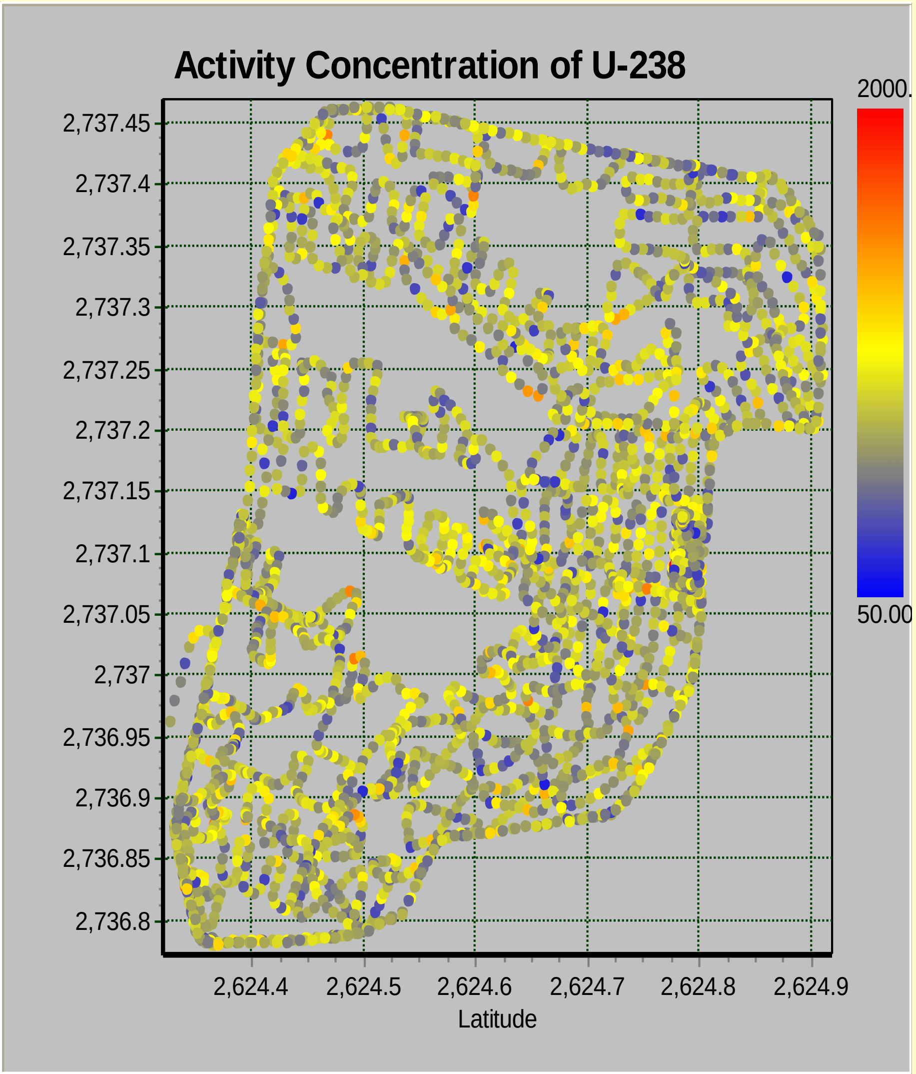
$$Normalization\_Factor = \frac{HPGe\_Concentration}{MEDUSA\_Concentraion}$$

	U-238	Th-232	K-40
Average Normalisation factors	0.54±0.05	0.21±0.01	0.37±0.03

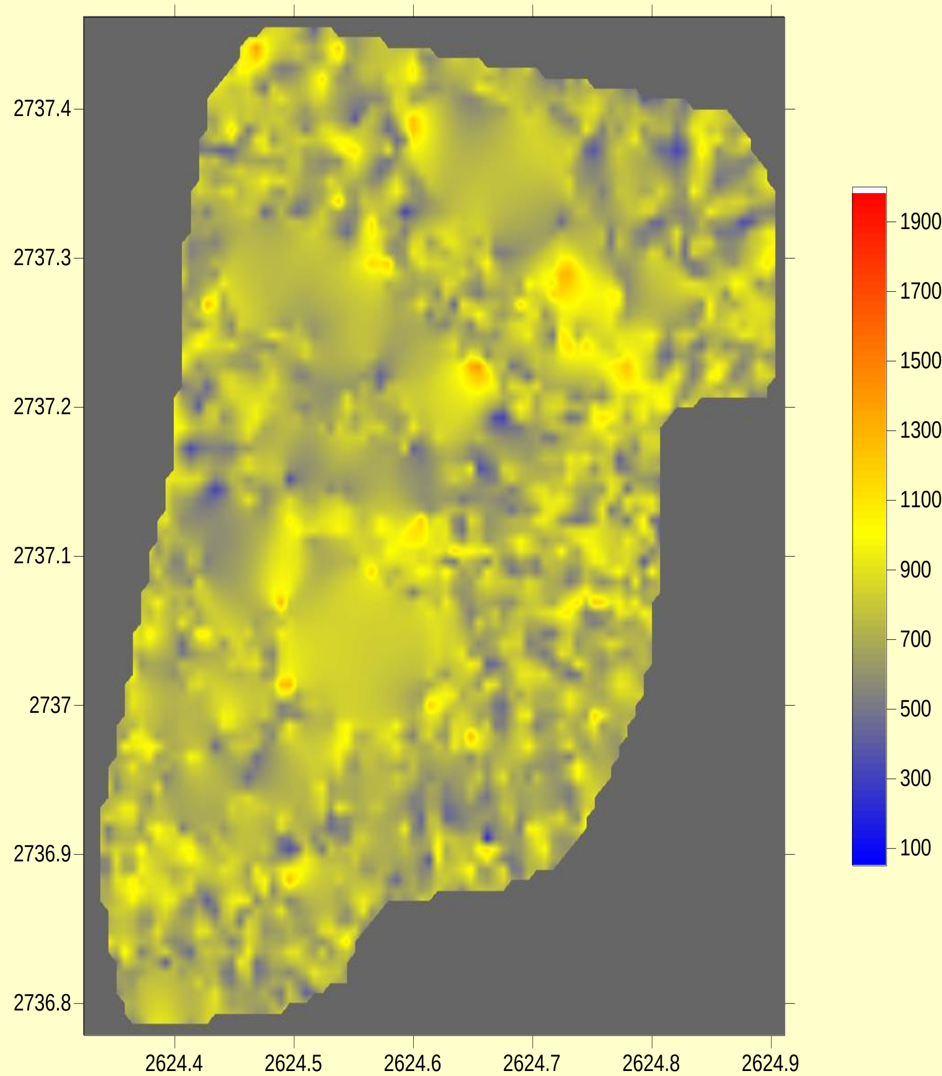


Next obtain ^{238}U, ^{40}K and ^{232}Th

Activity concentration of ^{238}U using Full Spectrum Analysis



Corresponding interpolated map of ^{238}U using Surfer 8



Radon Exhalation calculations

First approximation to radon flux - Ratio Method

$$Fraction = 1 - \left\{ (U_{dis} / K_{dis}) / (U_{eq} / K_{eq}) \right\}$$

where *F* is the fraction of radon that escapes, U_{dis} is the ^{238}U activity concentration from the field (MEDUSA), U_{eq} is the activity concentration of ^{238}U from the laboratory (HPGe) and similarly for the Potassium (or thorium).

Better Approximations: Diffusion leads to

$$C_{Rn} = C_0 (1 - e^{-z/\ell}) \longrightarrow \text{Flux} = \varepsilon D dC/dz = \varepsilon D C_0 / \ell$$

where C_0 = Concentration if no escape

D = effective Diffusion constant

ε = porosity and

ℓ = the diffusion length.

- Moisture correction

Validation of the method

1. Theory (IAEA, 1992)
2. Electrets

"Theory"

$$F = R\rho E\sqrt{\lambda D_e}$$

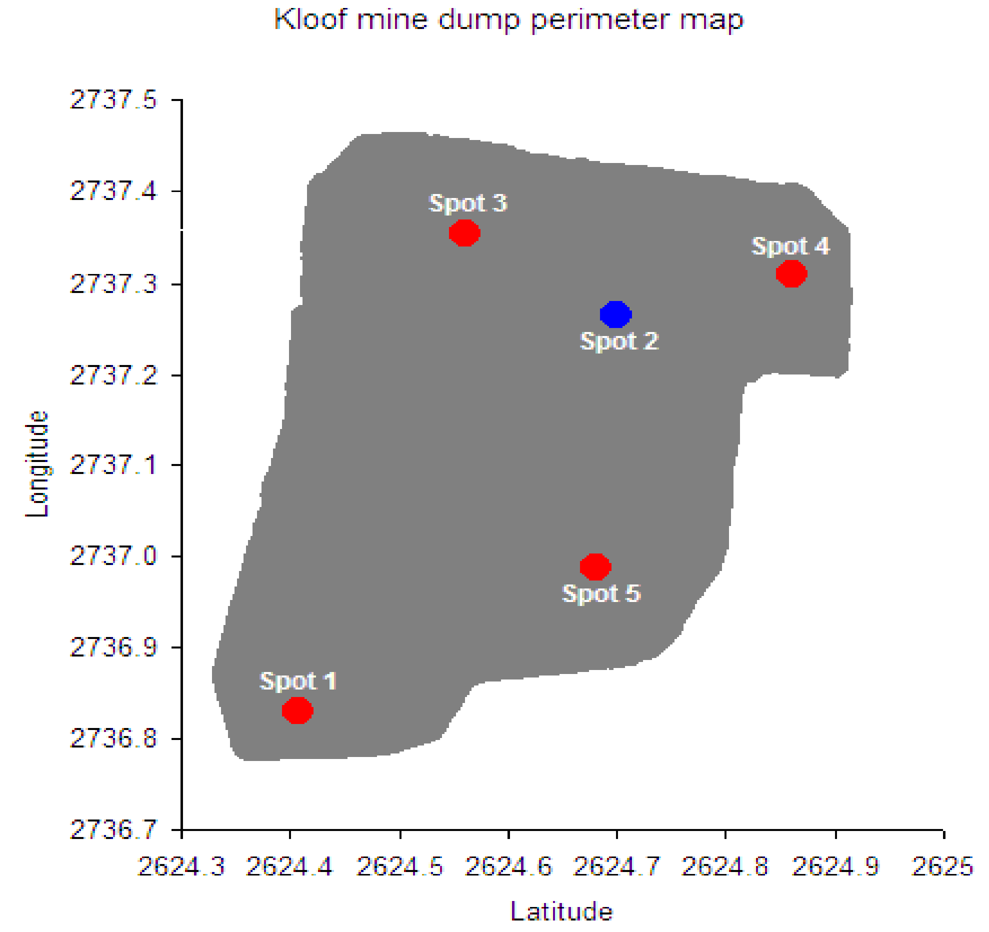
where, R is the radium content, E is the emanation coefficient, λ is the radon decay constant, ρ is the bulk density and D_e is the effective diffusion coefficient. ($\ell^2 = \lambda D_e$)

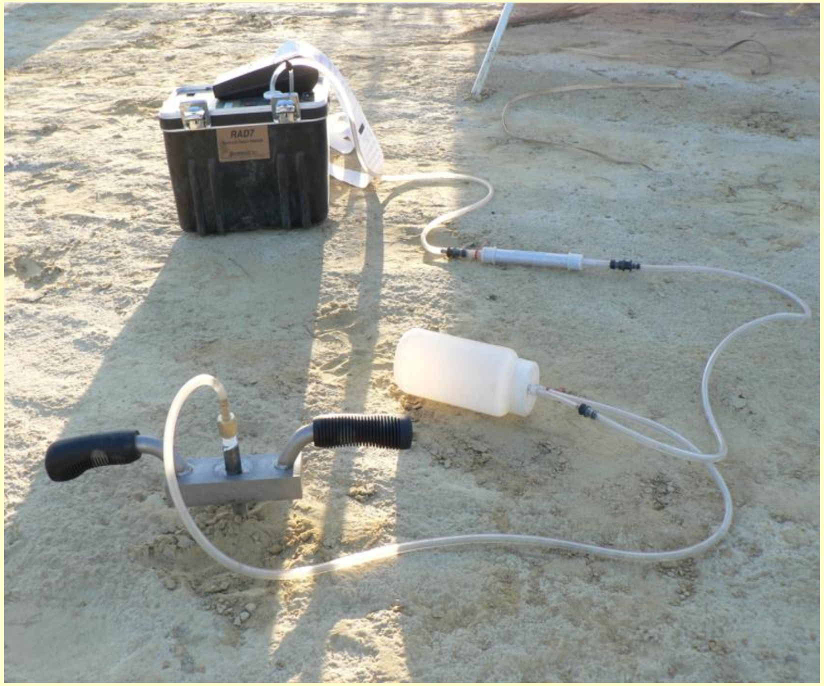
The average flux obtained using theory was 0.118 ± 0.015 Bq m^{-2} s^{-1}.

Theoretical range of flux is 0.03-0.21 Bq m^{-2} s^{-1}

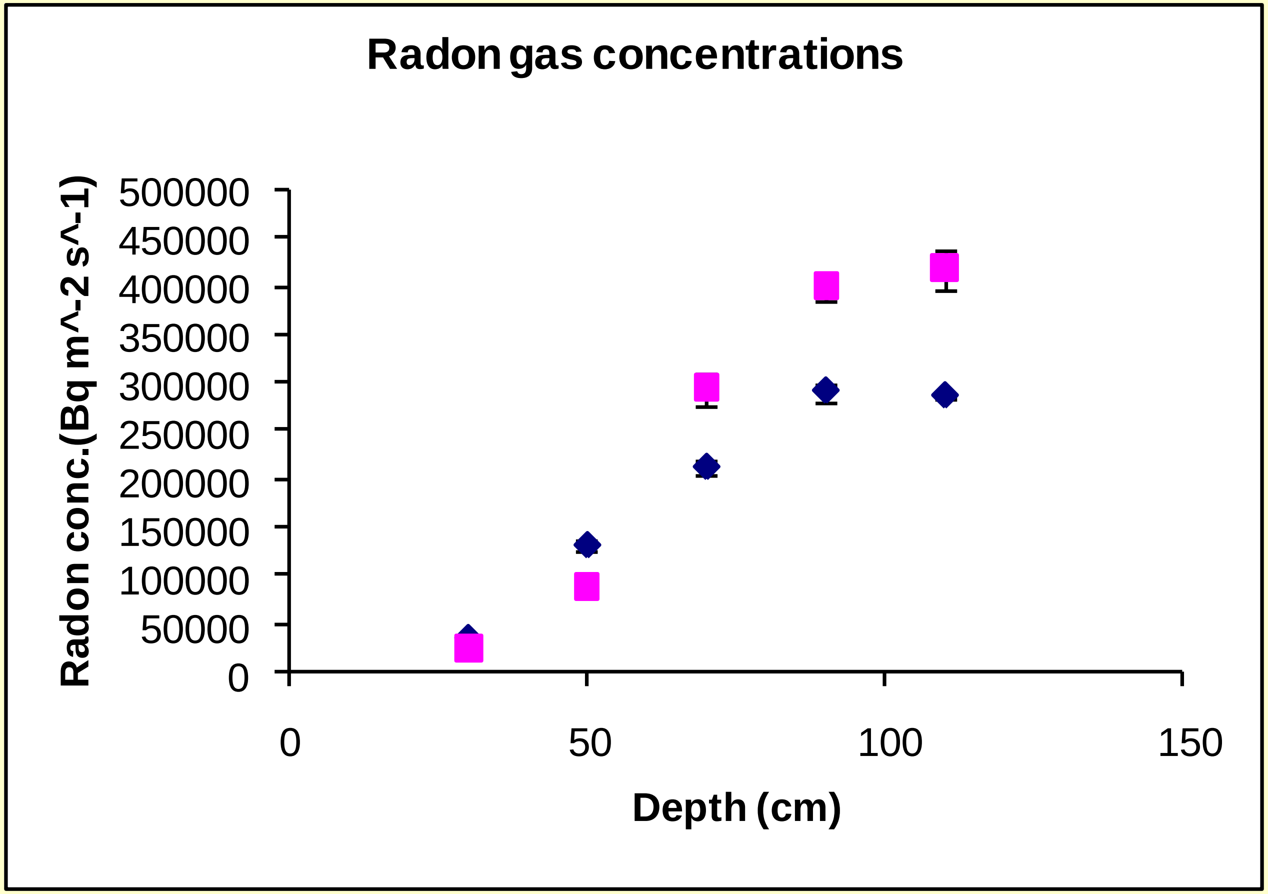
Radon gas concentration measurements in soil

- Radon gas concentration (Bq m^{-3}) measured using Rad7 and soil probes
- 5 Stationary spots were measured



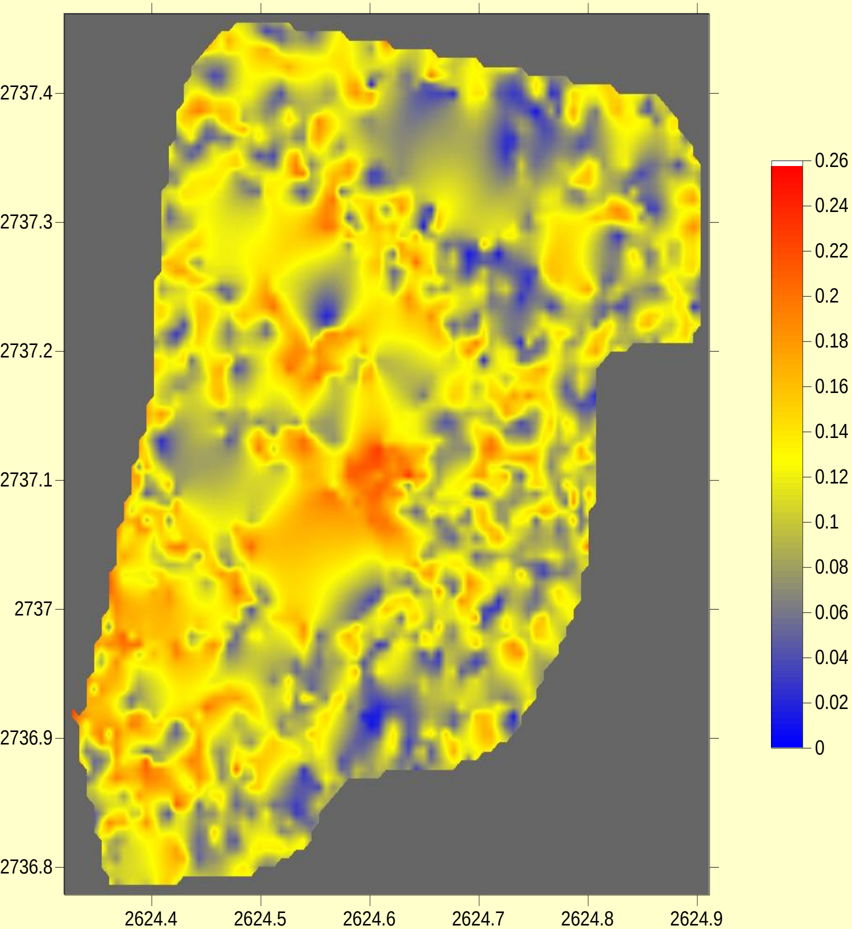


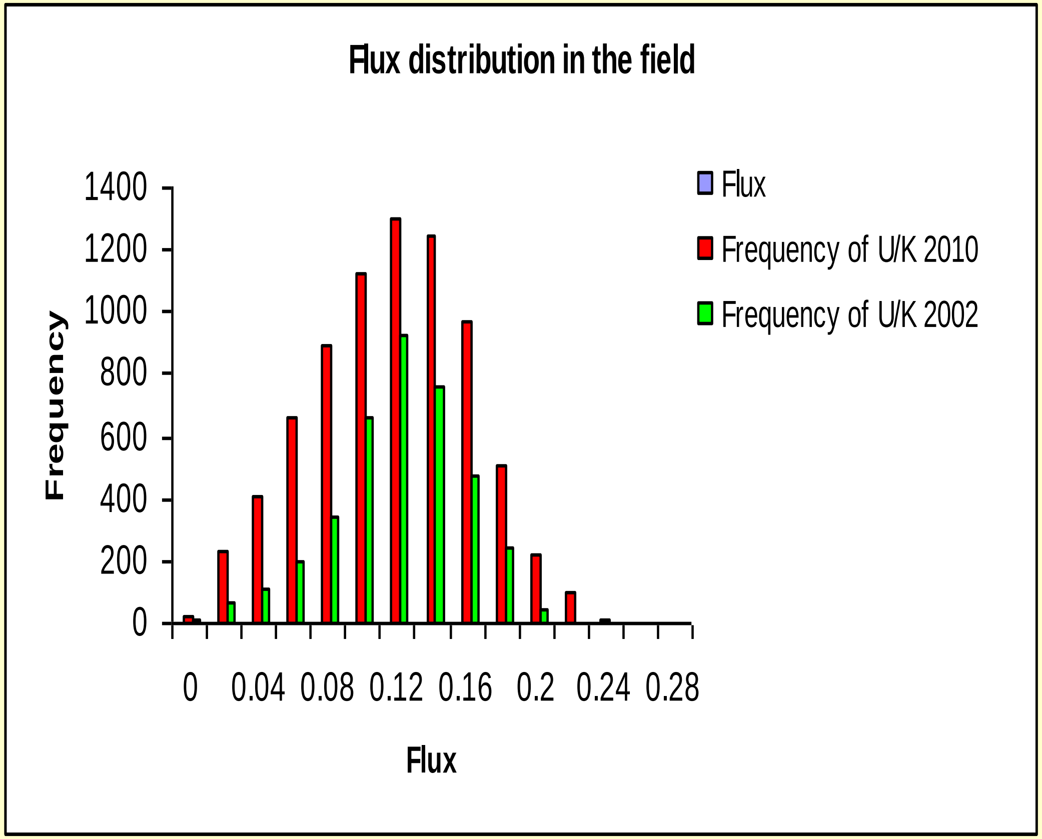
Radon depth profile concentrations



- The average flux obtained is 0.105±0.015 Bq m^{-2} s^{-1}.
- Range of flux is 0.02-0.26 Bq m^{-2} s^{-1}

Map of interpolated flux for Kloof mine dump





Summary and Conclusion

	Ratio Method	Theory
Flux ($Bq/m^2/s$)	0.11	0.12
Range of flux	0.02-0.26	0.03-0.21

- A gamma ray technique based on MEDUSA technology has been used to determine the radon exhalation from Kloof mine dump.
- This method practically provides a quick and accurate way to determine radon exhalation from an area in a relatively short period of time.

Thank you

See you in South Africa in 2016!

References

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Determining the absolute efficiencies of soil sample