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Reply to “Further considerations on ‘Towards the origins of over-dispersion in beta source calibration’ by Hansen et al., Radiation Measurements, 2018” by Munish Kumar

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Providing accurate calibration of the dose rates from beta sources used in laboratory irradiations is important when using luminescence for dose reconstruction. While the dose rate can be increased by increasing the activity of the source, this is associated with an increased radiation exposure risk, and is expensive. Instead, it has been suggested that the dose rate to the target sample can be increased by mounting the sample on a high Z material (Murray, 1981; Ingram et al., 2001; Goedicke, C., 2007; Greilich et al., 2008; Autzen et al., 2017 and Hansen et al., 2018)

Recently, Kumar (2019) commented on this suggestion, particularly citing the work of Hansen et al. (2018). He used the Rad Pro on-line calculator to derive the contribution from bremsstrahlung to the total dose rate when irradiating quartz grains on high Z substrates. From this he argued that, when irradiating on platinum, the bremsstrahlung contribution to the total dose rate is ~35%; this could be of concern because of the reported higher luminescence efficiency for low energy photons (Mejdahl, 1970; Attix, 1972; Alvaro et al. 2012; Guérin et al. 2018). We were very surprised by Kumar’s estimate of the relative significance of the bremsstrahlung contribution, and have since used Geant4 to model bremsstrahlung production, and its contribution to (a) the total dose rate to quartz and (b) the ionisation rate, when irradiating on various substrates. We found that the photon contribution to dose rate was <0.1%. This is not surprising, given the backscattered photon and electron spectra published by Autzen et al. (2017) for various 5 mm thick substrates.

We then turned to the Rad Pro Calculator (as used by Kumar, 2018) to derive the beta dose rate from a $^{90}\text{Sr}/^{90}\text{Y}$ beta source with an activity of 20 mCi at a distance of 1.5 cm and found perfect agreement with the 1.47 Gy/min given in Kumar's comment.

In order to use the Calculator to derive the bremsstrahlung contribution to this dose rate we had to make one assumption. There is no option for choosing Pt (Z=78) or inputting a user-defined shielding material, and so we selected lead (Z=92) as the closest; we assume that Kumar did the same. The online help file for Rad Pro states that the distance to be input when calculating the bremsstrahlung dose rate should be that from source to sample. Using the same source to detector distance as before (1.5 cm) we find that the contribution of bremsstrahlung to the total dose is approx. 0.04%, three orders of magnitude less than that derived by Kumar, but completely consistent with our GEANT 4 calculations. Kumar also states that he calculated the bremsstrahlung contribution at a sample distance of 0.5 mm from the substrate. Unfortunately entering this substrate to sample distance is not an option in Rad Pro, but if we instead use 0.5 mm as the source to sample distance we obtain a contribution from the bremsstrahlung to the total dose rate of ~35%, completely consistent with Kumar's value. The Rad Pro help file is unambiguous concerning the definition of the distance to be entered (source to sample, not shielding to sample), but we presume that Kumar misinterpreted the entry expected in the software, resulting in a significant error in his calculation.

We agree with Kumar that there is significant evidence in the literature (Mejdahl, 1970; Attix, 1972; Alvaro et al. 2012; Guérin et al. 2018) for a difference in luminescence efficiency between low and high energy photons (>120-150 keV). However, both GEANT4 simulations and the Rad Pro Calculator show the bremsstrahlung contribution to the total dose rate to be <0.1% when Pt is used as the substrate. Thus any efficiency difference is extremely unlikely to affect equivalent doses estimated using high Z substrates. We stand by our suggestion in Hansen et al. (2018) of using high-Z substrates to increase the dose rate to (multi-grain) samples, and reaffirm our view that doing so is unlikely to introduce significant additional uncertainty.

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