Health Protection Agency and the Secondary Electron effect:
Bad faith and bad science

In 2008 LLRC submitted information to the HPA's consultation on radiological criteria for the on-land disposal of solid waste. Among other issues LLRC drew attention to work on the Secondary Photoelectron effect.[1]

HPA summarily diverted LLRC's entire submission into a separate consultation on application of ICRP's 2007 Recommendations (ICRP Publication 103) in the United Kingdom. HPA went on to publish its advice on waste disposal without acknowledging the scientific issues presented by LLRC, stating [2] that they would be addressed at the time of publishing advice on ICRP Publication 103.

In the interim, an unpublished response from HPA discussed the Secondary Photoelectron effect.[3] It applied an inappropriate method which underestimated the potential impact of incorporated Uranium (see below for discussion). LLRC issued a short response pointing out the error.[4] HPA attempted a rebuttal [5] but refused to discuss the matter further.

John Cooper, Deputy Director of the HPA's Centre for Radiation, Chemical and Environmental Hazards, wrote

> HPA is continuing computational work and will submit a paper for publication in a peer-reviewed journal. Accordingly, we will answer further questions on this topic when the paper is published and available to all interested parties for a more general debate. We would regard this as the normal scientific process …[6]

As far as LLRC knows, HPA staff have not had such paper published.[7] HPA went on to publish its advice on ICRP Publication 103 without acknowledging the unresolved status of the dialogue.[8]

The specific error in HPA's treatment of the Secondary Photoelectron effect is the use of Mass Energy Absorption Coefficients. These are an inappropriate quantity for investigating the evidence submitted because they give a ratio for the two media (Uranium and tissue) without accounting for their differing densities. The lower part of HPA's Figure 1, reproduced here, [9] uses the spurious ratio μ_{en}/ρ for the y axis.

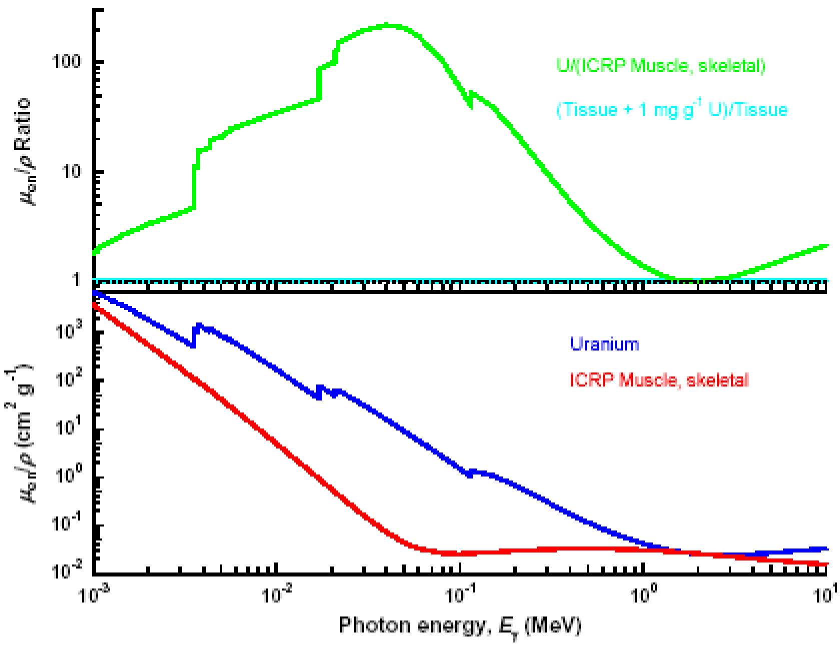

Figure 1. Comparison of the mass energy absorption coefficients for uranium and ICRP skeletal muscle. The lower part of the figure shows the direct comparison between uranium and skeletal muscle. The upper part of the figure gives the ratios of uranium to skeletal muscle and also with the addition of uranium to skeletal muscle: 1 mg g-1 of uranium has been added to exaggerate the difference, but the change in the absorption coefficient still peaks at only +1.1%.

[Note: the above legend is as provided by HPA.]

The value for 10^{-1} MeV on the x axis, for example, hence produces values of 10^{0} for Uranium and 10^{-2} for tissue. The ratio of these is 1:100. Using the more relevant quantity Linear Energy Dissipation or Linear Attenuation Coefficients (μ_{en}) for the same 10^{-1} MeV gives 10^{0} x 19.6 (Uranium) / 10^{-2} x 1 (tissue) = 1960.

The difference in opinion can be put another way as, in fact, HPA has;

> "When considering absorbed dose, this density-normalised parameter is the quantity of interest … " [10] (LLRC has added the emphasis)

and

> "… increasing the density of a medium increases the energy imparted to it but leaves the absorbed dose unchanged, since absorbed dose is defined as the energy imparted divided by the mass.".[11]

HPA accept [12] that LLRC showed correct ratios for Uranium and tissue using Linear Attenuation Coefficients. They accept that "this ratio is … useful since it can be used to calculate the number of interactions." The number of interactions is, in fact, the quantity of interest. It cannot be stressed too strongly that considering absorbed dose in this context is inappropriate, because this is one of the situations where, as the CERRIE Majority reported,

> "the actual concepts of absorbed dose become questionable, and sometimes meaningless, when considering interactions at the cellular and molecular levels."[13]

ICRP itself has acknowledged [14] the complexities and challenges of internal contamination under conditions where energy deposition is extremely heterogeneous.

The HPA graphs only work if the thought experiment is dealing with a homogeneous Uranium soup while in reality it is highly probable that the Uranium, and hence the interactions, will be on the DNA molecule itself. The energy absorbed by the Uranium is dissipated within the DNA or in tissue close by. A high proportion of the energy dissipated will be in the form of low energy electrons; one authority observed

> "[with reference to] Auger electrons, the point, as I'm sure you are well aware, is that low energy electrons give high density of ionisations along their track, comparable with the diameter of DNA (hence a greater possibility of double strand breaks). Also, because the shower is released instantaneously, there are many more ionisations (i.e. OH radicals) simultaneously in the vicinity of the emitting atom, hence an enhanced probability of DS breaks. […] This area of dosimetry is completely ignored in the "standard" models, but could be very important."[15]

The upper part of HPA's Figure 1 is derived from the lower, showing the result of dividing the Mass Energy Absorption Coefficients of Uranium at different energies by those of tissue. The peak difference is about 200:1. If Linear Attenuation Coefficients are used instead, the peak difference is about 4000:1. (The roughly 20-fold difference between these figures is equal to the ratio of the densities of the media involved.) However, we are discussing the Secondary Photoelectron effect which does not depend on ratios of density but on the ratios of the fourth powers of the atomic numbers (Z) of the elements. An atom of Uranium absorbs incident gamma or X rays 17,490 times as efficiently as an atom of Oxygen.

The foregoing calculations have been based on the conservative assumption that the absorption of gamma photons is proportional to the fourth power of the Z number. It has been pointed out [16] that the fifth power may be applicable. Authorities differ and this question has yet be resolved. If the fifth power is the relevant value the effect will be larger than the 17,490-fold difference given above.

The potential numbers of interactions implied by these large differences, and the consequent ionisation density in sensitive tissues must be considered for the purposes of regulating practices which involve releasing Uranium.

As for the location of the interactions, HPA's first paper [17] says that "little is known of the *in vivo* distribution of Uranium in cells." Data are available for DNA *in vitro* and it cannot be assumed that DNA binding does not happen *in vivo*. We suggest that the precautionary principle applies — i.e. that until the degree of Uranium binding in vivo has been demonstrated one should assume that it is at least as great as *in vitro*.

Other elements of high atomic number need consideration, especially those which bind to sensitive biological targets. The Secondary Photoelectron effect may provide a mechanism to explain heavy metal toxicity.

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[1] http://www.llrc.org/wobblyscience/subtopic/spe.htm

[2] HPA-RPD-052: Response to Comments Received during the Consultation on Proposed HPA Advice on Radiological Protection Objectives for the Land-based Disposal of Solid Radioactive Waste. K A Jones, S F Mobbs and T Anderson. HPA April 2009 ISBN 978-0-85951-639-6

[3] "Scientific / technical response to questions from Richard Bramhall relating to the assessment of doses and risks from internal emitters and ICRP methodology", pers. comm. HPA 9th December 2008. http://www.llrc.org/wobblyscience/subtopic/scientifictechnicalhpatobramhall.pdf

[4] http://www.llrc.org/wobblyscience/subtopic/uraniumhowler.pdf

[5] "Response to e-mail form [sic] Richard Bramhall, dated 5th January 2009". pers. comm. HPA 26th January 2009. Page 3 para 4.2.2
http://www.llrc.org/wobblyscience/subtopic/hparesponsetoemailfrombramhall.pdf

[6] email Dr. JR Cooper to Richard Bramhall 26th January 2009; "Re: ICRP 2007"

[7] HPA say they have submitted a paper to Radiation Protection Dosimetry. All we have so far (February 2010) is the abstract. A paper by Pattison *et al* is already published. For the citation and an appraisal see "Pattison's 2009 paper on the Secondary Photoelectron effect" at http://www.llrc.org/wobblyscience/subtopic/pattison2009spe.pdf or http://www.llrc.org/wobblyscience/subtopic/pattison2009spe.htm. Pattison says the effect is significant. So far, HPA hasn't said this. On the basis of the Pattison paper and HPA's abstract, we can say that the degree to which energy absorption and deposition are enhanced by the presence of a Uranium oxide particle in tissue is a function of distance from the particle's surface. We have no information on how Neither study reveals how it has modelled low energy photons. Neither Pattison nor HPA has addressed the issue of Uranium biologically bound to DNA, yet this is the nub of the issue; as particles dissolve they will cause very high U concentrations at the level of the cell and its internal structures.

[8] HPA-RPD-057: Response to Comments Received during the Consultation on Proposed HPA Advice on the Application of ICRP's 2007 Recommendations to the UK. J R Cooper, J Wellings and J R Simmonds HPA September 2009 ISBN 978-0-85951-649-5

[9] in "Scientific / technical response to questions from Richard Bramhall … " *op.cit.* p. 10

[10] "Response to e-mail … " HPA, Para 4.2.2

[11] We have paraphrased from HPA's para 4.2.2. *ibid.*

[12] in 4.2.2 *ibid.*

[13] from CERRIE (Government's Committee Examining Radiation Risks of Internal Emitters) Majority Report Chapter 2 *Risks from Internal Emitters Part 2* paragraph 11. Along with a number of extracts from other authorities, this paragraph from CERRIE was quoted in LLRC's paper to HPA's waste criteria dialogue. "*There are important concerns with respect to the heterogeneity of dose delivery within tissues and cells from short-range charged particle emissions, the extent to which current models adequately represent such interactions with biological targets, and the specification of target cells at risk. Indeed, the actual concepts of absorbed dose become questionable, and sometimes meaningless, when considering interactions at the cellular and molecular levels.*"

[14] http://www.llrc.org/wobblyscience/subtopic/dosemeaningless2.htm; http://www.llrc.org/wobblyscience/subtopic/dosemeaningless4.htm

[15] the late Dr. Philip Day pers. comm. 12th Jan 2009.

[16] Philip Day *op.cit.* and others.

[17] "Scientific / technical response to questions from Richard Bramhall … " HPA *op.cit*. p.11