Development of a Methodology for Assessing Radiation Exposure Scenarios for Workers in Accidents

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1. Introduction

In order to effectively and safely manage the radiation exposure to nuclear power plant(NPP) workers in accidents, major overseas NPP operators such as the United States, Germany, and France have developed and applied realistic 3D model radiation dose assessment software for workers.

Currently, programs that are actively used around the world include VISIPLAN developed in Belgium, VRdose developed in Norway, and PANTHERE-RP, ADRM, and DEMplus developed in France. Recently, continuous research and development has been conducted, such as performing NPP accidents management using 3D-VR based ALARA Planning Tool.

In line with this global trend, it is also required to secure technology to efficiently manage radiation exposure of workers in Korea. Therefore, in this paper, we intend to develop methodology for assessing radiation exposure scenarios for workers in response to accidents, which are elementary technologies for radiation exposure prediction, diagnosis, management, and utilization of training simulation following accidents.

2. Assessment of Radiation Exposure Scenarios for Workers in accidents

2.1 Investigation and analysis of response scenarios for accidents

In this study, loss-of-coolant-accident(LOCA), which can cause accidents such as melting the reactor core, was selected as the target accidents. The LOCA is an accidents in which the pipe of the reactor coolant system supplying coolant to a nuclear reactor core is damaged and coolant is lost through the damaged pipe. When LOCA happens, the post accident sampling system(PASS) must be turned on and a sample taken for analysis and evaluation within 8 hours[1]. The sampling procedure when LOCA occurs was analyzed and summarized as shown in Table I.

Table I: Sampling procedure after LOCA

	No.	Action	Time (sec)
Moving	1	Accessing the sampling module entrances	300
Water sampling	2	Preparing the sample tray	10
	3	Disconnecting the air line	15
	4	Loading the sample into the reservoir	30
	5	Leaving the room	15
Air sampling (three samples taken)	6	Taking a 1cc sample from the sample chamber(for hydrogen analysis)	30
	7	Putting the syringe containing the sample into the transport container	30
	8	Repeat steps 6 and 7(for oxygen analysis)	60
	9	Repeat steps 6 and 7(for radiation analysis)	60
	10	Leaving the room	15
Monitoring	11	On-line monitor scan	900
Moving	12	Transporting the sample to the laboratory	300

2.2 Assessment of worker exposure dose in accidents

In this study, a 3D model for MCNP was developed to assess the exposure dose according to the scenario of the sampling workers in accidents and to create a dose map to be applied to VRdose[2]. The MCNP code developed by LANL(Los Alamos National Laboratory) in the United States and is most widely used worldwide[3]. 3D modeling was performed for the assessment area selected in consideration of the path of sampling workers in accidents and the location of component containing high radiation source.

The generated model was used to assess the worker exposure dose in accidents, and radiation field data to be applied to VRdose were created(Fig. 1). The dose assessment was performed using the MCNP and was performed according to the following procedure.

a. Dose assessment in the corridor before opening the sampling valve
b. Dose assessment inside the sampling room after opening the sampling valve
c. Generation of radiation field in evaluation area using the result of dose assessment in the corridor and sampling room

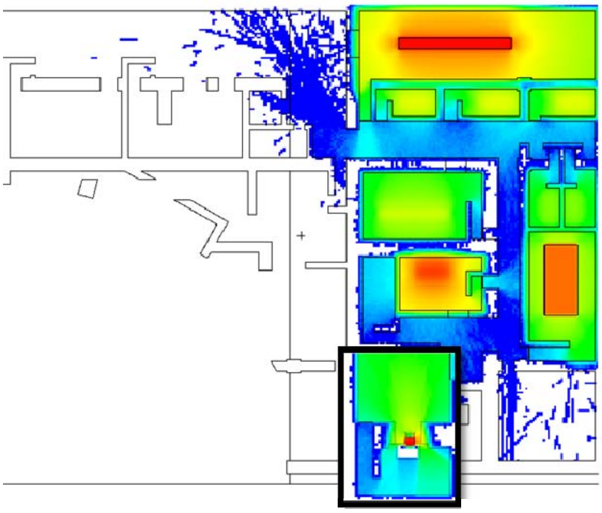

Fig. 1. Radiation field in assessment area

2.3 Assessment of radiation exposure scenarios for workers

2.3.1 Scope and assumptions

The assessment area of the sampling scenario after the LOCA was set to auxiliary building 55 ft floor-post accident sampling room-auxiliary building elevator. According to the set work range, the main path and sampling space were selected as the auxiliary building 55 ft floor-sampling room-auxiliary building elevator as shown in Fig. 2.

Fig. 2. Path and work space of sampling workers after LOCA

2.3.2 Development of the scenarios

The work scenarios were composed of a total of five(5) types, including scenarios A to E, in consideration of the three(3) principles of radiation protection: time, distance, and shielding. To construct each scenario, detailed work procedures and expected work hours were constructed using the work scope assumed above. In addition, in order to set the estimated time for each path, weighting factors were given by weight considering the weight of the sample storage device and lead shielding, and the time for each path of the workers was assumed. Major assumptions for each scenarios are as shown in Table II.

Table II: Number of workers and radiation protection measures for each scenario

Scenario	Number of Workers	Number of radiation shielding (left/right)	Radiation protective measures
A	2	3/3	X
B	2	3/3	O
C	3	3/3	O
D	3	4/2	O
E	3	5/1	O

2.4 Results

VRdose Dose-rate Analyzer was used to assess the worker exposure dose in each scenario. The dose rate for each scenario shows a peak as shown in Fig. 3. This is the point at which the workers open and close the valve. Therefore, radiation exposure of workers was not affected by the exposure due to the path and the installation of the radiation shielding, and the main cause of the radiation exposure of workers was the length of time which sampling was conducted in the sampling room.

The Nuclear Safety Act and ALARA regulatory guidelines require radiation exposure management by setting design targets for the collective dose of workers and the individual dose of the public in the planned exposure situation of NPP workers, and it is regulated so that the radiation exposure of radiation workers does not exceed the dose limit. Therefore, the worker exposure dose in the sampling scenario after the LOCA was evaluated based on the maximum individual dose and collective dose. Table III shows the worker exposure dose for each scenario calculated by VRdose.

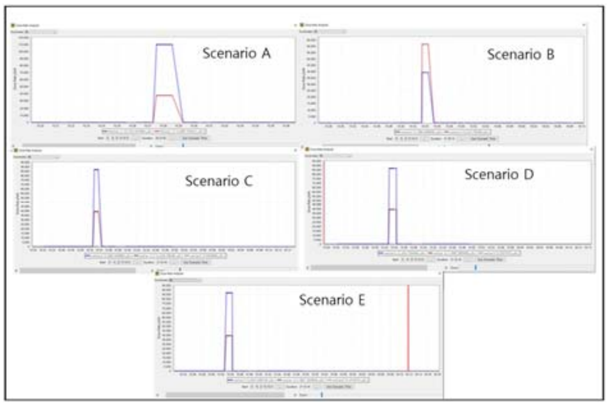

Fig. 3. Worker exposure dose rate by scenario using VRdose

Table III: Worker exposure dose by scenario

Scenario	Worker 1 [μSv/h]	Worker 2 [μSv/h]	Worker 3 [μSv/h]	Collective Dose [man·mSv]
A	3176.03	1085.70	N/A	4.262
B	2012.79	1286.64	N/A	3.299
C	2268.44	1029.23	0.54	3.298
D	2163.70	985.38	0.53	3.149
E	1904.34	867.26	0.47	2.782

3. Conclusions

In this paper, methodology for assessing radiation exposure scenarios for workers in accidents, which are elementary technologies for exposure prediction, diagnosis, management, and utilization of training simulation following accidents was developed.

First, a VRdose 3D model was developed and optimized for the assessment area, and a dose map derived from MCNP computational analysis was imported into VRdose to build a virtual environment for dose assessment for the scenarios.

As for the worker scenarios to be applied to the evaluation using VRdose, a number of response scenarios were derived according to the moving and working time changes according to the number of workers, the presence of lead shielding during work, and how to use them, considering the three(3) principles of radiation protection: time, distance, and shielding. According to each scenario, the radiation exposure dose received by workers during work was compared and analyzed, and the optimal scenario was derived based on the results.

It is expected that the results of this study can be used as a basic technology to secure workers safety through simulation of various types and scenarios in the future. In addition, based on the input and output data of the exposure dose prediction and diagnosis program, it is expected to secure the possibility of data-based analysis of radiation environment data and exposure following the occurrence of accidents.

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