DEDUCTION OF KOREA LEVEL3 PSA ISSUES AND PRELIMINARY OFF-SITE RISK ANALYSIS

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Off-site risk analysis needs more realistic and accurate evaluation especially in case the population density is relatively high such as Korea. However, detailed analysis methodology and regulatory framework have not been established yet in Korea. As a results, lots of confusion would be occurred due to the lack of assessment experience and detailed guideline when off-site risk analysis is fully adopted in regulatory framework. In the point of advance preparation, it is necessary to derive the issues concerning the off-site risk analysis through the reviews of related documents and technology status. Some alternatives which are related to each issue are used as WINMACCS input parameters for preliminary off-site risk analysis. Sensitivity analysis is performed to identify the result variation due to the changed input variables. By using the sensitivity analysis results, some issues are ranked according to their importance.

I. INTRODUCTION

After Fukushima NPP accident, many people are concerning about the risk of NPP. Korea is operating twenty-four units and they produce about 22,562MWt. More accurate off-site analysis is essential especially in Korea because population density is relatively high. In case of Kori NPP, over three million people are living within 30km. The off-site risk analysis results have been submitted to obtain operating license since Shin-Kori 3 & 4 units. Moreover, severe accident legislation which contains mandatory submission of Level 3 PSA results is established in 2015. But, there are few experience of domestic off-site risk analysis and most of parameters are identical to those of international existing analysis regardless of Korean site characteristics. In this study, some issues for introducing Level 3 PSA were derived and some alternatives which are related to each issues are presented. Finally, current MACCS input was updated using presented alternatives.

II. RESEARCH RESULTS

II.A. WinMACCS code & Existing Domestic Model

II.A.1. WinMACCS

WinMACCS is developed by Nuclear Regulatory Commission to evaluate off-site risk when the radioactive materials leak from containment. This code is originated from CRAC code which is used at WASH-1400 study. The calculation framework and relation diagram of WinMACCS are described in Fig.1.

WinMACCS can treat below phenomenon by utilizing some site-specific data (Ref.1)

- Atmospheric transport and deposition onto the ground
- Statistical effect of variability in weather
- Dose pathways for cloudshine, groundshine, inhalation, ingestion, and deposition onto skin
- Protective actions during emergency, intermediate, and long-term phases

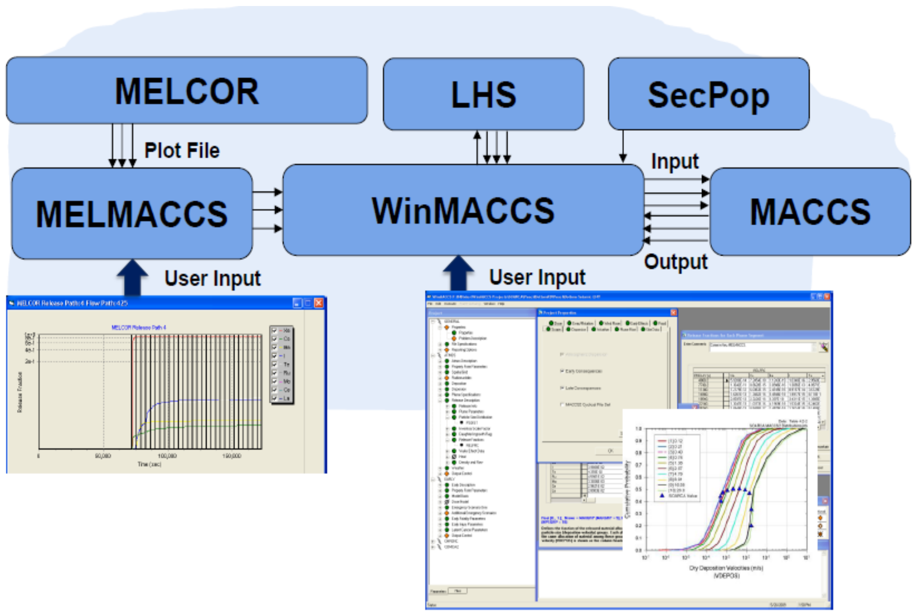

Fig. 1. WinMACCS Calculation Framework (Ref.2)

II.A.2. Existing domestic model

Existing domestic off-site risk analysis used old MACCS version. Most of input variables are identical to MACCS sample problem A. (Ref.3) The biggest difference between domestic model and sample problem A is whether emergency response is simulated or not. In domestic model, emergency response is not considered for conservative approach. And recent research results are also not reflected in domestic model. The site-specific data such as weather and population data are obtained from Korean National Statistical Office.

II.B. Issues Deduction & Comparison to Existing Results

In this section, some issues which are related to domestic analysis status are derived through the review of related material and technology status. (Ref. 4, 5) Some alternatives which are more appropriate the derived issues are remarked in bold type. Sensitivity analysis was also performed to confirm the results variation due to the application of alternatives.

II.B.1. Dispersion coefficient & Surface Roughness

Dispersion coefficient decides the magnitude of dispersion in Gaussian Plume Model. The WinMACCS code offers two options (Power law, Lookup Table) to set the diffusion coefficient. Power law function derives dispersion coefficient from Tadmor and Gur(1979) study before State-of-the Art Reactor Consequence Analyses (SOARCA). And Since SOARCA study, dispersion coefficient has been derived from latest tracer experiment. Lookup table also use dispersion coefficient from Tadmor and Gur study. This method provides pre-calculated coefficient according to distance in the form of table. Based on this table, it is possible to calculate any distance by using interpolation. (Ref. 6)

Below table shows us the population-weighted risk when applying lookup table and power-law function. In case of applying lookup table, early fatality is relatively high in all distance. On the other hand, cancer fatality is low within 16.1km using lookup table. In general, power law function method has been recommended as a more convenient way to represent the reliability of dispersion coefficient.

TABLE 1. Comparison Results for Dispersion Model

Population-weighted Risk	Lookup Tables (WinMACCS Sample)	**Power Law Function (SOARCA)**	Change Rate

Early Fatality/Total (1.6 km)	3.87E-07	6.65E-08	-82.82%
Early Fatality/Total (16.1 km)	1.62E-08	2.79E-09	-82.78%
Early Fatality/Total (80.5 km)	4.13E-10	7.11E-11	-82.78%
Cancer Fatality/Total (1.6 km)	4.38E-04	5.28E-04	20.55%
Cancer Fatality/Total (16.1 km)	1.62E-04	2.02E-04	24.69%
Cancer Fatality/Total (80.5 km)	8.15E-05	7.60E-05	-6.75%

The surface roughness is used as correction factor which can effect vertical dispersion coefficient depending on the state of ground condition. The converted correction factor can be calculated by below Eq. (1)

$$ZSCALE = \left[\frac{Z_0}{Z_{0,ref}}\right]^{0.2} \qquad (1)$$

Z_0 = Surface roughness at evaluation region
$Z_{0,\,ref}$ = Surface roughness at reference region (0.03cm)

$Z_{0,\,ref}$ is set to 0.03cm which represent the flat terrain. Z_0 is changed depend on the surface states. Considering the domestic site characteristic, surface roughness should have used bigger value than 10cm which is used as traditional value. If the magnitude of surface roughness is larger and larger, then vertical diffusion coefficient also become bigger. It means that radioactive material density per unit volume became lower. Below table shows us the comparison results for surface roughness. (Ref. 7)

TABLE 2. Comparison Results for Surface Roughness

Surface roughness (Z_0, cm)	0.1		1		**10 (Base Case)**		100		1000	
Correction factor (ZSCALE)	0.51		0.80		1.27		2.02		3.20	
Population-weighted Risk	Risk	Change Rate	Risk	Change Rate	Risk	Change Rate	Risk	Change Rate	Risk	Change Rate
Early Fatality/Total (0-1.6 km)	9.64E-07	149.10%	6.78E-07	75.19%	3.87E-07	0	1.68E-07	-56.59%	5.31E-08	-86.28%
Early Fatality/Total (0-16.1 km)	4.04E-08	149.38%	2.84E-08	75.31%	1.62E-08	0	7.05E-09	-56.48%	2.23E-09	-86.23%
Early Fatality/Total (0-80.5 km)	1.03E-09	149.39%	7.24E-10	75.30%	4.13E-10	0	1.80E-10	-56.42%	5.67E-11	-86.27%
Cancer Fatality/Total (0-1.6 km)	4.14E-04	-5.48%	4.28E-04	-2.28%	4.38E-04	0	4.47E-04	2.05%	4.49E-04	2.51%
Cancer Fatality/Total (0-16.1 km)	1.55E-04	-4.32%	1.62E-04	0.00%	1.62E-04	0	1.57E-04	-3.09%	1.48E-04	-8.64%
Cancer Fatality/Total (0-80.5 km)	1.00E-04	22.70%	9.00E-05	10.43%	8.15E-05	0	7.60E-05	-6.75%	7.61E-05	-6.63%

Regardless of distance, the early fatality/total tends to decrease as the surface roughness becomes lager. The reason for this result is lowered concentration caused by increased vertical diffusion coefficient. In contrast, the variation of cancer fatality/total depending on surface roughness was negligible. For the practical analysis, it is preferred to define site-specific surface roughness value which is appropriated to Korean terrain near the NPPs.

II.B.2. Deposition model

Deposition consist of two phenomenon, which are dry and wet deposition. These deposition phenomenon can lower the density of radioactive materials in the air. Dry deposition is caused by gravity, dispersion and inertia. And it can be effected by particle size, particle density, surface roughness, wind speed and so on. In MACCS, the particle size of each radionuclides group is used for determining dry deposition. Before SOARCA project, single particle size value that is representative all the particle groups is used. On the other hand, several particle size values obtained from MELMACCS are entered at MACCS since SOARCA project. The removal equation 2 is used for single dry deposition velocity and equation 3 is for multiple dry deposition velocity in MACCS.

$$\frac{Q}{Q_0} = f_d = \exp\left(-\frac{v_d \Delta t}{F'}\right) \qquad F' = \sqrt{\frac{\pi}{2}}\sigma_z \frac{1}{F} \tag{2}$$

$$\frac{Q_i}{Q_{0i}} = f_{di} = \exp\left(-\frac{v_{di} \Delta t}{\bar{z}}\right) \tag{3}$$

F' = sum of all of the exponential terms that contain σ_z
$\triangle t$ = time required for the segment
v_d = dry deposition velocity
i = size section of aerosol materials
$\bar{z}$ = effective height of plume
Q_{oi} = amount of aerosol of section i transported into the spatial element
f_{di} = fraction remaining after the plume segment traverses the spatial element

The comparison results between two models is shown in Table 3.

TABLE 3. Comparison Results for Dry Deposition Model

Population-weighted risk	**10 Groups Classification according to Particle Size**	1 Group regardless of Particle Size	Change Rate
Early Fatality/Total (1.6 km)	3.87E-07	1.43E-06	269.51%
Early Fatality/Total (16.1 km)	1.62E-08	5.98E-08	269.14%
Early Fatality/Total (80.5 km)	4.13E-10	1.52E-09	268.04%
Cancer Fatality/Total (1.6 km)	4.38E-04	4.74E-04	8.22%
Cancer Fatality/Total (16.1 km)	1.62E-04	2.02E-04	24.69%
Cancer Fatality/Total (80.5 km)	8.15E-05	9.33E-05	14.48%

The population-weighted risk was increased when applying 1 group particle size as compared to 10 groups regardless of distance. The reason for these results is related to particle size distribution of each element group.

Wet deposition is caused by rainout and washout. The term of rainout means that radioactive aerosol acts as condensation nucleus to form droplets. The washout means the case that radioactive materials are deposited due to the collision or absorption with raindrops. Since wet deposition process are complicated, deposition velocity and washout coefficient are used as input to approximate equation in MACCS.

In case of strong rainfall, even if weak rainfall, wet deposition gives great effect to atmospheric dispersion compared with dry deposition. Wet deposition phenomenon can be concentrated on specific region, so it is possible to generate a high radiation zone, which is called hot-spot region. Aerosol removal process by wet deposition in the MACCS code is simulated in the following equation 4.

$$R = C_1 \mathrm{I}^{C_2} \qquad (4)$$

R = fractional rate at which aerosols are removed from the plume(s^{-1})
C_1 = empirical linear coefficient(s^{-1}), CWASH1
I = rain intensity (mm/hr)
C_2 = empirical exponent (dimensionless), CWASH2

In SOARCA research, new wet deposition parameters has been updated. To confirm how much impact on results, comparison analysis between SOARCA research and existing wet deposition parameter (MACCS sample problem A) is conducted. Table 4 shows us the comparison results for wet deposition parameters.

TABLE 4. Comparison Results for Wet Deposition Parameter

Population-weighted risk	**SOARCA wet deposition parameter**	Existing wet deposition parameter	Change Rate
Early Fatality/Total (1.6 km)	3.87E-07	6.41E-07	65.63%
Early Fatality/Total (16.1 km)	1.62E-08	2.70E-08	66.67%
Early Fatality/Total (80.5 km)	4.13E-10	6.87E-10	66.34%
Cancer Fatality/Total (1.6 km)	4.38E-04	4.42E-04	0.91%
Cancer Fatality/Total (16.1 km)	1.62E-04	1.68E-04	3.70%
Cancer Fatality/Total (80.5 km)	8.15E-05	8.14E-05	-0.12%

As shown in Table 4 most of population-weighted risk is low when applying SOARCA parameters. For application of realistic simulation, it is recommended that use the SOARCA wet deposition parameter and classified groups.

II.B.3. Plume Rise Effect

Plume containing the heat can be higher than initial release height, which is called plume rise effect. As the plume became higher than initial condition, the radiation exposure became low at the surface. The plume rise effect can be effected by wind speed, weather stability, plume sensible heat, building wake effect and so on. Plume rise effect can be simulated on the basis of power model or density & flow model. The power model is a method for estimation the buoyancy applied to the sensible heat release rate. This method considers the difference between plume temperature and ambient air temperature. On the other hand, the density & flow model considers not only temperature difference but density difference due to the molecular weight difference for estimation of plume buoyancy. It can be concluded that density & flow model is more improved than power model by taking into account the additional density difference. The density & flow model is divided into original and improved Briggs model. (Ref. 8) Depending on which the Briggs model is applied, the magnitude of plume rise is determined. Below Table 5 show us the difference of population-weighted risk when applying each Briggs model.

TABLE 5. Comparison Results for Plume Rise Effect

Population-weighted risk	**Improved Briggs Model**	Original Briggs Model	Change Rate
Early Fatality/Total (1.6 km)	3.87E-07	3.79E-07	-2.07%
Early Fatality/Total (16.1 km)	1.62E-08	1.59E-08	-1.85%
Early Fatality/Total (80.5 km)	4.13E-10	4.05E-10	-1.94%
Cancer Fatality/Total (1.6 km)	4.38E-04	4.37E-04	-0.23%
Cancer Fatality/Total (16.1 km)	1.62E-04	1.58E-04	-2.47%
Cancer Fatality/Total (80.5 km)	8.15E-05	7.86E-05	-3.56%

Recent research has been reported that original Briggs model has a drawback to overestimate degree of elevation. (Ref. 9) In case of applying original Briggs model, population-weighted risk has more optimistic result than applying improved Briggs model. The improved Briggs model is appropriated to domestic application because this method is based on realistic phenomenon and recommended in worldwide. In order to apply domestic analysis, MELMACCS should be preceded. Because most of input parameters which are needed to simulate plume rise effect are calculated from MELMACCS.

II.B.4. Shielding factor

The shielding factor is applied to each cohorts which performs emergency actions such as normal activity, evacuation and sheltering according to exposure pathways during emergency phase. Since the exposure dose changes proportionally according to shielding factors, these variables have a significant effect on the risk results. The shielding factor should be set by considering the site-specific information such as the ratio of building type and resident activities. The table 6 shows the reduction factor of exposure dose for each pathway according to the building types. (Ref. 10)

TABLE 6. Reduction factor for each building types

Exposure pathway	Place & Building Types	Reduction factor
Groundshine	1m above ground in infinitely large flat areas	1.0
	1m above ground in daily living area	0.7
	1m above ground on the 50% contaminated road with 16m width	0.4
	Car on the 100% contaminated road	0.5
	50% contaminated road	0.5
	Fully decontaminated road	0.25
	Train	0.4
	Wooden building below 2nd floor	0.4
	Brick/tile-roofed house below 2nd floor	0.2
	Basement in Brick/tile-roofed house	Less than 0.1
	The lower layer of four or more floor building	0.05
	The upper layer of high-rise building	0.01
	Basement in high-rise building	0.005
	Basement in 3 or 4 story building	0.01
Cloudshine	Outdoor	1.0
	On the car	1.0

	Wooden building / basement of wooden building	0.9/0.6
	Stone building / basement of stone building	0.6/0.4
	Large concrete building	Less than 0.2

However, existing domestic analysis uses the information of Surry NPP regardless of Korean site-specific situation. In this study, some of shielding factors are derived with consideration of Korean domestic condition using the reference methodology. (Ref. 11) The summarized reduction factor according to building types in Busan are on the Table 7. The house type is assumed as a places which are classified in reference methodology.

TABLE 7. House Type and related Reduction factor in Busan

House Type	Normal House	Apartment House	Town House	Multiplex House	House for non-resident	ETC
Assumption for Groundshine	Brick/tile-roofed house below 2nd floor	The upper layer of High-rise building	The lower layer of four or more floor building	The lower layer of four or more floor building	The lower layer of four or more floor building	20%:wooden Building, 80%: The lower layer of four or more floor building
Assumption for Cloudshine	Stone Building	Stone Building	Stone Building	Stone Building	Stone Building	20%: Wooden Building, 80%: Stone Building
Population	1,087,037	1,813,892	93,619	241,501	43,033	89,350
Population distribution ratio	32%	54%	3%	7%	1%	3%
Reduction factor for Groundshine [ref]	0.2	0.01	0.05	0.05	0.05	0.12
Reduction factor for Cloudshine [ref]	0.6	0.6	0.6	0.6	0.6	0.66

Time utilization rate of resident is needed to calculate the shielding factor in case of normal activity. These values are obtained from National Statistical Office as shown in Table 8.

TABLE 8. Korean Time Utilization Ratio

Place & Activity	Time Utilization Ratio
Home	69.7%
School or Work	18.3%
Commuting	6.9%
Outdoors	5.1%

First, evacuation shielding factor can be calculated by utilizing the reduction factor of outdoor exposure. In case of cloudshine, shielding effect is assumed to be zero, since both the reduction factor of ‘outdoor’ and ‘on the car’ are 1, as shown in table 6. On the other hand, groundshine shielding factor was set in consideration of the reduction factor in accordance with a variety of outdoor conditions. Considering the domestic site characteristics, ‘1m above ground in infinitely large flat areas’ did not contains in analysis. And ‘100% decontaminated road’ is also not considered for conservative analysis. Equivalent weight ratio was applied for the remaining outdoor activities. Equation 5 shows the calculation process for the reduction factor of groudshine shielding during evacuation.

[1m above ground in daily living area * 0.2] + [1m above ground on the 50% contaminated road with 16m width * 0.2] + [Car on the 100% contaminated road * 0.2] + [50% contaminated road * 0.2] + [Train * 0.2] = 0.5 (5)

Second one is normal shielding factor which can derived with population distribution and time utilization ratio as shown in Table 8. Detailed calculation process is as followed in equation 6.

[Reduction factor for house * Time at home] + [Reduction factor for school or work * Time at school or work] + [Reduction factor for commuting or outdoor * time at commuting or outdoor] = [∑(Reduction factor according to house type * house type ratio) * Time at home] + [Reduction factor for school or work * Time at school or work]+[Reduction factor for commuting or outdoor * Time at commuting or outdoor] (6)

Thus, the normal cloudshine and groundshine shielding factor can be calculated as shown in below equation 7 and 8.

$$[(0.6\times0.32+0.6\times0.54+0.6\times0.03+0.6\times0.07+0.6\times0.01+0.66\times0.03)\times 0.697] + [(1\times0.1+0.6\times0.9)\times 0.183] + [1\times0.12] = 0.65 \quad (7)$$

$$[(0.2\times0.32+0.01\times0.54+0.05\times0.03+0.05\times0.07+0.05\times0.01+0.12\times0.03)\times0.697]+[0.5\times0.1+0.01\times0.9)\times 0.183] + [0.5\times0.12] \fallingdotseq 0.13 \quad (8)$$

In case of sheltering, all the residents are assumed to be in the house. Thus, sheltering shielding factors are calculated as below equation 9.

∑(Reduction factor according to house type * house type ratio) * Time at home(=1) (9)

As a results, cloudshine and groundshine shielding factors during sheltering are as followed in equation 10, 11.

$$(0.6\times0.32+0.6\times0.54+0.6\times0.03+0.6\times0.07+0.6\times0.01+0.66\times0.03)\times1 \fallingdotseq 0.60 \quad (10)$$

$$(0.2\times0.32+0.01\times0.54+0.05\times0.03+0.05\times0.07+0.05\times0.01+0.12\times0.03)\times1 \fallingdotseq 0.079 \quad (11)$$

Preliminary estimated shielding factors with other research results are presented in table 9 and table 10 shows us the population-weighted risk when applying estimated shielding factors.

TABLE 9. Preliminary Estimated Shielding factors with other research results

Variable Name	Description	NUREG-1150 Peach Bottom	Sample Problem A Surry	SOARCA Peach Bottom	SOARCA Surry	WinMACCS Sample Surry	**Preliminary Estimated Shielding factor**
CSFACT (Cloud shine)	Evacuation	1	1	1	1	0.724	1
	Normal	0.75	0.75	0.6	0.68	0.8	0.65
	Sheltering	0.5	0.6	0.5	0.6	0.8	0.6
GSHFAC (Ground shine)	Evacuation	0.5	0.5	0.5	0.5	0.396	0.5
	Normal	0.33	0.33	0.18	0.26	0.216	0.13
	Sheltering	0.1	0.2	0.1	0.2	0.104	0.079
PROTIN (Inhalation)	Evacuation	1	1	0.98	0.98	0.724	0.98
	Normal	0.41	0.41	0.46	0.46	0.692	0.46
	Sheltering	0.33	0.33	0.33	0.33	0.251	0.33

SKPFAC (Skin)	Evacuation	1	1	0.98	0.98	1	0.98
	Normal	0.41	0.41	0.46	0.46	0.41	0.46
	Sheltering	0.33	0.33	0.33	0.33	0.33	0.33

TABLE 10. Comparison Results for Shielding Factor

Population-weighted Risk	Current Shielding Factor	**Preliminary Estimated Shielding Factor**	Change Rate
Early Fatality/Total (1.6 km)	3.87E-07	3.52E-08	-90.90%
Early Fatality/Total (16.1 km)	1.62E-08	1.48E-09	-90.86%
Early Fatality/Total (80.5 km)	4.13E-10	3.76E-11	-90.90%
Cancer Fatality/Total (1.6 km)	4.38E-04	4.03E-04	-7.99%
Cancer Fatality/Total (16.1 km)	1.62E-04	1.52E-04	-6.17%
Cancer Fatality/Total (80.5 km)	8.15E-05	6.71E-05	-17.67%

The calculated groudshine shielding effect during evacuation and normal activity is greater than those of SOARCA. This result came from the domestic site conditions that the relative high proportion of high-rise buildings have been reflected. Therefore, the result of applying the estimated shielding factor, the risk was reduced compared to conventional analysis as shown in Table 10.

II.B.5. Emergency response

Emergency response is defined as the emergency activities of residents after accident. Emergency scenarios are divided into sheltering and evacuation. Evacuation is divided into 'Radial' and 'Network' model again. Residents evacuate in radial direction when radial model is applied. And network model specify the evacuation pathway of each cohort taking into account the traffic and the road network. Emergency response is not considered in domestic application for conservative. In addition, radial model is partially used in the research area. In this chapter, the population-weighted risk which can be obtained from apply existing radial model and network model was compared each other. When applying network model, all the information which are needed at WinMACCS code should be derived from Radiological Emergency Plan report. [ref] Radiological Emergency Plan contains assembly area, evacuation pathway, evacuation duration, dose criteria of emergency protection measures and so on. But lots of assumptions are needed to simulate the network model by utilizing only the data of radiological emergency plan. Therefore, only available site-specific data is used as WinMACCS input data. And remaining input data were used from WinMACCS sample. The comparison results are followed in Table 11.

TABLE 11. Comparison Results for Evacuation Model

Population-weighted Risk	**Network Model**	Radial Model	Change
Early Fatality/Total (1.6 km)	3.87E-07	5.77E-05	14809.56%
Early Fatality/Total (16.1 km)	1.62E-08	4.66E-07	2776.54%
Early Fatality/Total (80.5 km)	4.13E-10	1.65E-08	3895.16%

Cancer Fatality/Total (1.6 km)	4.38E-04	5.62E-04	28.31%
Cancer Fatality/Total (16.1 km)	1.62E-04	1.02E-04	-37.04%
Cancer Fatality/Total (80.5 km)	8.15E-05	3.32E-04	307.36%

Especially early fatality risk when applying the network model showed better results than applying radial model. In the future, the remaining input analysis should be carried out to reflect Korean situation.

II.C. Preliminary off-site risk analysis & Sensitivity Analysis

Preliminary off-site risk analysis was performed by utilizing previously selected alternatives on the basis of existing Korean domestic off-site risk analysis. To check the results variation, existing off-site risk analysis is used as reference. The comparison results is as followed.

TABLE 12. Comparison Results for Updated and Existing Model

Population-weighted Risk	Updated model	Existing model
Early Fatality/Total (0-1.6km)	7.21E-05	4.90E-02
Cancer Fatality/Total (0-1.6 km)	1.14E-03	3.69E-02
Early Fatality/Total (0-16.1 km)	5.82E-07	4.37E-04
Cancer Fatality/Total (0-16.1 km)	1.47E-04	1.87E-03
Early Fatality/Total (0-80.5 km)	2.06E-08	1.55E-05
Cancer Fatality/Total (0-80.5 km)	3.03E-04	3.40E-04

The population-weighted risk of updated model is much lower than that of existing model. These results confirmed that existing domestic model used a conservative assumption about the uncertain phenomena. The sensitivity analysis for modified input was performed to determine the impact on the results as shown in Table 13. In the emergency response category, two models which are network evacuation model and non-evacuation model are compared. The updated model which is first column means base case. From second column, each parameters is replaced by existing input data. Table 13 shows the degree of impact to risk results followed by the change of input variables.

TABLE 13. Sensitivity Analysis Results for Updated Model

Population-weighted Risk	Updated Model	Diffusion Coefficient	Dispersion Model	Plume Rise Effect	Shielding Factor	Emergency Preparedness
Early Fatality/Total (0-1.6 km)	7.21E-05	7.80E-05	1.32E-04	1.51E-04	4.42E-05	1.44E-02
Change rate		-8.18%	-83.08%	-109.43%	38.70%	-19872.26%
Cancer Fatality/Total (0-1.6 km)	1.14E-03	8.44E-04	1.14E-03	1.16E-03	1.06E-03	1.12E-01
Change rate		25.96%	0.00%	-1.75%	7.02%	-9724.56%

Early Fatality/Total (0-16.1 km)	5.82E-07	6.30E-07	1.07E-06	1.22E-06	3.57E-07	1.16E-04
Change rate		-8.25%	-83.85%	-109.62%	38.66%	-19831.27%
Cancer Fatality/Total (0-16.1 km)	1.47E-04	1.35E-04	1.84E-04	1.50E-04	1.42E-04	3.26E-03
Change rate		8.16%	-25.17%	-2.04%	3.40%	-2117.69%
Early Fatality/Total (0-80.5 km)	2.06E-08	2.23E-08	3.77E-08	4.33E-08	1.26E-08	4.13E-06
Change rate		-8.25%	-83.01%	-110.19%	38.83%	-19948.54%
Cancer Fatality/Total (0-80.5 km)	3.03E-04	3.12E-04	2.82E-04	3.00E-04	2.08E-04	4.63E-04
Change rate		-2.97%	6.93%	0.99%	31.35%	-52.81%

As shown in Table 13, emergency preparedness gives the greatest effect to results and plume rise effect, dispersion model, shielding factor and diffusion coefficient are followed in the order.

III. CONCLUSIONS

In this study, some issues concerning the adoption of off-site risk analysis are deducted through the review of latest experiment and related documents. Deducted issues are diffusion coefficient, dispersion model, plume rise effect, shielding factor, emergency response. Some alternatives which are appropriated to each issues are derived and input model is proposed. The updated input model contains more realistic analysis than existing model. The base of update model is WinMACCS sample model. In case of site-specific parameters, available information could be obtained from National Statistical Office. The risk impact of updated model application is confirmed through sensitivity analysis. The sensitivity analysis results shows us the emergency response has the greatest impact to results. Existing model didn't simulate emergency response. As a results, the difference between two models about emergency response is relatively high. Therefore, the simulation model that reflects site-specific radiological emergency plan should be performed for realistic off-site risk analysis. The other additional analysis, especially source-term and tomographic analysis should be performed in same purpose. Through continuous research, uncertainty reduction will be needed to improve the reliability of the analysis result.

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