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Suggested PAZ Size of Pressurized Light Water Reactor

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1. Introduction

The goals of the protective actions during nuclear accident are to prevent the occurrence of severe deterministic effects and keep the dose below the level at which protective actions and other response actions are justified to reduce the risk of stochastic effects [1]. To meet these goals, off-site emergency zones for taking urgent protective action have to be identified in advance, i.e. during emergency preparedness phase.

Especially Precautionary Action Zone (PAZ) is defined by the international requirement as the area within which arrangements should be made to implement precautionary urgent protective actions before or shortly after a major release with the aim of preventing or reducing the occurrence of severe deterministic effect [1, 2]. However, PAZ is not introduced in domestic emergency preparedness system. In this study, preliminary calculation results to suggest PAZ size are presented.

2. Methods and Results

In this section considerations and methods employed to calculate PAZ size are presented. Action levels for acute exposure, such as 1 Gy/2days bone marrow dose were referred as a dosimetric basis [3]. Probabilistic safety assessment (PSA) method and emergency response consequence assessment code were used for zone size calculation.

2.1Calculation of PAZ size using PSA

Among the source term categories from level 2 PSA results of a Korea Standard Nuclear Power Plant (KSNP) type reactor, early containment failure (rupture) case with very low probability (1.16×10^{-8} year^{-1}) was considered. Containment hold-up and release duration were 1.1 hours and 24 hours respectively. This source term was selected to consider a scenario which gives rise to a release of fission products causing severe deterministic effects in public before protective action. Also international guides recommend to address the full range of possible emergencies including low probability [1]. Ground level release with Straight Line Gaussian model was considered. A meteorological data of a Korean NPP site was used for release simulation. MASS 2 code was employed to calculate off-site dose [4].

Maximum radii which exceed action level at each downwind direction are shown in table 1. The results from PSA showed that the maximum radius of PAZ is 0.8 km.

Table 1. Maximum distance exceeding action level (1 Gy/2day, bone marrow) each downwind direction

Down wind	Distan ce(km)	Dose (Sv)	Down wind	Distan ce(km)	Dose (Sv)
N	0.4	0.877	S	0.6	0.835
NNE	0.4	0.877	SSW	0.6	0.816
NE	0.4	0.936	SW	0.7	0.951
ENE	0.4	0.827	WSW	0.8	0.991
E	0.4	0.795	W	0.6	0.955
ESE	0.4	0.857	WNW	0.4	0.956
SE	0.5	0.915	NW	0.4	0.738
SSE	0.6	0.830	NNW	0.4	0.787

2.2 RASCAL code calculation

To calculated PAZ size, RASCAL code version 4.2 with some simple assumptions was employed [5]. To specify fission product release characteristics, a 3000 MWth power level reactor was chosen. In this study, release amount was assumed to be 10 % of the volatile fission products such as Cesium and Iodine in the core inventory with 10 hours release duration. These were based on existing severe accident analyses [6, 7]. According to those analyses, there is hold-up time before large release into environment. But hold-up in containment was not considered in this study for conservative approach. 100 % core melting condition was applied since only severe core damage can result in significant amount of fission product release. Core inventories and calculated source term (Cs-137, I-131) by RASCAL were shown in table 2.

Table 2: RASCAL estimates of I-131 and Cs-137 releases (Bq)

I-131 Inventory	2.99E+18
I-131 Release	2.9E+17
I-131 release fraction	9.7%
Cs-137 inventory	2.83E+17
Cs-137 Release	3.1E+16
Cs-137 release fraction	11.0%
Total amount	7.4E+18

Default burn up data (30,000 MWd/MTU) of RASCAL was used to calculate Cs-137 core inventory. Table 2 showed that case 2 was much significant condition than existing severe accident analyses. These source terms were larger than those of Fukushima Daiichi Nuclear accident. Total radionuclide release estimates from Fukushima Units 1,2 and 3 were 1.3×10^{17} - 1.6×10^{17} Bq and 6.5×10^{15} - 1.5×10^{16} Bq, for I-131 and Cs-137 respectively (release fraction 3 to 10% and 2 to 3 % core inventory respectively) [8].

Ground level release with default meteorological data (Stability class D, wind speed 4 mph, No rain) of RACAL was used for release simulation. Dose to bone marrow and lung during 48 hours after release were calculated according to international guides [GS-G-2.1]. Acute bone dose and lung dose (action level 6 Gy) calculation results are shown in Table 3. The results showed that the maximum radius of PAZ is 4.8 km.

Table 3. Acute bone marrow dose (whole body) and lung dose (Gy) from RASCAL code calculation

Distance(km)	Bone	Lung	Distance(km)	Bone	Lung
0.32	41.0	51.0	3.22	1.5	1.8
0.48	22.0	27.3	4.8	1.0	1.3
0.8	10.0	12.3	6.4	0.92	1.2
1.13	6.0	7.3	8.0	0.76	1.0
1.61	3.3	4.1	11.3	0.55	0.74
2.41	1.9	2.4	16.1	0.36	0.51

3. Conclusions

PSA methodology and RASCAL code were used to calculate PAZ size. Suggested radius of PAZ from the preliminary calculation results is between 0.8 and 4.8 km. These results were calculated with simple assumptions and only considered technical aspect, such as fission product release characteristics and radioactive material dispersion in environment.

The actual boundaries of PAZ need to be defined by site specific information, such as local landmarks and population distribution. The results in this study can be used as base information to stakeholders and decision makers who are response in arrangement of emergency preparedness.

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