Simulation of dose to the eye lens from Co-58 and Co-60 in overhaul of a PWR nuclear power plant

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1. Introduction

In 2012, the International Commission on Radiological Protection (ICRP) announced for the lens dose of the eye. The threshold of lens in absorbed dose is now considered to be 0.5 Gy. For radiation worker in planned exposure situation, the ICRP recommends an equivalent dose limit for the lens of the eye of 20 mSv/year, averaged over a 5-year period, with no single year exceeding 50 mSv[1].

The Commission continues to recommend that optimisation of protection to reduce absorbed dose for lens of eye. Thus an accurate assessment of eye lens is necessary to reduce lens dose.

In this study, MCNPX, the monte carlo simulation code, was employed to evaluate lens dose. We measured gamma energy spectrum using NaI sintillator-based detector in overhaul of a PWR nuclear power plant and simulated the eye lens to evaluate absorbed dose by Co-58 and Co-60.

2. Methods and Results

To measure presence of gamma radiation nuclide species in overhaul of a PWR (Pressurized Water Reactor) nuclear power plant, the Inspector^{TM} 1000 Digital Hand-Held Multichannel Analyzer (Canberra industries, Inc.) which is gamma radiation energy analysis spectrometer based on NaI(Tl) scintillator was used. The dimension of NaI(Tl) scintillator is 50 × 50 mm and sensitivity of Cs-137 is 13,000 cps/mrem/hr. Energy deposition in the eye lens for the incident gamma radiation was calculated by using MCNPX 2.6e[2].

Fig. 1, depicts the geometrically modeling of the eye and radiation field. The total volume and diameter of the eye are 65 mm^3 and 25.5 mm respectively. Lens of the eye is largely composed of hydrogen (9.6 %), carbon (19.5 %), nitrogen (5.7 %), and oxygen (64.6 %). The dose depth of the eye lens is 3 mm and the density of lens is 1.070 kg/cm^3[3]. A field size of gamma radiation source used in these simulations is 20 × 20 cm^2 and the flux was 2.5 × 10^3 particles/mm^2. The distance from gamma radiation field to the eye was 1000 mm. And thickness of lead glass which is used to reduce absorbed dose of the lens is 2 mm.

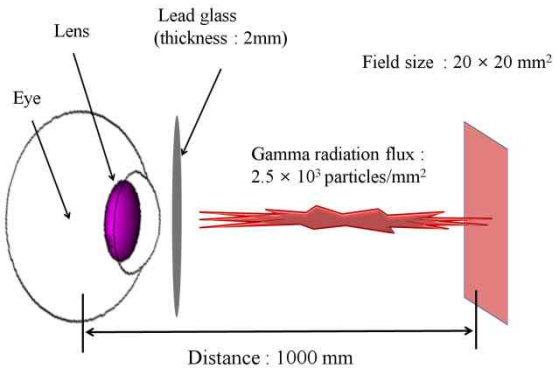

Fig. 1. Geometric modeling of the eye and gamma radiation field.

Fig. 2, shows measured gamma energy spectrum at RCB 88ft of the plants using Inspector^{TM} 1000. The peak of gamma energy spectrum was measured at about 511, 811, 1170, 1330 KeV. These energies are almost same with Co-58 (511 and 811 KeV) and Co-60 (1170 and 1330 KeV). Through this result, the Co-58 and Co-60 were expected to exist in overhaul of a PWR nuclear power plant.

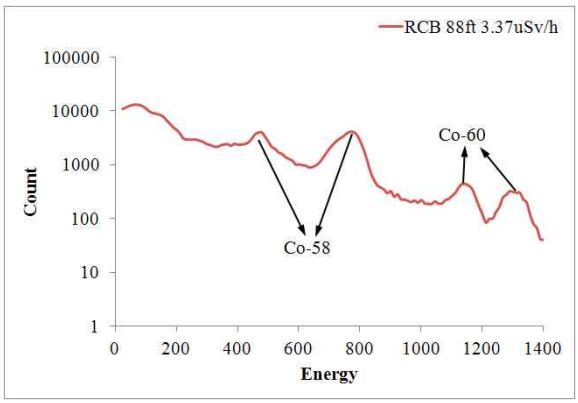

Fig. 2. The measured gamma energy spectrum at RCB 88ft of a PWR nuclear power plant using Inspector^{TM} 1000.

To evaluate absorbed lens dose in the overhaul, we calulated lens dose by Co-58 and Co-60 using MCNPX. Also a shielded lens dose by 2 mm thick of lead glass which has 2 mm of thickness and located in front of eye was calculated to compared with absorbed dose by shielding material.

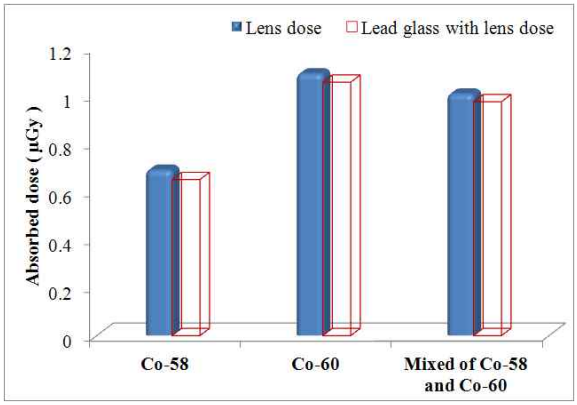

Fig. 3. Absorbed dose and shielding dose by 2 mm thickness of lead glass at eye lens

Fig. 3, shows absorbed lens dose and shielded lens dose by 2 mm thickness of lead glass. The absorbed lens dose were 0.69, 1.09, 1.0 μGy and shielded dose were 0.65, 1.05, 0.97 μGy in Co-58, Co-60 and mixed of Co-58 and Co-60 respectively.

The dose rate attenuated by lead glass were calculated about 5.6 % (Co-58 average energy 611 KeV) , 3.1 % (Co-60 average energy 1250 KeV) and 3.1 % (mixed average energy 955.5 KeV). From this result, the absorbed dose and attenuated dose rate was higher than lower energies. Generally, the absorbed dose and shielded dose by lead glass are dependent on its gamma radiation energies[4]. Therefore, the dose is higher than lower energies and shielding performance of lead glass is more falling down at higher gamma energy.

3. Conclusions

In this study, we have calculated a lens dose of human eye in overhaul of a PWR nuclear power plant. The MCNPX was used for simulating absorbed lens dose of eye and shielded dose by 2 mm thick of lead glass in presence of gamma radiation energy which had Co-58 and Co-60. Using Inspector^{TM} 1000 Digital Hand-Held Multichannel Analyzer, Co-58 and Co-60 were measured at RCB 88ft of the plant during overhaul. using Inspector^{TM} 1000. To evaluate dose rate, we simulated the absorbed lens dose and shielded dose by lead glass. The absorbed dose were 0.69, 1.09, 1.0 μGy and shielded dose rate were 5.6 %, 3.1 %, 3.1 % in Co-58, Co-60 and mixed of Co-58 and Co-60 respectively. Further studies will be carried out to fabricate a eye phantom for measuring accurate absorbed lens dose using TLD and other radiation dosimeters.

REFERENCES

[1] ICRP, Radiological Protection in Fluoroscopically Guided Procedures Performed Outside the Imaging Department, Publication 117, Annals of the ICRP 40(6), 2012

[2] D. B. Pelowitz, MCNPX User's Manual, Version 2.6.0, Los Alamos National Laboratory report LA-CP-07-1473 , 2008.

[3] ICRP, Report on the Task Group on Reference Man, Publication 23, 1975.

[4] NCRP, Structural Shielding Design for Medical X-ray Imaging Facilities. NCRP Report No. 147, 2005.