

The objective is to show that near a radioactive source the commonly used exposure rate equation has to be modified in order to take photon divergence into consideration. This is accomplished by showing the derivation of the standard equation in detail and then illustrating where photon divergence needs special consideration.

The commonly used equation for calculating the exposure rate is Eq.1 and the modified equation Eq.2. The reason for the modification is that the irradiated volume per unit entrance area is larger at close proximities. This means that charge produced per unit volume per photon penetrating the entrance area is smaller at close proximities than at a distance. Since the exposure is defined as charge liberated per unit volume or unit mass of air this results in Eq.1 overestimating the exposure rate. This is of relevance (a deviation of 10% or more between expected and measured value) at distance smaller than 5 cm. At larger distances the difference between both equations becomes negligible. An experiment using a Tc-99m point source and a calibrated exposure rate meter is performed to compare theoretical and experimental values and to show the difference between the predictions of the two equations. This comparison showed very good agreement of the measured values and the predicted values based on Eq.2 and an overestimation of the exposure rate calculated using Eq.1. This has also implications for the tabulation of Gamma factors (Γ) and their units: $(\text{mR}\cdot\text{cm}^2)/(\text{mCi}\cdot\text{hr})$ vs. $(\text{mR}\cdot\text{cm}^3)/(\text{mCi}\cdot\text{hr})$.

$$\text{Eq. 1: } \dot{X} \left[\frac{\text{mR}}{\text{hr}} \right] = \Gamma \frac{\text{Activity}}{\text{distance}^2} \quad \text{Eq. 2: } \dot{X} \left[\frac{\text{mR}}{\text{hr}} \right] = \Gamma \frac{3 \text{ Activity}}{(\text{distance} + 1)^3 - \text{distance}^3}$$