Preliminary analysis of exposure dose fraction by radioactive elements for the Postulated Severe Accidents in the Shin Kori Unit-1

Man-kyu Lee[1], Yu-Jung Choi[1]
Korea Hydro & Nuclear Power Central Research Institute
[1] KHNP-CRI, 70, Yuseong-daero 1312-gil, Yuseong-gu, Daejeon, Republic of Korea, 34101
[*]Corresponding author: leemankyu@khnp.co.kr

1. Introduction

As can be seen from the Fukushima accident in 2011, the result of a severe accident at the nuclear power plants is the tremendous threats to the public and environment caused by massive release of radioactive materials.

In this paper, it was studied that the accident analysis and the fraction of elements contributing to the public exposure dose assuming the postulated severe accident in the Shin Kori Unit-1, which is a representative 1000 MWe nuclear power plant. As a result, it was estimated that the exposure dose fraction by each radioactive element caused by the severe accidents.

2. Methods

Modular Accident analysis Program (MAAP) 5.03 code was used to calculate the amounts of radioactive materials for the severe accident scenario [1]. And the Radionuclide Transport, Removal, And Dose (RADTRAD) 3.03 code was used to evaluate the exposure dose fraction by each radioactive element using the output of MAAP calculations. [2].

2.1 Selection of Accident Scenario

The large loss of coolant accident (LLOCA) assumptions are as follows.

- The break point is cold leg.
- The design safety function is unavailable except by passive safety injection.
- The mitigation strategies of severe accidents are available; hydrogen control equipment, mobile pumps, and so on.

2.2 Selection of Representative Elements

Reflecting the radionuclide group according to RG-1.183, the following 9 representative elements were selected [3].

Table 1: the selected representative elements

No.	representative elements	including elements
1	Noble Gases	Xe, Kr
2	I	-
3	Cs	Rb
4	Te	Sb
5	Ba	-
6	Sr	-
7	Ru	Rh, Mo, Tc
8	La	Zr, Nd, Nb, Pr, Y, Cm, Am
9	Ce	Np, Pu

2.3 Inventory of fission products in core

Inventory of fission products was calculated using SCALE6.1 (ver.6.1.2) code [4]. And the Results are based on enough conservative assumptions.

2.4 To estimate the amount of radioactive materials released to the environment

Using MAAP 5.03 Code, it was performed to calculate existence fraction of representative elements by time steps in reactor containment building. Design basis leakage rate of Shin Kori unit-1 reactor containment building was considered to estimate environmental release of radioactive materials, if the containment pressure was less than the design basis pressure. For a realistic estimation, the amounts of radioactive materials released to the environment was calculated in 5-minute time steps. The basic analysis period is 72 hours.

2.5 Atmospheric dispersion factor

It was based on the latest meteorological data measured by Shin Kori site. To evaluate atmospheric dispersion factor (χ/Q), RG-1.145 methodology was applied [5].

2.6 Exposure Path and Dose Conversion Factor

It was assumed the following exposure pathways and dose conversion factors (DCF).

- External exposure from the plume: FGR-13 [6]
- External exposure from surface contamination: FGR-13
- Internal exposure by inhalation of contaminated air: ICRP-72 [7]

In the case of inhalation, iodine DCF is assumed to be 97% in elemental type and 3% in organic type for the conservative evaluations.

2.7 Methodology for dose assessment

NUREG/CR-6604 methodology was applied to evaluate exposure dose [8].

- External exposure dose from the plume is calculated as;

$$D_{EED} = \frac{\chi}{Q} \times \sum_i \left(DCF_{EEDi} \times Q_i\right)$$

Where:

- D_{EED} = air immersion(cloudshine) dose [Sv]
- χ/Q = atmospheric dispersion factor at EAB [s/m^3]
- DCF_{EEDi} = air immersion(cloudshine) dose conversion factor for nuclide i [Sv·m^3/Bq·sec]
- Q_i = released activity for nuclide i [Bq]

- external exposure dose from surface contamination is calculated as;

$$D_{GD} = \sum_i \frac{A_{0i} \times DCF_i}{\lambda} (1 - e^{-\lambda_i t})$$

Where:

- D_{GD} = groundshine dose [Sv]
- A_{0i} = surface contamination for nuclide i[Bq/m^2]
- DCF_i = groundshine dose conversion factor for nuclide i [Sv·m^3/Bq·sec]

- Internal exposure dose by inhalation of contaminated air is calculated as;

$$D_{IED} = \frac{\chi}{Q} \times B \times \sum_i \left(DCF_{IEDi} \times Q_i\right)$$

Where:

- D_{IED} = inhalation dose [Sv]
- χ/Q = atmospheric dispersion factor at EAB [s/m^3]
- B = RG-1.183 breathing rateinhalation [m^3/s]
- DCF_{IEDi} = inhalation dose conversion factor for nuclide i [Sv/Bq]
- Q_i = released activity for nuclide i [Bq]

3. Results

Fig 1 and 2 show that the portion of radioactive materials released to the environment and the exposure dose fraction by radioactive elements for the LLOCA in the Shin Kori Unit-1.

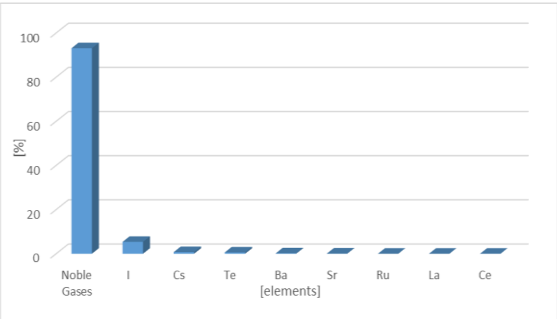

Fig 1. The portion of radioactive materials released to the environment

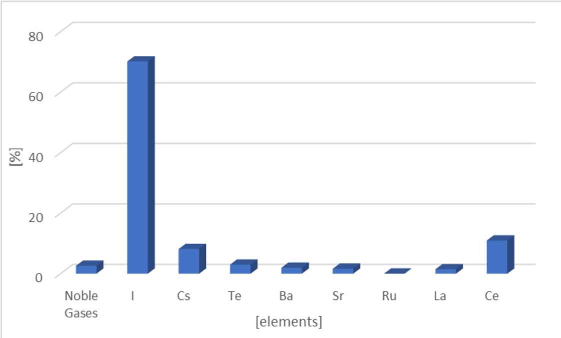

Fig 2. The exposure dose fraction by radioactive elements

4. Conclusions

Several insights could be confirmed in this study.

- Noble gases are the majority of the radioactive materials released to the environment, but the exposure dose fraction is relatively small.
- Iodine has relatively small portion of radioactive materials released to the environment, but it is the most significant element in the aspect of the exposure dose fraction.

The results show that iodine is more significant than noble gases in the view of exposure dose, although noble gases are much more than iodine in the radioactive materials released to the environment. The main reason is the DCF. The DCF of noble gases are much smaller than that of iodine; FGR-13 (cloud shine and ground shine) DCF of noble gases is smaller than that of iodine about 100 times, and ICRP-72 (inhalation) DCF of noble gases is "0".

As a result, iodine is the most significant element in exposure dose for LLOCA in Shin Kori Unit-1. Based on this result, it is necessary to establish a severe accidents mitigation strategy that can reduce iodine release from the viewpoint of public exposure dose.

REFERENCES

[1] EPRI, MAAP 5.03, EPRI, Dec. 2013
[2] US.NRC, RADTRAD 3.03, SNL, Feb. 2003.
[3] US.NRC, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors", Regulatory Guide 1.183, Jul, 2000.
[4] SCALE6.1 (ver.6.1.2), ORNL, Mar, 2013.
[5] NRC, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants", Regulatory Guide 1.145, Revision 1, Nov, 1982
[6] EPA, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides", Federal Guidance Report No.13, Sep. 1999
[7] ICRP, "Age-dependent Doses to Members of the Public from Intake of Radionuclides; Part 5 Compilation of Ingestion and Inhalation Dose Coefficients", International Commission on Radiological Protection Publication 72, 1996
[8] US.NRC, "RADTRAD; A Simplified Model for Radionuclide Transport and Removal and Dose Estimation" NUREG/CR-6604, Dec, 1997