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Sensitivity Analysis for Iodine Spiking Effect on Main Steam Line Break in Westinghouse type Nuclear Power Plants

Seung Chan Lee*, Duk Joo Yoon and Dong Soo Song
Korea Hydro Nuclear Power Electricity Co., KHNP Central Research Institute, Yuseong-daero 1312, Yuseong, Daejeon 305-343 Korea.
**Corresponding author: eitotheflash@khnp.co.kr*

1. Introduction

In the RCS (Reactor Coolant System) of NPP (Nuclear Power Plant), so many kinds of fission products are generated from radiation decay. Specially, FSAR (Final Safety Report) includes radiation dose results of DBAs (Designed Basis Accidents). In this case, two types are estimated as radiation dose. First one is an internal dose and another one is an external dose. The internal dose is arranged by the fission products of Iodine isotopes and the external dose is arranged by the others except for iodine isotopes.

Iodine of them has various behaviors in the case of impacting into human. This study introduces the patterns and results from spiking effects which are the phenomena of immediately increasing the iodine concentration in RCS. In addition, the sensitivity results are shown regard to Iodine spiking in Main Steam Line Break [1, 2, 3].

2. Methodology and Strategy

Generally speaking, Iodine spiking effect is very important to estimate LCO (Limiting Condition of Operation) criteria. Therefore, the strategy of sensitivity is carried out using the method implemented in KHNP Central Research Institute in 2011, 2015. In Fig. 1, the strategy is shown [1, 2].

2.1 Parameters in Sensitivity Analysis

In Fig. 1, we use the process between “Impact Analysis for Criteria” and “Recommend Dose Rate Limit for LCO” as the impact factor to check the sensitivity intensity of analyzing the iodine spiking.

Here some processes are excluded from Fig. 1, because the processes are not useful in this study.

In this study, a general process is shown in Fig. 1.

In Iodine spiking, the SGTR (Steam Generator Tube Rupture) is strongly sensitive in the case of the leakage between primary coolant and secondary coolant. But radiation dose rate of MSLB is strongly impacted in Iodine spiking phenomena [1].

This phenomena is generated from the rapidly pressure changing rather than SGTR. The reason why a MSLB is selected in this study is the very unstable pressure phenomena. The analysis input parameters of MSLB are shown in Table 1.

From Table 1, PIS (Pre Iodine Spiking) means that Iodine spiking effect is in the starting point before a general accident of MSLB.

Another one, GIS (coincident event-Generated Iodine Spiking) means that Iodine spiking effect is in the beginning after MSLB immediately.

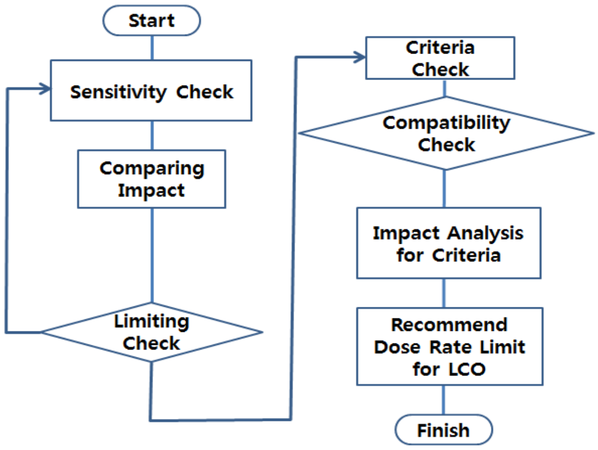

Fig. 1 Sensitivity strategy for analyzing Iodine spiking effect [4].

Table 1. Input Parameters for MSLB

Input parameters	Value
Fuel Failure	
-Gap Activity ratio	0.1
-Cladding Failure ratio	0.02
-Radial Peaking Factor(radius)	1.65
Iodine Spiking from Accident	
-RCS Liquid Inventory	1.97E+05 kg
-Iodine Escape Ratio	1.38E-08
-Spiking Factor (PIS case)	500
-Spiking Factor (GIS case)	0.01
-Fuel Failure Ratio	
Dose Equivalent Iodine	0.01
-RCS(PIS case)	60 uCi/g
-RCS(GIS case)	1.0 uCi/g
-Secondary Coolant	0.01 uCi/g
Time during Accident	
-Equilibrium time	1800 sec
-Initial time	7200 sec
-Later time	28800 sec
Exclusion Area Boundary	700 m
Breathing rate	3.47E-4 m^3/sec
Atmospheric Dispersion Factor	1.96E-4 sec/m^3

2.2 Analysis Basics

RADTRAD software is used to implement the sensitivity analysis of Iodine spiking effect.

So many conditions are made from RCS concentration based on TS (Technical Specification). The basic increase source term is slowly increased from 0.1 uCi/gram to 1000uCi/gram by using unit term of 0.1uCi/gram. And the reaching time to LCO is compared with the Iodine concentrations. Other hand, the calculated radiation dose is compared with the radiation dose of the Iodine deposition condition. Generally, Iodine isotope is easily deposited on the soil surface because of particle characteristic behavior.

FSAR includes the results of thyroid dose and whole body dose. The thyroid dose is arranged from internal dose in the concept of the target organ. Also whole body dose is arranged from external dose in the concept of the photon energy generated from gamma decay of unstable fission products. Therefore in the side of external dose, Iodine distribution is excluded because Iodine has only beta decay method except for meta-stable Iodine isotopes generated from mother fission products such as Te-132, Te-133, Te-134. Generally speaking, beta ray impact into human body is very light. And then the beta ray impact is negligible in the effect of external dose. Furthermore, Iodine spiking effect conditions exclude the meta-stable Iodine isotope. The reason is that all isotopes are in the equilibrium state.

In another word, this means that all of Iodine is not in the meta-stable state. So many reasons as above can exclude the unstable Iodine. Gamma ray (photon) of unstable Iodine is neglected.

2.3 Sensitivity Analysis Items

Analysis categories are consisted of four items. These items are below:

a. Spiking effect
b. Deposition effect
c. Fission products distributions
d. Dose Conversion Mode effect

In this chapter, the methods of each item are explained.

The spiking effect is calculated by the spiking factor and then the non-spiking result is compared with spiking result. In addition, on increasing the concentration of Iodine, the reaching time to LCO is compared each other.

Deposition effect will show that how much difference dose each fission product deposited in soil have, on comparing with fission products in no deposited condition.

Fission products distributions are just the ratio between the offsite dose and the distributing dose of each fission product.

Modeling effect is the difference between a radioactive cloud and a radioactive submersion.

2.4 Analysis procedure and Assumptions

RADTRAD software is designed to calculate offsite dose. Calculation procedure is below:

a. Modeling each compartment
b. Modeling each pathway
c. Generating source term information
d. Making exhalation rate for each fission product per unit time
e. Generating accumulation and timing files
f. Link to fission product library file and editing library files
g. Link to dose conversion information
h. Making input of timely atmospheric dispersion factors
i. Generating the analysis execute file
j. Generating output of calculated results.

Here, dose conversion factors are based on ICRP 30, FGR11 (Federal Guidance Report No. 11) and FGR12.

The external dose conversion factor of deposition effect caught the value of soil surface model in FGR12.

And also the radioactive submersion modeling is made from FGR12 [5, 6].

The some assumptions of the analysis are used as followings [4]:

a. MSLB is calculated using the following two cases:
   - GIS : Iodine spiking at the start of an accident
   - PIS : Iodine spiking before an accident conditions
b. Dose equilibrium conditions are 1.0 uCi/gram in the primary coolant and 0.1 uCi/gram in the secondary coolant of the limiting condition of operation.
c. GIS spiking factor is 500.
d. In the PIS case, the dose equivalent I-131 concentration is 60 uCi/gram, according to NPP technical specifications.
e. During the accident, the intact steam generator has the release rate of 0.5 gpm.
f. The flashed condition is assumed to have a decontamination factor of 100.
g. Dose calculation includes the total release accumulation of the intact steam generator and the faulted steam generator.
h. In this study, the atmosphere dispersion factor is referred from the FSAR.
i. The pathway between the system and environment has a decontamination factor of 1.

The continuous time is 2 hours in EAB[4, 5, 6] from FSAR referred from the RG(Regulatory Guide 1.4, 1.195)

3. Results and Discussions

3.1 Spiking Effects and Deposition Effects

Generally, Iodine spiking of PIS is known as about more than 19 times comparing with non-spiking. Also the assumed spiking factor of GIS is about 500. NRC's reports shows that the range of the spiking factor is in the period between 100 and 200. Although those conservative assumptions are applied into dose estimation, in order to compare the iodine spiking effect with non-spiking condition, the matching graph is shown in Fig. 2.

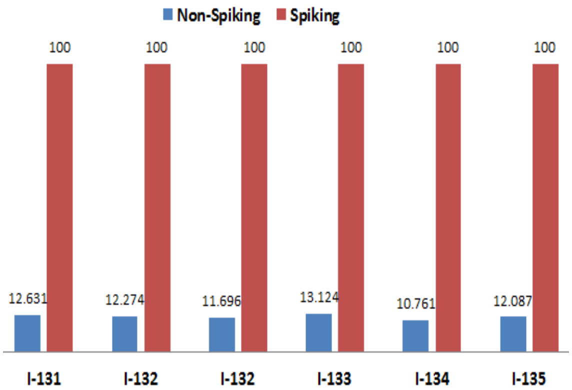

Fig. 2 Spiking effects in Iodine isotopes.

In the FSAR, the internal dose of offsite dose estimation is calculated in terms of thyroid based on Iodine radiation effect. Otherwise, the external dose is calculated in terms of whole body based on photon radiation.

Fig. 3 shows that the deposited fission products are not distributed into the external dose. The deposition phenomena make the external dose far less than non-deposition condition.

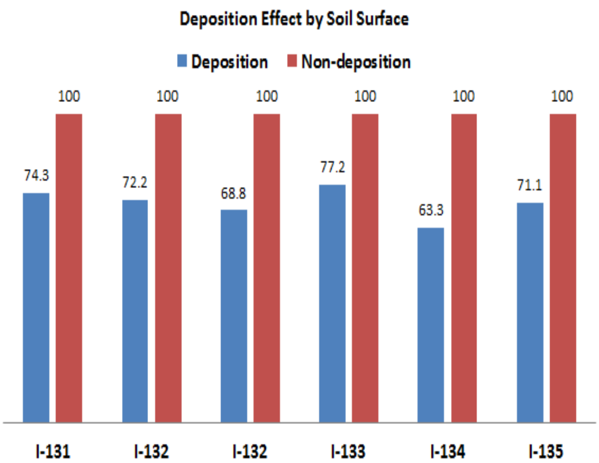

Fig. 3 Sensitivity results of deposition effects by the fission products of external dose.

3.2 Isotopes distribution and Dose Conversion Model

In Fig. 4, it is shown that the dose conversion model give the isotopes a various effects. The models considered in here are four-type models. In Fig.5 and Fig. 6, the internal dose (thyroid dose) has very strong effect in scope of a breathing model. The external dose (whole body or gamma ray dose) has very strong effect in a soil surface model. From Fig. 4, in the case of Iodine, because of beta ray only, the radiation effect is very small outside of human body such as the soil surface model, the radioactive cloud model and the radioactive submersion model. These models get to impact indirectly into human body outside. But in the radioactive submersion model, it is assumed that the distance between the human body and the source term is very close just like it's contacting to human body skin. Although it is indirect condition, the radioactive submersion model is stronger than the radioactive cloud. The assumption of the radioactive cloud model is that the distance is longer relatively because of no contacting to human body. In Fig. 6, in the case of Cs-137, because of the gamma ray only, the radiation effect is dependent on the deposition characteristic only. The effect of Cs-137 shows that it is stronger than any other models in the case of the soil surface model.

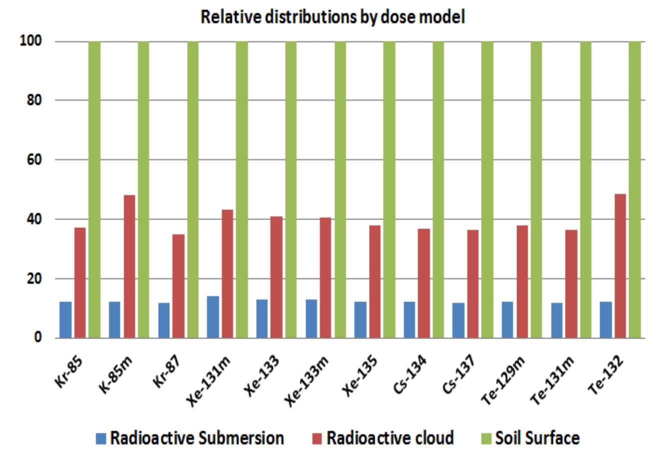

Fig. 4 Sensitivity results between a radioactive cloud and a radioactive submersion.

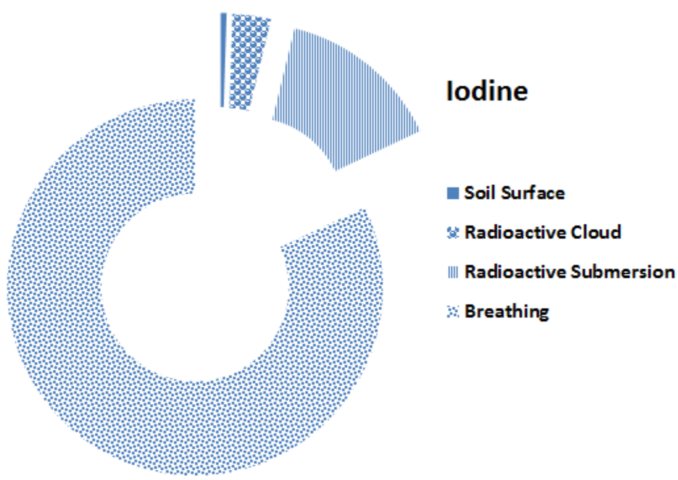

Fig. 5 Sensitivity results between the internal source terms based on various dose conversion models.

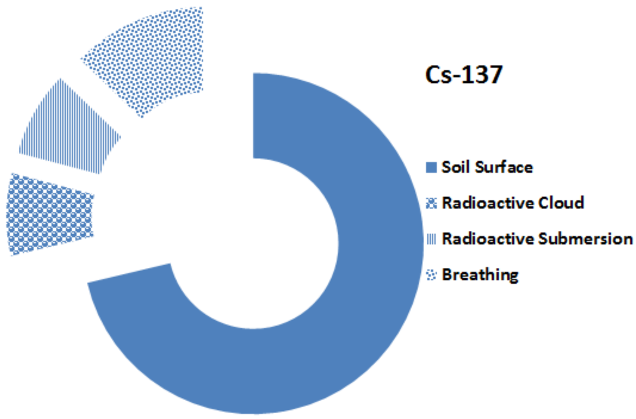

Fig. 6 Sensitivity results between the external source terms based on various dose conversion models.

3.3 Sensitivity Discussions

In this study, to carry out the sensitivity analysis, the difference between variable parameters such as variation of fission products, atmospheric concentrations, specific concentrations, and the variation gaps of variable parameters is not considered. The target of sensitivity is the impact of dose evaluation model itself. Therefore, each model is sensitivity elements. From sections of 3.1 and 3.2, external sources and internal sources are compared in the scope of modeling effect, the behavior by modeling, and calculation methods by dose conversion model. Section 3.1 shows that Iodine spiking effect is very realistic. Section 3.2 shows that external sources very strongly impact to the human body on comparing with internal sources. In other word, the internal sources have the only internal impact and the external sources have the only external impact.

4. Conclusions

Previously, some discussions are appeared in this study as shown in from Fig. 2 to Fig. 6.

a. Spiking effect is more conservative than 10 times comparing with non-spiking condition
b. From Fig. 3, current spiking effect could be decreased up to about 30% in using the deposition condition.
c. From various dose conversion models, an additional reduction of spiking effect can be appeared by Fig. 4, Fi. 5 and Fig. 6.
d. In considering the effects of Fig. 3 and Fig. 5, spiking effects are decreased up to more than about 40%.
e. In considering the effects of Fig. 4 and Fig. 6, external doses are decreased up to about 30%.

In this study, it is shown that spiking effects are impacted from deposition effect and various dose conversion models such as the deposition model, soil surface model, the radioactive cloud model and the radioactive submersion model. Finally, the sensitivity results as Fig. 2 ~ Fig. 6 show that the internal dose rate can be decreased up to more than 40% and the external dose rate can be decreased up to about 30%.

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