A Review of Impact of Protective Actions on Off-site Consequence

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1. Introduction

Level 3 PSA is the last step for estimating the risk of Nuclear Power Plant (NPP) expressed by the multiplication of frequency (or probability) and consequence. Using Level 3 PSA, we can evaluate a consequence from the accident of NPPs. Generally, a consequence includes the health effects for the public, environmental effects, and economical effects.

To perform Level 3 PSA, many kinds of input data such as site information, population distribution, and weather data are needed. Most of these data are dependent on site-specific features. Among them, a radiological protective actions such as evacuation and sheltering for the public are one of the important elements that is mainly affecting a consequences

In this paper, we carried out Level 3 PSA for the pilot plant and reviewed the impact of protective actions on the consequence in terms of the health effects of the public. Especially, we focused on protective actions at Precautionary Action Zone (PAZ), which was set from the site boundary to 5km.

2. Development Level 3 PSA model considering protective actions

2.1 Emergency Planning Zone and protective actions

The Radiological Emergency Planning Zone (EPZ) can be defined as an area that establishes the proactive actions such as sheltering and evacuation for the public in the event of a NPP accident. In Korea, EPZ consists of two zones. The first zone is PAZ, and the other is Urgent Protective action planning Zone (UPZ). According to IAEA recommendation [1], the PAZ was set within 3 ~ 5km from the site boundary of NPP, and the UPZ was set within 20~30km. it is noted that PAZ and UPZ differ slightly from site to site.

Radiological emergency alarms consists of three levels: facility, site area, and general alarm. Protective actions for the public are actively started with a general alarm. If a general alarm goes off, protective actions are differently carried out in PAZ and UPZ. In PAZ, all people who lives in PAZ is immediately evacuated to the outside of the EPZ (20~30km). In UPZ, the protective actions are differently implemented depending on the expected dose in each sector and each distance in UPZ. If a general alarm goes off, the expected dose of each sector in UPZ is evaluated by computer code in the initial phase of that alarm, and then sheltering or evacuation for the public are determined by dose basis for protective actions as shown in Table 1.

Table 1. Protection actions by dose in Korea

Protective Action	**Generic Intervention Level**	**Remarks**
Sheltering	10 mSv	No more than 2 days
Evacuation	50 mSv	No more than 1 week
Distribution of medicines (KI) for protecting the thyroid gland	100 mGy	
Temporary relocation	30mSv in first month 10mSv in a subsequent month	1 month is assumed to be 30 days
Permanent resettlement	1 Sv in Lifetime	Lifetime is assumed to be 70 years

2.2 Assumptions and considerations

To consider protective actions, we assumed postulated accident scenario leading to early containment failure. In this scenario, general alarm goes off 1 hour after the initiating event and the containment fails 3 hours after general alarm (Table 2).

Table 2. Accident scenario

Accident scenario	**Assumed Time**
Core Damage	2 hours after Initiating event
Containment Failure	4 hours after Initiating event
General Alarm	1 hours after Initiating event
Notify the public of the implementation of protective action	15 minutes after general alarm
Evacuation preparation time	During 2 hours*

* ETE report published by KHNP Central Research Institute (CRI) [2] estimated the evacuation preparation time from 15 minutes to 2 hours. In this study, 2 hours was assumed conservatively

2.2 Development Level 3 PSA model

In this paper, we used MACCS2 code, which was developed by U.S. NRC [3], to develop Level 3 PSA models. Three models were developed to compare the consequences.

- Case 1: no protective actions
- Case 2: dose-dependent relocation was applied. This works when the dose in the region exceeds the user-defined relocation threshold dose. People in that region is relocated to the outside of EPZ at the time entered by users after the first plume arrives at that distance
- Case 3: immediate evacuation within PAZ was applied by the emergency preparedness plan. Dose-dependent relocation applied in Case 2 is implemented after the arrival of radioactive plume regardless of release timing of radioactive material and alarm time, and this produces relatively conservative results compared to actual situation.

3. Results

To compare the results, we used two kinds of consequences [4] as follow.

- Early risk within 1.6km (approximately 1mile) of the NPP site boundary
- Latent cancer risk within 16km (approximately 10miles) of the NPP site boundary

Figure 1 shows the result of early risk normalized to the Case 1. Both Case 2 and Case 3 results were reduced compared to that of Case 1. Case 2 decreased about 60% compared to that of Case 1, and the result of Case 3 was greatly reduced compared to that of Case 1. This is because the exposure of the public from the radioactive plume decreased significantly in the early stage of the accident by conducting protective actions for the public. In particular, immediate evacuation applied in Case 3 has a great impact on early risk.

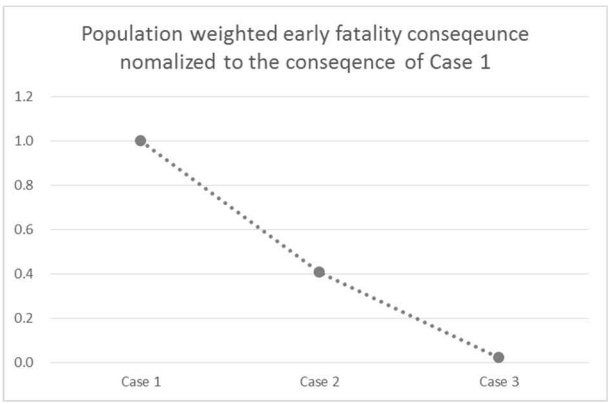

Figure 1. Comparison of early risk (1.6km)

Figure 2 shows the result of latent cancer risk normalized to the Case 1. Protective actions for the public led to a decrease in the latent cancer risk, but the decrease rate was relatively small compared with early risk. The population who lives within PAZ is relatively small compared to that of area (~ 16km) considered in the calculation for latent cancer risk. That is, protective actions applied only in PAZ have relatively small impact on the result compared with that of early risk.

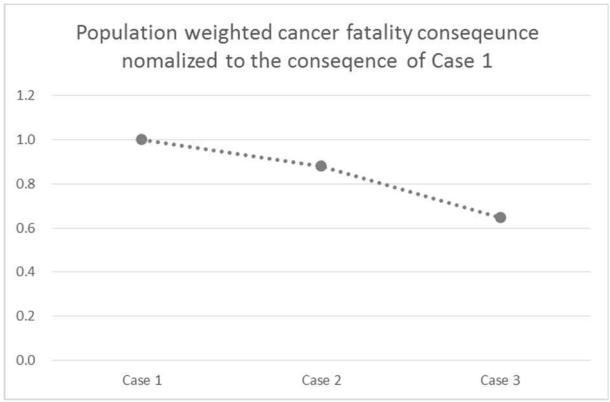

Figure 2. Comparison of latent cancer risk (1.6km)

5. Conclusions

In this study, we carried out Level 3 PSA for the pilot plant and reviewed the impact of protective actions on the consequence in terms of the health effects of the public. Protective actions applied in PAZ led to a reduction of the consequence in both early and latent cancer risk. It especially had a greater impact on early risk. That is, if protective actions are properly conducted in the early stage of the accident, consequences can be significantly reduced, particularly the consequence for early risk.

It is noted that this study was carried out to identify the impact of protective actions using many assumptions and is not an assessment of an actual plant.

REFERENCES

[1] IAEA, Arrangements for preparedness for a nuclear or radiological emergency, IAEA Safety Standards Series GS-G-2.1, 2007

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[3] D. Chanin, M.L. Young, J. Randall, K. Jamali, Code Manual for MACCS2, User's Guide, NUREG/CR-6613, 1, U.S. NRC, Washington D.C., 1998. SAND97-0594.

[4] U.S. NRC, Safety goals for the operation of nuclear power plants, 1986