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Evaluation of worker's dose on a virtual dismantling environment

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1. Introduction

The motivation of this study is to provide a basis for a minimization of worker's dose during dismantling activities. In the present study, we proposed methods for identifying an existence of radioactivity which is contained in the dismantling objects and for evaluating a worker's dose under a virtual dismantling environment. To evaluate a worker's external dose, the shape of the exposure room in the KRR 2(Korean Research Reactor TRIGA MARK III) by 3D CAD was created and the radiation dose surrounding the facility by using MCNP-4C(Monte Carlo N-Particle-4C)[1] was calculated. The radiation field of the exposure room was visualized three dimensionally by using the radiation dose that was obtained by the code.

2. Mapping of radioactivity distribution

The assessment of a radioactivity inventory is one of the most important issues as means to improve the efficiency of a dismantling by predicting a radioactivity level in advance. The exposure room at KRR-2 which was chosen to visualize the radioactivity is a facility with high density concrete of 3.4m-thick. Using a measured radionuclide concentration (29 points) of ^{60}Co[2] it was created with a contour mapping of concrete shielding in the facility(Fig. 1). As shown in the picture, the wall where the radioactivity concentration represents the highest was in the right side of the east area and the next area was in the center of the west area.

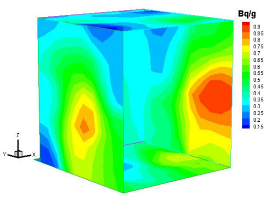

Figure 1. Visualization of the radioactivity in exposure room

3. Design a virtual dismantling environment

3.1 Modeling of dismantling environment and worker

The radiation field of the exposure room divided 3m x 3.7m into a number of nodes(6 x 6) in order to classify the radiation dose inside the facility. To model a worker's external exposure, we assumed that concrete shielding in the exposure room is ordinary heavy concrete, it was only activated on the east wall where the radioactivity was the highest, the gamma-radiation distributes uniformly from the wall, the radiation source emits isotropic from the gamma-radiation, the workers are a standard Korean who wear a protection cloth with TLD badge, and the volume dose regarded a worker's internal organs and texture are not taken into account in this study.

3.2 Computation of radiation dose

In order to obtain the radioactivity level of the radiation field in the exposure room, the energy spectrum of the radionuclide was calculated by using the Monte Carlo N-Particle(MCNP-4C) transport code. For the point sources, Monte Carlo simulation was done for a very fine grid set of source locations(146 source locations between 3m and 3.7m from the phantom) and 2 photon energies 1.17 and 1.33 MeV in ^{60}Co and eight photon energies 0.122 through 1.408 MeV in ^{152}Eu and ^{154}Eu, respectively.

The dose conversion factor of ICRP Publication 74[3] is employed to calculate the effective dose rates in order to calculate the dose rate from a particle fluence. To obtain the density of the concrete, reference chemical compositions such as O, Al, Si, Ca, and Fe were used. A density value of 2.347 g/cm^3 was obtained from the neutron and gamma quantum attenuation parameters.
For an error of lower than 0.01, the history of the simulation was selected as 5,000,000. In addition, a power detector tally("F5 type" estimates in MCNP) was applied to the calculation. The radiation dose by node that was calculated from MCNP is shown in Table I.

Table 1. Radiation dose by node near exposure room

(unit: uSv/s)

	300	250	200	150	100	50
370	1.44E+02	1.26E+02	1.14E+02	1.46E+02	1.77E+02	2.16E+02
310	1.65E+02	1.27E+02	1.07E+02	1.26E+02	1.61E+02	2.25E+02
250	1.88E+02	1.42E+02	1.28E+02	1.63E+02	1.92E+02	2.22E+02
190	2.74E+02	1.96E+02	1.74E+02	2.19E+02	2.51E+02	3.07E+02
130	2.26E+02	1.63E+02	1.46E+02	1.87E+02	2.17E+02	2.53E+02
70	1.74E+02	1.26E+02	1.07E+02	1.23E+02	1.87E+02	2.07E+02

3.3 Algorithm of worker's behavior

3D coordinates are measured with the help of three axes: X, Y, and Z. The axes meet at a point in the shape of a tripod as shown in Fig. 3. This point is called the origin point, which is the 0,0,0 location of all the coordinates. All distances can be measured by using this point as a reference. The highest radiation dose represents 307 uSv/sec at a point (50, 190, 0) of the X, Y, Z-coordinates, which means a distance of 190cm from the origin point to the Y-axis and 50 cm from the origin point to the X-axis. The lowest dose rate was 107 uSv/sec at (200, 70, 0) located at 200cm from the X-axis and at 70cm from the Y-axis. A time that was spent for dismantling has programmed it by using function of timesensor and a distance used the following equation:

$$\text{Distance} = \sqrt{coor.ofstart^{2} - coor.ofmoving^{2}}$$

Algorithm in order to evaluate an exposure dose for worker is described in Figure 2.

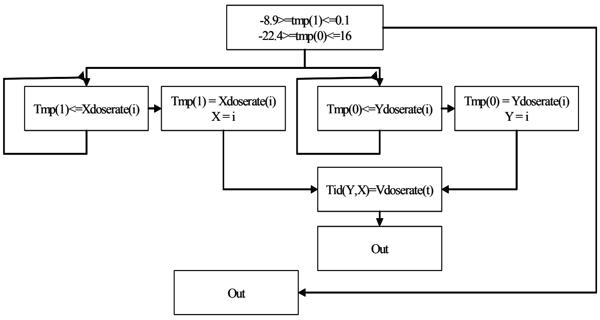

Figure 2. Algorithm for calculation of worker's dose

3.4 Evaluation of worker's dose

To evaluate the exposure dose in a real-time while the worker dismantles the concrete shielding of the exposure room, an animation and simulation module was constructed. Many of the components that are needed to design the animation were established by using AutoCAD, 3D MAX, and EON software. Under the circumstance of the animation, a simulation module enables estimation of personnel dose during a dismantling of the objects inside a room. Fig 3 illustrates that a worker is dismantling the concrete shielding according to the decommissioning scenario through an animation and it also represents simultaneously the dose rate that the worker will be exposed to. This picture shows that dose rate a worker is exposed to is 28 uSv/sec during 120 minutes and moved 88m to dismantle the exposure room.

4. Conclusion

This study was conducted to establish basic technology for a visualization and evaluation of a worker's dose based on information that was collected from a core sampling. Based on the radioactivity inventory that was irradiated at the object, the radiation dose by using MCNP-4C to estimate a worker's dose after a modeling, a virtual dismantling environment was calculated. On the basis of the radiation dose the radiation field surrounding the exposure room by using computer graphics was visualized. This simulated dose rate can correctly illustrate a worker's dose rate in a real-time.

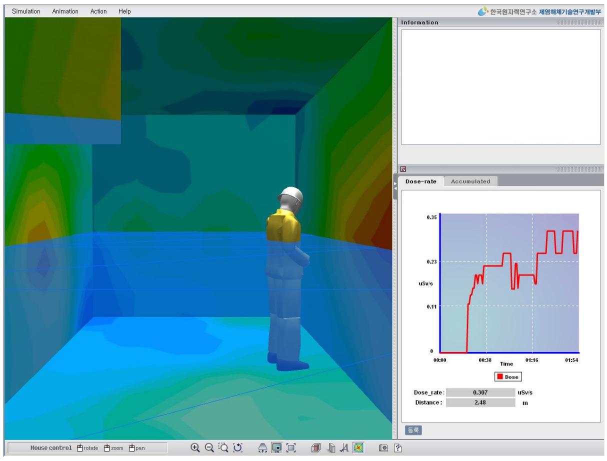

Figure 3. Scene of dismantling exposure room and dose

Acknowledgements

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[1] G. W. Mckinney., et al., "MCNP Application for the 21st Century ", Form SNA 2000 Conference, Tokyo, Japan, Sept. 4-7, 2000

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[3] Annals of the ICRP, 1996. Conversion Coefficients for use in Radiological Protection against External Radiation. The International Commission on Radiological Protection. 26, No. 3/4, ISSN-0146-0453.