Calculation of dose rates due to 4.44 MeV gamma emitted by Am-Be source*.

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Abstract: Monte Carlo simulations (MCS) are carried out to estimate dose rates at several locations due to cylindrical Am-Be source, which emits 4.44 MeV gamma ray with sufficient intensity. Since, the source is contained in a doubly encapsulated thick stainless steel which prevents the escape of 59.5 keV X-ray emitted by it and hence does not contribute for the dose rate outside the source. It is found in the literature the measurement of count spectrum for this gamma ray obtained with 2”×2” NaI (Tl) crystal at a particular distance. The dose rate from the count spectrum is deduced by estimating the photon flux and then convoluting with the ANSI-FLUX-TO-DOSE conversion factor. It is to be noted here to get the photon flux, the counts under the photo-peak and single and double escape-peaks are considered. The agreement between the simulated result and the deduced rate is very good.

Besides, Monte Carlo simulations have been carried out to estimate the dose rates due to both neutrons and gamma rays. The gamma rays comprises of those produced in the source as a result of alpha interaction as well as those secondary gamma rays produced in the structural materials. Significant amount of gamma rays are due to 4.4 MeV gamma ray from the source and 2.2 MeV gamma ray produced by the hydrogen present in the concrete structure due to absorption of a neutron. The gamma dose rates for 4.44 MeV and 2.2 MeV are deduced from the count spectrum (as mentioned above). MCS results are compared with dose rates deduced with count spectrum and are in good agreement. The neutron and total gamma dose rates measured with neutron survey meter and GM survey meter are compared with the MCS result. Agreement is excellent in the case of neutron whereas a large discrepancy observed in the case of total gamma dose rate.

Introduction:

Am-Be sources are widely employed to carry out both neutron and gamma radiation experiments such as transmission, attenuation and activation etc. The measurement and estimation of radiation field strength both in quality and quantity are important for safety in experimental facilities. The radiation source needs to be housed in a suitable container which can reduce the strength of the radiation field in the vicinity of the source. The intensity of radiation fields around the source are required to be known in order to carry out experiments safely.

In the present work, MCS have been carried out using Monte Carlo N-particle transport code[2](MCNP) for the calculation of dose rate due to 4.44 MeV gamma, which is then compared with the dose rate estimated using the gamma count spectrum measured with 2”x2” NaI(Tl) detector. Further neutron and gamma total dose rates are computed with MCS for a particular location, where experimental results are available enabling comparison between them.

Material & Methods:

The present experimental facility has a 16 Ci Am-Be source housed inside a concrete bunker, which emits 4×10^7 neutrons/s[1] and 3×10^7 photons/s[3]. The gamma dose rates due to 4.44 MeV and 2.2 MeV are deduced from the count spectrum obtained with 2”×2” NaI(Tl) detector as shown in figure 1. The gamma count spectrum in figure 1 has been taken from reference 1. There are several peaks at 4.44 MeV (source emission), 2.2 MeV (Capture gamma from the hydrogen present in the concrete bunker). The 3.4 MeV is not a peak due to gamma ray but appears as a result of double escape of positron annihilation gamma ray produced due to pair production effect inside the NaI crystal. The photon fluence deduced from the count spectrum are then used to estimate the dose rate by using the ANSI-FLUX-TO-DOSE conversion factors. Estimated dose rates are due to 4.44 MeV gamma and are compared with the dose rate estimated with the count spectrum. The total neutron and gamma dose rates calculated using MCNP are then compared with the dose rates measured with neutron survey meter and GM survey meter, and the details are given in the following sections.

Results & Discussion:

MCS results compared with measured dose rates for Am-Be source of strength 16 Ci housed in a concrete bunker which emits 4×10^7 neutrons/s[1]. Am-Be source emits neutrons besides it emits 4.44 MeV gamma ray with sufficient intensity produced from the ^{13}C excited state, whose strength is 3×10^7 photons/s (0.75 photons per neutron[3]). The gamma ray of 59.5 keV emitted by Am source does not contribute to the dose rate at experimental location since it gets absorbed by the stainless steel structure(5 mm) present around the source. MCS have been carried out accounting the bunker structure in detail. The dose rate estimated from the gamma count spectrum for the 4.44 MeV and 2.2 MeV are then compared with the dose rate computed using the MCNP[2]. The computations also include the total dose rates due to both neutron and gamma (source and capture gammas). The total neutron and gamma dose rates are computed with the Monte Carlo simulations which are then compared with the measured results and are presented in detail.

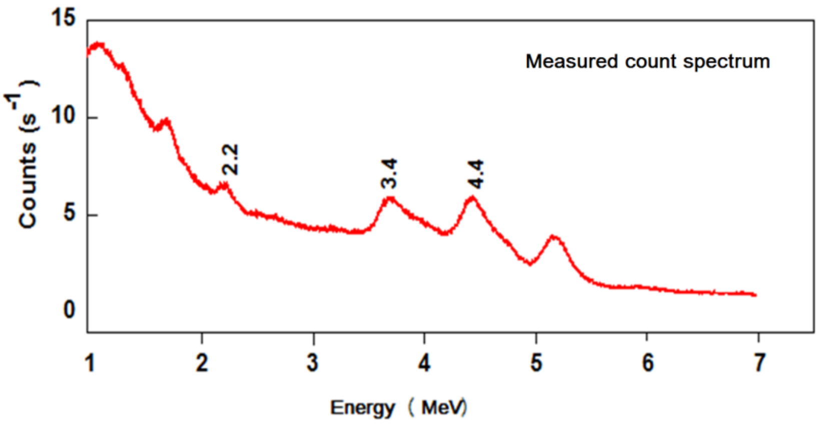

Figure 1 - Measured count spectrum

(Reproduced from reference 1)

A. Comparison of Neutron dose rate:

Monte Carlo simulations has been carried out accounting the concrete bunker structure for the estimation of neutron fluence by the source at a distance of 85 cm from the source. The dose rate by the fluence is calculated using the ANSI-FLUX-TO-DOSE conversion factors. The neutron dose rate measured with Gamma neutron survey meter at the same distance and is compared with the calculated dose rate. Measured and estimated neutron dose rates are using MCNP are in excellent agreement with each other and the dose rate values are given below.

MCS dose rate at 85 cm from source: 2036.8 µSv/hr

Measured dose rate at 85 cm from source: 1985.0 µSv/hr

B. Deduction of dose rates for 4.44 MeV & 2.2 MeV gamma from NaI(Tl) count spectrum:

Gamma dose rate mainly comprises of 2 components viz. 4.44 MeV source gamma (emitted by the source by the C^{13} excited state) and 2.2 MeV capture gamma (emitted as result of absorption of neutron by the hydrogen present in the concrete bunker structure). The count spectrum measured with the help of 2”×2” NaI(Tl) detector which is placed at a distance of 85 cm from the source. For the estimation of the photon fluence from the count spectrum the counts from the 2.2 MeV peak and 4.44 MeV peaks are considered with the single and double escape peaks. The counts under 4.44 MeV and 3.4 MeV (double escape peak) are summed to estimate the gamma fluence rate falling on the detector. In estimating the gamma fluence rate the base line constant background counts are subtracted from the peak totals. The photon fluence rates are then converted to dose rates by using the ANSI-FLUX-TO-DOSE conversion factors. The flux at these values are deduced from the count spectrum shown in table 1. The resulting dose rate are compared in table 1 and are in good agreement.

Table 1– Comparison of dose rates

Parameters		4.44 MeV	2.2 MeV *
FWHM (keV)		223	128
Channels		52	67
Counts(s^{-1})	4.44 MeV	215.45	70.47
	3.42 MeV †	34.7	
Efficiency of Detector		3.4 %	6.0 %
Photons ($p/cm^2.s$)		293.58	46.6
Dose rate (μSv/hr)		15.85 ±0.8	1.99 ±0.03
MCS dose rate (μSv/hr)		16.11 ±0.1	1.59 ±0.01

*Capture gamma by $^{1}H(n,\gamma)^{2}H$ interaction.

† Double escape peak of 4.44 MeV.

C. Comparison of total dose rate by gammas:

The total gamma dose rate measured at a distance of 85 cm from the source with GM survey meter. Monte Carlo simulations has been carried out using MCNP accounting the bunker structure to estimate the total dose rate due to gamma radiation. The comparison between the measured and total computed dose rate is given below.

Measured total dose rate: 9.0 μSv/hr

Simulated total dose rate: 17.84 μSv/hr

Conclusion:

The neutron dose rate calculated is in good agreement with the measured dose rate. However, the under estimate of measured total gamma dose rate might have resulted due to less sensitivity of GM counter survey meter for 4.44MeV gammas. This statement is further corroborated by the agreement of 2.2 MeV and 4.44 MeV values between measured and simulated dose rates.

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