The Interaction of Natural Background Gamma Radiation with Depleted Uranium Micro-Particles Located Deep within the Human Body

John E Pattison

School of EIE – Applied Physics, University of South Australia, Adelaide, Australia

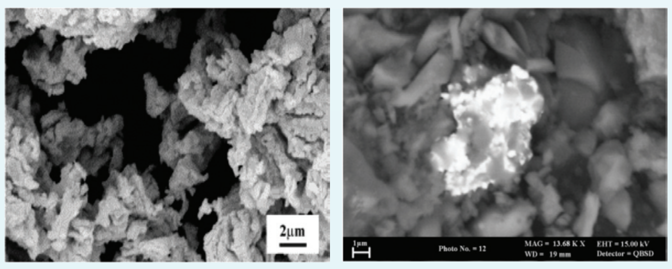
- Controversy over the health effects of the depleted uranium munitions used during the first Persian Gulf war in 1991 and subsequent wars.
- The combustion products of depleted uranium have been suggested as one cause, amongst others, for the "Gulf War Syndrome".
- Many reviews held to determine the health effects of depleted uranium, including the UK Royal Society, the European Commission, the IAEA and WHO, which concluded that it does not present as serious a radiological hazard as some have asserted. The chemical toxicity of uranium was acknowledged.
- Attention then focussed on the dose enhancement that uranium particles in the body would produce upon exposure to naturally occurring background gamma radiation (Busby 2005; Tickell 2008).
- It was estimated, based on rough calculations, that the enhancement would be a factor of 500 to 1000, and that this enhanced dose of the background gamma radiation would contribute a significant radiation dose in addition to the dose received from the radioactivity of the depleted uranium.
- A following study (Pattison *et al* 2010) showed that the maximum dose enhancement factor immediately surrounding micron-sized particles was less than 10. But some other questions were left unanswered.
- The aim of the study reported here was to examine the photoelectrons produced in such particles in more detail still using the Monte Carlo code EGSnrc to determine:
  - The electron fluence spectra both in the uranium particle and in the immediate surrounding tissue and, hence, determine the mean energies and ranges of the electrons in both materials.
  - The dose enhancement in the tissue as a function of distance from the particle and, hence, obtain another estimate of the range of the electrons in the surrounding tissue.
- Only a 10 micron-sized pure uranium particle located at the centre of the body was examined in this study as the previous study showed that this situation produced the greatest enhancement factors.

Materials and Method

Nature of Uranium

- Naturally occurring uranium consists of: 99.3% U-238 (4,500 Myrs), 0.7% U-235 (710 Myrs), 0.006% U-234 (0.25 Myrs), and is only weakly radioactive
- Depleted uranium 99.8% U-238 (4,500 Myrs), 0.2% U-235 (710 Myrs), 0.001% U-234 (0.25 Myrs), and its activity is only ~ 60% that of natural uranium
- Chemically toxic as a heavy metal
- Pyrophoric; in fine powder form spontaneously combusts producing various oxides, but mainly U_3O_8

Figure 1 *Shapes, Sizes and Composition of Depleted Uranium Particles*



- SEM micrographs from Cho *et al* (2002) & Milodowski (2001)
- Shapes are highly irregular
- Typical sizes range 1 -10 μm
- Composition of the depleted uranium particles is complex: not just Uranium Oxide, but may also contain other materials and oxidation may not be complete

Figure 2 *Attenuation curves for Uranium*

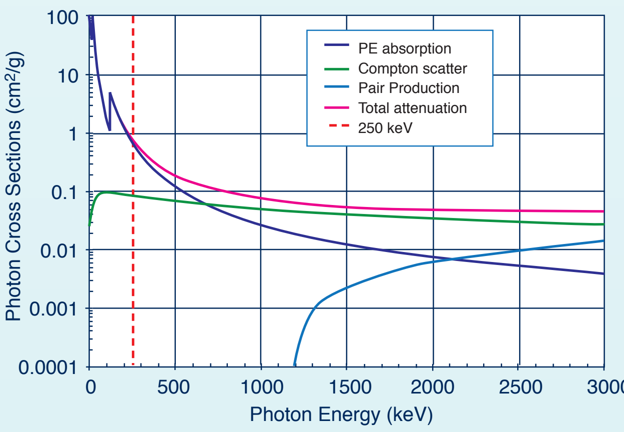


Figure 3 *Photoelectric Effect*

At low photon energies (< ~250 keV), γ-rays are absorbed in high atomic number materials nearly entirely by the Photoelectric Effect (see Figure 3) which produces low energy photoelectrons.

Water/Tissue	Z = 7.5	Platinum	Z = 78
Bone	Z = 12	Gold	Z = 79
Gadolinium	Z = 64	Uranium	Z = 92

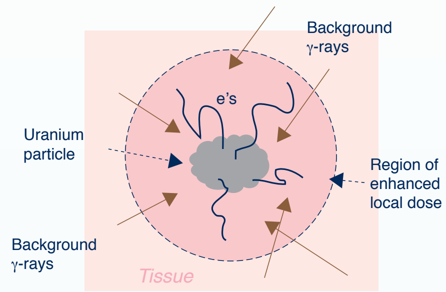


Figure 4 *Particle Model*

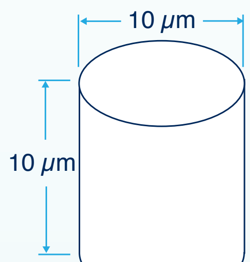


Figure 5 *Typical Animal Cell (~10 μm diameter)*

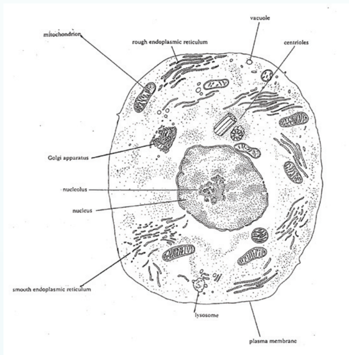
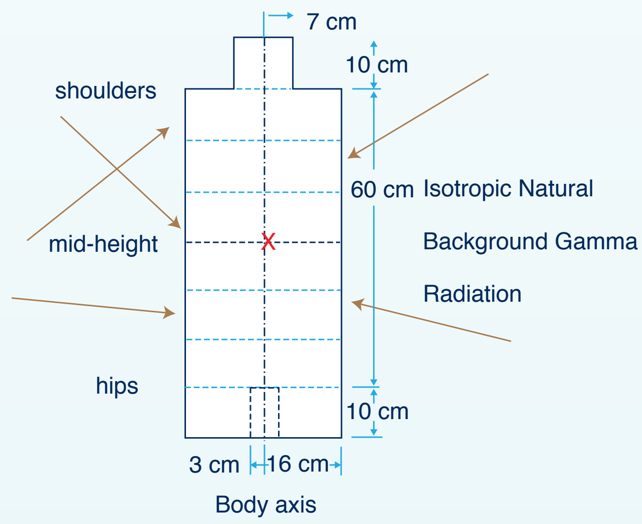


Figure 6 *Body (Torso) Model*



- An average measured natural background gamma spectrum was unfolded (see Pattison *et al* 2010) to give the spectrum incident on the outside of the model body (Fig 7).
- The incident photon spectrum was then transported through the body using FLURznrc (in EGSnrc) to obtain both the photon (Fig 7) and electron (Fig 8) fluence spectra at the centre of the body.

Figure 7 *External and Internal Photon Spectra*

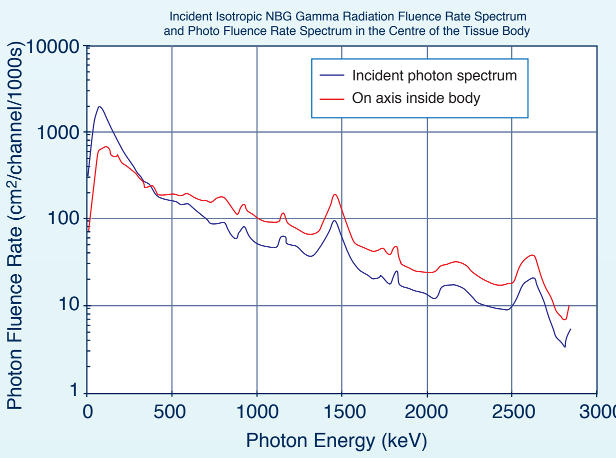
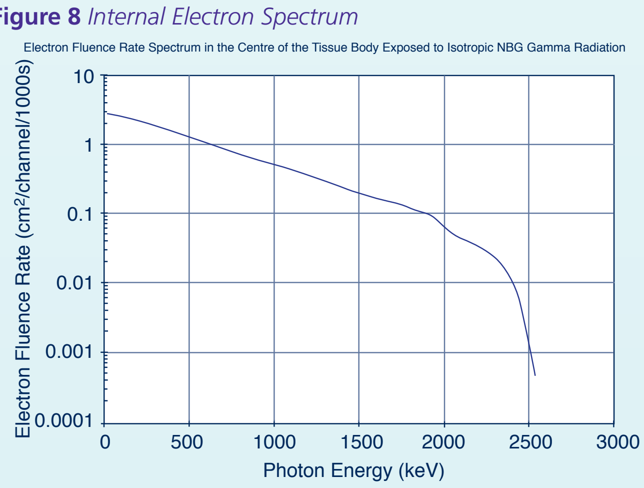


Figure 8 *Internal Electron Spectrum*



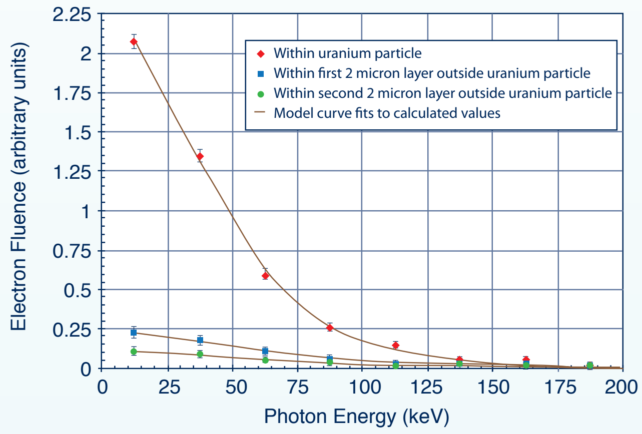
Fluence, Dose and Enhancement Calculations

- The electron fluence spectra were determined using FLURznrc (in EGSnrc) within the uranium particles and in a 2 micron layer immediately outside of it.
- Radiation doses were determined, using DOSrznrc (in EGSnrc) and utilizing both the internal photon and electron fluences (Figures 7 & 8), for a range of distances from the uranium particle at the centre of the body (X in Figure 6).
- The above dose calculations were then repeated with the uranium particle replaced by tissue.
- The dose enhancement factors were then calculated for the various distances:

  Dose Enhancement Factor = Dose in region with Uranium particle/Dose in same region without Uranium particle.

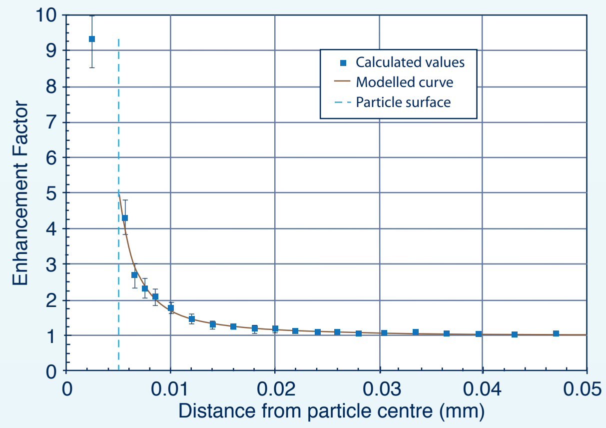
Results

Figure 9 *Electron fluence spectra in the uranium particle and in two 2 μm wide regions immediately outside of the particle.*



Note that, from Figure 2, greater than 93% of the total electron fluence, with energies below 200 keV, are photoelectrons. The contribution of the Compton electrons are within the error bars shown.

Figure 10 *Dose Enhancement Factors as a function of distance from the centre of the uranium particle*



Conclusions

For a 10 μm pure uranium particle in the centre of the human body:

From the fluence curves Figure 9

- The photoelectron fluence immediately outside of the uranium particle is only 14% of the fluence in the particle.
- The average electron energies are 39 keV in the particle, and 49 keV in the immediately surrounding tissue
- The corresponding ranges, calculated from the average energies, are 13 μm in the particle, and 39 μm in the immediately surrounding tissue

From the enhancement curve Figure 10

- The enhancement factor is only about 5 immediately next to the uranium particle, and about 9.3 inside the uranium particle
- The curve is roughly exponential in shape, as expected for poly-energetic electrons, and drops off fairly quickly with distance
- The range of the electrons in the tissue is about 35 μm. This value agrees favourably with the range determined from the electron fluence spectrum.

References

- Busby, C. 2005 Depleted uranium weapons, metal particles, and radiation dose. *Euro. J. Biol. Bioelectromag.*, 1, 82-93.
- Cho, W. D., Han, M-H., Bronson, M. C. & Zundelevich, Y. 2002 Processing of uranium oxide powders in a fluidized-bed reactor. I. Experimental. *J. Nucl. Mat.*, 305, 106-111.
- Milodowski, A. E. 2001 A trial investigation by scanning electron microscopy of uranium particulate in building debris associated with a depleted uranium munitions strike site during the Kosovo conflict. Commercial Report CR/01/145. Keyword: British Geological Survey.
- Pattison, J. E., Hugtenburg, R. P. and Green, S. 2010 Enhancement of natural background gamma-radiation dose around uranium microparticles in the human body. *J. Roy. Soc. Interface*, 7, 603-611.
- Tickell, O. 2008 How war debris could cause cancer. *New Scientist*, 195, 8-9.