Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Contribution of the Exposure Pathways After a Severe Accident

Joeun Lee [a*], Wontae Hwang [a], Moonhee Han [a], Moosung Jae [b]
[a] *Korea Atomic Energy Research Institute, 111, Daedeok-Daero 989Beon-Gil, Yuseong, Daejeon, 34057, Korea*
[b] *Dept. of Nuclear Engineering, Hanyang University, Seoul, 04763, Korea*
[*] *Corresponding author: leejoeun@kaeri.re.kr*

1. Introduction

A radiological dose assessment calculates the amount of radiation energy absorbed by a potentially exposed individual as a result of a specific exposure. Public can be exposure from several exposure pathways. External doses occur when the body is exposed to radioactive material outside the body. Internal doses occur from exposure to radioactive material taken into the body by inhalation or ingestion. Furthermore, depending on the radionuclide, the dose can be localized to specific organs, or distributed across the whole body.

When making the emergency preparedness for severe accident from NPPs, therefore, we need to have comprehension about those exposure pathways. Thus, in this study, an evaluation of external and internal dose from radioactive materials during severe accident was performed to find out exposure pathway from which the dose has the highest value for several radionuclides.

2. Methods and Results

2.1 Severe Accident Management

"Severe accidents" are those in which substantial damage is done to the reactor core, regardless of whether serious offsite consequences occur. That is, severe accidents, which are beyond the traditional design-basis events, constitute the major remaining risk to the public associated with radioactive releases from nuclear power plant accidents[1]. According to the IAEA report, the accident management has five objectives: Preventing significant core damage; Terminating the progress of core damage once it has started; Maintaining the integrity of the containment as long as possible; Minimizing releases of radioactive material; Achieving a long term stable state[2]. To achieve these objectives, a number of strategies should be developed. Therefore, in this study, dose assessment during a severe accident was conducted to identify dose contribution according to the exposure pathways.

2.2 Exposure Pathways

To evaluate external and internal dose from radioactive materials during severe accident, MACCS2 code was used. Thus, the exposure pathways considered in this study are from the model in MACCS2 code. In the model, the time scale after the accident is divided into three phases: early phase, intermediate phase, and long-term phase[3]. Of the three time phases, the only one which must be defined by the user is the emergency phase. In this study, only the early phase and long-term phase two were considered.

The early phase begins immediately after the accident and could last up to seven days following the accident. In this period, the exposure of population to both radioactive clouds and contaminated ground is modeled. Various protective measures can be specified for this phase, including evacuation, sheltering, and dose-dependent relocation[3]. For conservative evaluation, the emergency response was not considered from the dose calculation.

The long-term phase represents all time subsequent to the intermediate phase. In this phase, the radioactive clouds are assumed to be gone and the only exposure pathways considered here are those resulting from the contaminated ground. A variety of protective measures can be taken in the long-term phase in order to reduce doses to acceptable levels: decontamination, interdiction, and condemnation of property. The duration of the exposure period modeled by the long-term phase is essentially infinite[3].

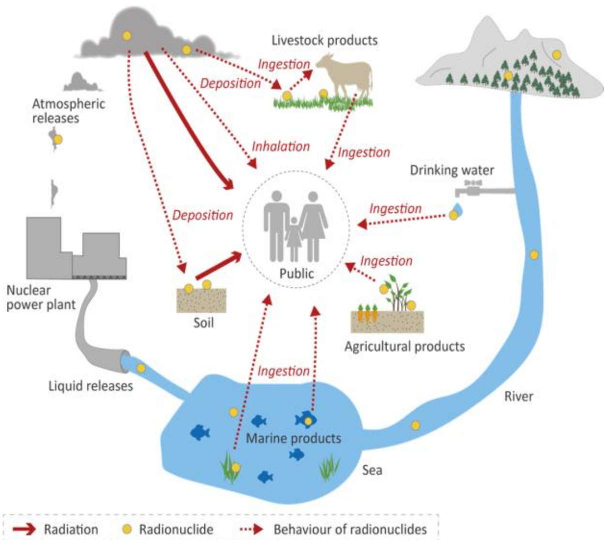

Fig. 1. Main exposure pathways relevant to a nuclear accident[4]

2.3 Source Term

In order to evaluate the dose from each pathway, source term has to be defined. For this, amount of radionuclides released after major accidents was checked up.

Table I: Estimates of Atmospheric Releases of Radionuclides from Major NPP Accidents(PBq)

Radio-nuclide	Fukushima Daiichi	Chernobyl
Kr-85	6.4–32.6	33
Xe-133	6000–12000	6500
Te-129m	3.3–12.2	240
Te-132	0.76–162	~1.15×10^3
I-131	100–400	~1.76×10^3
I-133	0.68–300	2500
Cs-134	8.3–50	~47
Cs-136	–	36
Cs-137	7–20	~85
Sr-89	4.3×10^{-2} – 13	~115
Sr-90	3.3×10^{-3} – 0.14	~10
Ru-103	7.5×10^{-6}–7.1×10^{-5}	>168
Ru-106	2.10×10^{-6}	>73
Ba-140	1.1–20	240

Based on this information, several important nuclides were selected for source term. The radionuclides were ^{85}K and ^{133}Xe for fission noble gas, ^{131}I and ^{137}Cs for volatile fission product, and ^{90}Sr for low volatile fission product. In order to focus on the dose contribution of the exposure pathways, it was assumed that all nuclides release with same amount.

2.4 Comparison of Radiation Exposure

In case of noble gas, the radionuclides only effect on public in the emergency phase. The dominant exposure pathway of noble gas was cloudshine. The dose from cloudshine between 1.6 km to 80 km accounted over 75% for both nuclides, ^{133}Xe and ^{85}Kr.

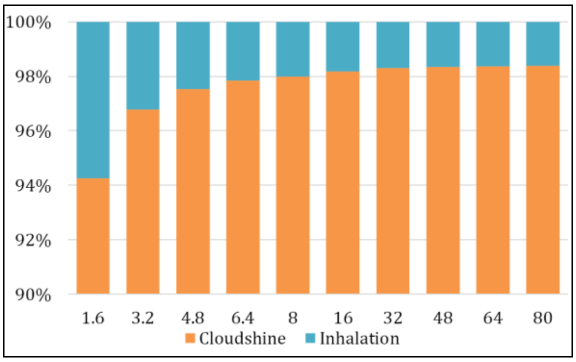

Fig. 2. Dose composition at each distance, ^{133}Xe

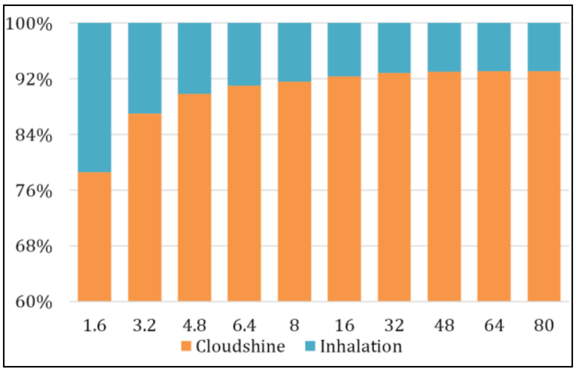

Fig. 3. Dose composition at each distance, ^{85}Kr

In case of particulates, the effect of the radionuclides' release in emergency phase was negligible in comparison with the long-term phase. The fig.4. shows the dose composition at 80 km for the particulates. Especially, since food ingestion was thoroughly restricted by the accident management, the dose from food ingestion was evaluated as very low. The most dominant exposure pathway was the water ingestion for ^{137}Cs and ^{90}Sr. Also, the population dependent decontamination dose was the most dominant pathway for ^{131}I.

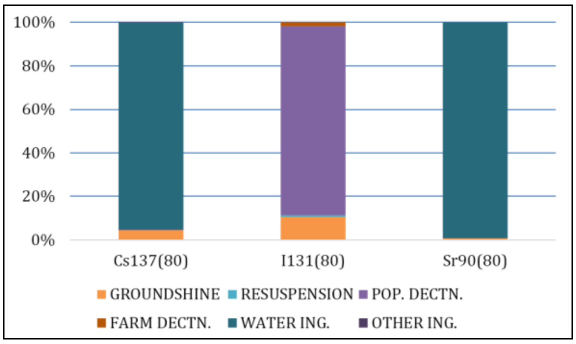

Fig. 4. Dose composition from exposure pathways for ^{85}Kr

3. Conclusions

The basic study to make out the relation between exposure pathways and dose from them was performed. In the emergency phase, the most affecting nuclide type on public was noble gas, especially ^{133}Xe, and the dominant exposure pathway was couldshine. Also, in the long term-phase, the most affecting nuclide type on public was fission product, especially ^{90}Sr, and the dominant exposure pathway was water ingestion.

The information of the dose composition from exposure pathway obtained in this study might be basic data for making emergency preparedness plan for severe accident. In the future, assessment of the source term is expected to enhance the reliability of dose assessment during severe accident.

Acknowledgement

This work was support by Nuclear R&D Programs of Ministry of Science, ICT and Future Planning of Korea (Grant No. 2012M2A8A4025914)

REFERENCES

[1] U.S. Nuclear Regulatory Commission, Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, NUREG-1793, Supplement 2, 2012.
[2] IAEA, Severe Accident Management Programmes for Nuclear Power Plants, Safety Guide No. NS-G2.15, 2010.
[3] H-N Jow et al., MELCOR Accident Consequence Code System (MACCS) Model Description, Sandia National Laboratories, NUREG/CR-4691, 1990.
[4] IAEA, The Fukushima Daiichi Accident Report, Technical Volume4, Radiological Consequences, 2015.