Minimum Detectable and Maximum Missable Activities

The HPA Approach

David Williams

18 May 2005

Centre for Radiation, Chemical and Environmental Hazards
Radiation Protection Division
formerly the National Radiological Protection Board

Minimum Detectable Activities

Considerations:

- Detector type and dimensions
- Nuclide of interest
- Influence of ‘background’ radiations
- Environmental aspects i.e. soil type and density
- Survey technique
- Surveyor experience

Minimum Detectable Activities

Sensitivity of NaI(Tl) vs. Detector size

- At 60 keV, the probability of interaction in a 3” x 3” detector is only 5 times higher than a 1” x 0.1” detector
- At 1.25 MeV, the probability of interaction in a 3” x 3” detector is 80 times higher than a 1” x 0.1” detector
- The probability of interaction in a 1” x 0.1” detector is 20 times higher at 60 keV than 1.25 MeV
- The probability of interaction in a 3” x 3” detector is approximately the same at 60 keV and 1.25 MeV

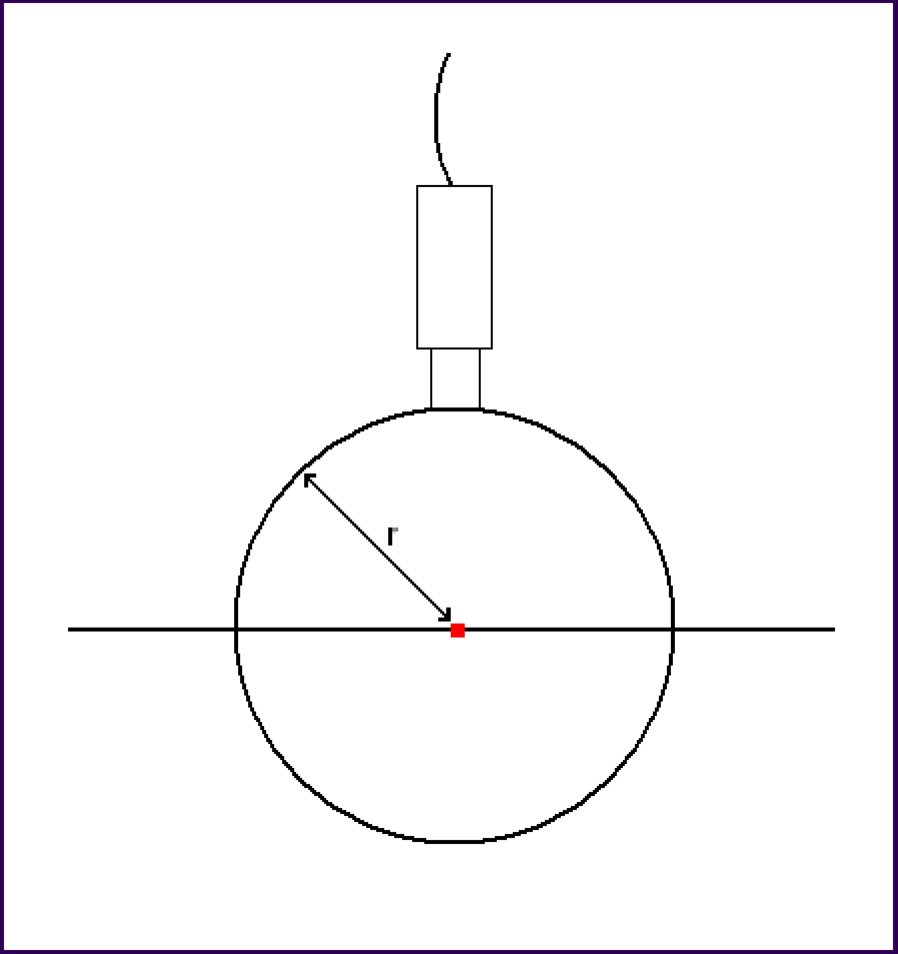
Minimum Detectable Activities

Nuclide of interest

- Probability of interaction
  - Calculate efficiency from detector dimensions
- Number of emissions and their yields
- Daughter products
  - half lives in decay chains

Minimum Detectable Activities

Survey technique:



Minimum Detectable Activities

Survey technique:

Value of r	Detector size		
	2.54 cm x 2.54 cm (1" x 1")	5.08 cm x 5.08 cm (2" x 2")	7.62 cm x 7.62 cm (3" x 3")
5 cm	1.6 %	6.4 %	14.5 %
10 cm	0.4 %	1.6 %	3.6 %
15 cm	0.2 %	0.7 %	1.6 %
25 cm	< 0.1 %	0.25 %	0.6 %

Minimum Detectable Activities

Survey technique:

- Count rate in excess of background
  - action limit for scanning stage of survey
  - balance true and false positive occurrences
    - survey area conditions
    - end point contamination levels
    - required uncertainty
    - speed of survey
    - cost and other logistical issues

Minimum Detectable Activities

Survey technique:

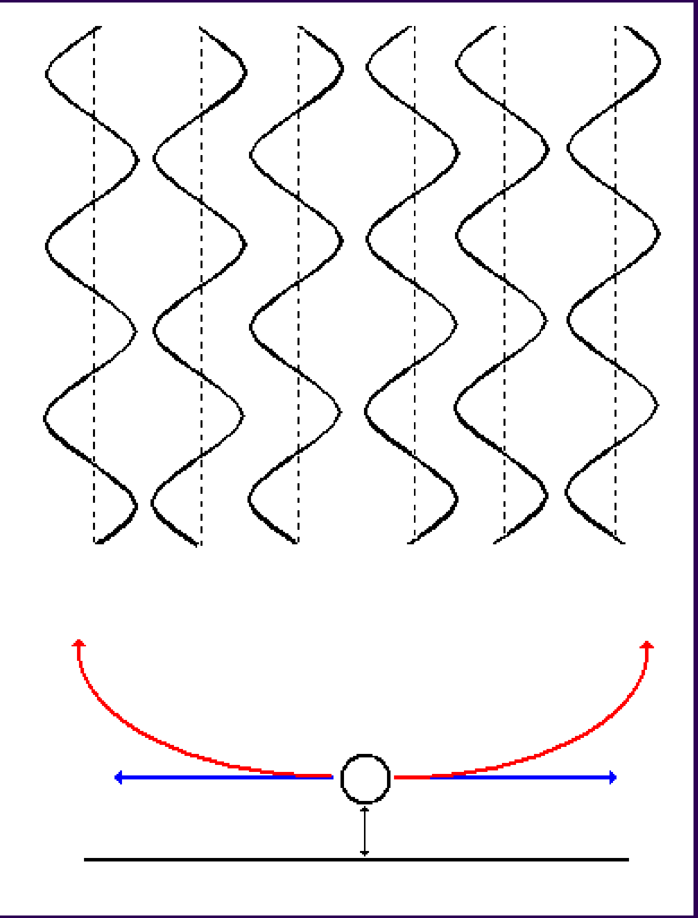
- HPA tend to work on 25% or 50% increase on background count rates
- MARSSIM prescribes a balance between the true and false positive occurrences, but is generally intended for calculations and surveyor comparison than practice

$$s_i = d'\sqrt{b_i}$$

Minimum Detectable Activities

Surveyor experience:

- Sine wave search pattern
- Ground to detector separation to remain uniform
- Response to audio output
- Survey ground condition and uniformity



Minimum Detectable Activities

Minimum Detectable Activity calculated from minimum detectable number of photons:

$$\text{Minimum Detectable emission} = \frac{\text{Minimum detectable excess}}{\text{Detector efficiency}} \times \frac{1}{\text{Effect of total distance}}$$

e.g. Min photons = 25 ÷ 0.75 ÷ 0.01

= 3333 photons

The photon yield for the radionuclide in question is then accounted for to produce the Minimum Detectable Activity.

Minimum Detectable Activities

MARSSIM approach:

- Calculate the exposure or dose rate from the minimum detectable count rate
    - e.g a 2” x 2” $\Rightarrow$ ~1600 counts s^{-1} per µGy h^{-1}, ^{137}Cs
    - Minimum detectable excess count rate determined to be 25 counts s^{-1}
    - $\therefore$ minimum detectable dose rate = 16 nGy h^{-1}
- Use modelling program Microshield™ to calculate activities per unit mass

Minimum Detectable Activities

Assuming:

- 0.1 Bq provides a dose rate of 6.2 nGy h^{-1}, ^{137}Cs, provided from Microshield™ (converted to sensible units)
- Minimum Detectable Dose Rate = 16 nGy h^{-1}

Then:

- Minimum Detectable Activity = ~ 0.25 Bq g^{-1}, ^{137}Cs

Minimum Detectable Activities

Values provided by MARSSIM (6-47) for 2” x 2” NaI

Nuclide	Minimum Detectable Concentration (Bq kg^{-1})
^{60}Co	126
^{137}Cs	237
^{241}Am	1170
U Nat	2960
U 3% Enriched	3540

Maximum Missable Activities

Essentially, as the term implies, the maximum amount of activity which may not be detected under normal survey conditions.

Accounting for:

- radionuclide
- possible burial depths

It will not account for the unforeseen or unreasonable presence of radioactivity, e.g. deliberate burial

Maximum Missable Activities

A two stage process for point source contamination:

- determine the fraction passing through the soil
- determine the fraction reaching the detector from the surface

The HPA model is simplified since any buried activity in the form of point sources quickly becomes undetectable. Therefore an estimate of the magnitude is considered sufficient.

MARSSIM relies upon modelling to determine count rates for uniform contamination and does not consider point source activity and particular

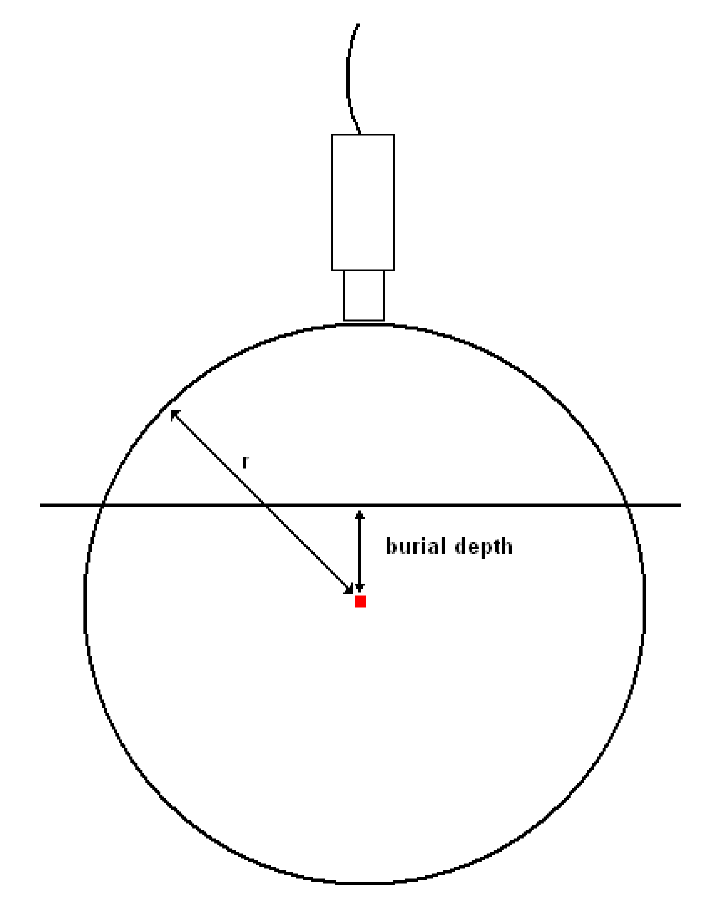
Maximum Missable Activities

Method:

- Determine the fraction which would reach the detector without presence of soil

- Determine the fraction passing through the soil

- Account for emission yields



Maximum Missable Activities

Maximum Missable Activity calculated from minimum detectable number of photons:

$$\text{Maximum missable emission} = \frac{\text{Minimum detectable excess}}{\text{Detector efficiency}} \times \frac{1}{\text{Effect of total distance}} \times \frac{1}{\text{Emission yield}}$$

$$\text{Maximum Missable Activity} = \frac{\text{Maximum missable emission}}{\text{Fraction passing through soil}}$$

Minimum Detectable Activities

Sources of information:

- Radiation Detection and Measurement
  - Glenn F Knoll
- Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)