Estimation of the Risks of Early Fatality for Internal Events in Korean NPPs

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1. Introduction

The Korean nuclear power plants (NPPs) must be operated in a manner that they meet the quantitative health objectives (QHOs) stated at the Policy on Severe Accident[1]. In order to assess the health risks to the public quantitatively, it is needed to perform the Level 3 PSA[2]. Recently, as a result of Level 2 PSA, the accident source terms were evaluated for all the Korean NPPs. Thus, in this paper, we estimated the site-specific health risks of early fatality for internal events based on those data and site-specific meteorological and population distribution data. Also, emergency response scenarios were modeled based on the Radiological Emergency Response Plan of each site. We used MACCS2[1] code for the calculation.

2. Data and Methodology

2.1 Source Terms

The starting points for a consequence analysis are the radionuclide releases to the atmosphere. The released source terms were evaluated through the Level 2 PSAs. During the last decade, in accordance with the implementation plan of the Policy on Severe Accident[2], KHNP performed PSAs[3] for all operating NPPs in Korea. The PSAs covered Level-2 analyses on the internal event, internal fire, internal flood and seismic events during the full power operation.

Table 1. PSA status of Korean NPPs in operation.

Units	PSA Activities	
Kori 1	2003, 2007(R*)	
Kori 2	2003, 2007(R*)	
Kori 3,4	1992(typhoon), 2003(R*)	
Yonggwang 1,2	1992(typhoon), 2003(R*)	
Yonggwang 3,4	1994(Design stage), 2004(R*)	
Ulchin 1,2	2005	
Ulchin 3,4	1997(Design stage), 2004(R*)	
WolSong 1	2003,2007(R*)	
WolSong 2,3,4	1997(Design stage),2007(R*)	
Yonggwang 5,6	2000,5005(R*)	Level 1 PSA During shutdown
Ulchin 5,6	2002,2006(R*)	

* Revision

Generally, the accident source terms were evaluated through MAAP code calculation and they consist of about 9~19 source term categories (STCs). The amounts of each radionuclide released are calculated by multiplying the release fractions to the core inventory of radioactive materials.

In addition to the quantity of the source terms, the release parameters include the starting time and duration of the release, the amount of energy associated, the height of release point and predicted frequency of the event.

In the aspect of emergency response, the delay time before the release to atmosphere is important. During the delay time, it is possible to evacuate the public effectively, which may reduce the risk of early fatality. Based on the Level 2 PSA results, we examined the delay time available for the protective actions. Followings are the kinds of STCs which could be categorized into the groups with short delay time before the release.

a) Early containment failure
  - Core uncover~containment failure: 1.75~6.6 hours
  - Including alpha mode
b) Containment bypass
  - Core uncover~atmospheric release: 0.1 ~ 6.4 hours
  - Including SGTR, low pressure interface bypass
c) Containment isolation failure
  - Core uncover~atmospheric release: 0.3~0.77 hours
d) Containment failure before reactor vessel failure
  - Core uncover~atmospheric release: 0.5 ~ 1.0 hours

Although there are some definitions on the Large Early Release (LER), No consensus was made on it. Thus, in this paper, we will define the STCs listed above as the LER.

2.2 Meteorological Data

Yearly meteorological data have been obtained from 2000 through 2005. The meteorological data consist of wind direction, wind speed, and stability categories. The utility recorded the wind direction and speed at the height of 10m and 60m. In this paper, we used the data of the height in 60m, which is most probable release height.

2.3 Population Distribution

The population distribution has been obtained from local government statistics available between 2002 and 2005. The 80km radius area around the plant was considered and divided into sixteen directions that are equivalent to a standard navigational compass rosette. This rosette was further divided into 10 “inner” rings, each with sixteen azimuthal sections.

[1] MACCS : MELCOR Accident Consequence Code System

2.4 Emergency Response

In the EARLY module of MACCS2 code, the user can specify emergency response scenarios that include the evacuation, sheltering, and dose-dependent relocation. The emergency evacuation has been modeled as a single evacuation zone extending out 8km from the plant. Outside the evacuation region, dose-dependent relocation actions can take place. Dose dependent relocation parameters outside the evacuation region selected as follows.

- hot spot relocation criteria : 500 mSv
- hot spot relocation time : 6 h after plume arrival
- normal relocation criteria : 250 mSv
- normal relocation time : 12 h after plume arrival

Fig 1 shows the time sequence used to model the sheltering and evacuation. Although, it may be available additional time before the release depending on the accidents, we assumed that the emergency declaration was made at the time of release conservatively. The emergency response data used were based on the radiological emergence response plan of Kori site.

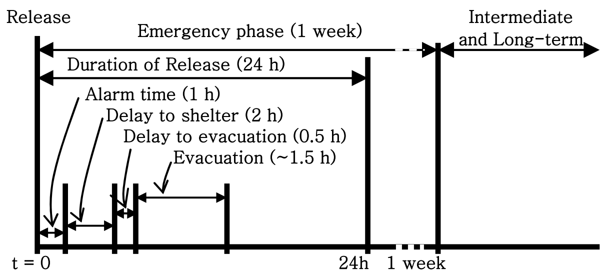

Fig. 1. Time table for the sheltering and evacuation.

2.5 Deterministic Health Effects

Health effects are generally classified as either 'deterministic' or stochastic'. MACCS2 code calculates acute doses for deterministic health effects including early fatality. The Individual Early Risk (IER) of fatality can be written as follows;

- Risk of early fatality [4]

$$IER = \sum_{1}^{N} LERF_n \times \frac{EF_n}{TP(1.6km)} \tag{1}$$

where

$LERF_n$: frequency of a large early release sequence "n"

EF_n : number of early fatalities within 1.6km in case of accident sequence "n"

$TP(L)$: total population within distance L from NPP

3. Results

Table 2 shows the risks of early fatality for Korean NPPs in case of internal events by applying those conditions discussed at the previous section. The results reflect the site-specific meteorological condition, population distribution and source terms with the corresponding accident frequencies. The Wolsung 2,3,4 units show the smallest risks. The reason is that they have lower LERF values and lower quantity of released source terms than those of PWR units. The protective actions like sheltering and evacuation decrease the risks of fatality one or two orders in all cases. The results in Table 2 can be directly compared to the QHOs stated in the Policy on Severe Accident. Recent study shows that the early QHO has the value of about $6.935X10^{-7}$/y [5].

Table 2. Risk of early fatality for internal events (/Ry)

Units	Case 1[a)]	Case 2[b)]	Case 3[c)]	Case 4[d)]
Kori 2	2.82E-09	3.35E-09	1.31E-08	2.41E-07
Kori 3,4	8.71E-09	9.56E-09	2.58E-08	1.47E-07
UL 1,2	2.62E-09	3.08E-09	1.15E-08	1.67E-07
UL 3,4	3.34E-08	3.45E-08	6.80E-08	1.73E-07
WS 2,3,4	1.04E-12	1.85E-12	1.71E-11	7.33E-10
YGN 1,2	1.59E-09	1.91E-09	8.01E-09	1.01E-07
YGN 3,4	2.32E-09	2.64E-09	8.72E-09	6.75E-08

a) Case 1 : 100% evacuation
b) Case 2 : 95% evacuation, 5% shelter
c) Case 3 : 100% sheltering
d) Case 4 : No protective actions

4. Conclusions

In this paper, the risks of early fatality for Korean NPPs were evaluated based on the up-to-date site-specific data including Level 2 PSA results. Although, the risks mainly depend on the quantity of source terms and the accident frequency, they also greatly depend on the scenarios of protective actions. Also, meteorological data and population distribution can affect the results.

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