Monte Carlo characterization of a new directional Pd-103 high dose rate source for brachytherapy application

Pd-103 is traditionally used for low dose rate applications. However, when comparing the activity necessary to achieve a similar dose rate to Ir-192 at 1 cm, we found that:

For the same dose rate at 1 cm ($^{103}$Pd and $^{192}$Ir):

$$D_{Pd} = D_{Ir}$$

$$\Lambda_{Pd} \cdot PdS_K = \Lambda_{Ir} \cdot IrS_K \Rightarrow PdS_K = \frac{\Lambda_{Ir}}{\Lambda_{Pd}}$$

$$PdA \cdot 1.293 \frac{Ci}{mCi} = 10^4 mCi \cdot 4.6 \frac{Ci}{mCi} \cdot \frac{\Lambda_{Ir}}{\Lambda_{Pd}}$$

$$PdA = \frac{10^4 mCi \cdot 4.6 \frac{Ci}{mCi} \cdot \Lambda_{Ir}}{1.293 \frac{Ci}{mCi} \cdot \Lambda_{Pd}} = \frac{10^4 mCi \cdot 4.6 \frac{Ci}{mCi}}{1.293 \frac{Ci}{mCi} \cdot 0.687 \frac{Gy}{Ci}}$$

$$PdA = 5.8 \times 10^4 mCi = 58 Ci$$

The specific activity (SA) required for a high dose rate palladium source would be: SA=58 Ci/0.0923 g = 628 Ci/g. With a theoretical specific activity = 74680 Ci/g, we would need 0.84% of the theoretical value. For comparison, a high dose rate Ir-192 source is 0.6 mm diameter by 3.5 mm = 0.000989 cm$^3$. With the 10 Ci activity, the SA=450 Ci/g (about 4.9% of the theoretical value).

Therefore we tested the dose emitted from a simulated directional Pd-103 high dose rate source (Figure 1). Using MCNP5 at radial distances r(cm) = 0.5, 1.0, 1.5, 2.0, 3, 4, 5, 6, 7, 8, 9, 10 and polar angles (deg) = 0, 45, 90, 135, 180, 225, 270. The relative dose emitted from the Pd-103 seed (Figure 2) shows the directionality of the dose profile for selected distances. As you can see the dose is shaped toward the unshielded side of the seed (180 deg) with relatively little dose emitting from the shielded side (0 deg).

Figure 1. MCNP image of transverse and axial cross section image of Pd-103 directional seed (colors: pink-P active volume, blue-titanium encapsulation, yellow-osmium shielding, light green-air gap, light blue cube-tally surfaces.)
Figure 2. Relative dose for radial distance $r = 0.5, 1.0, 1.5$ and $10$ cm, at a given angle.