Domestic Model and Code Development for the Cost-Estimation of Population Evacuation and Area Decontamination After Nuclear Power Plant Accident

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1. Introduction

After the Chernobyl and Fukushima Accident, there has been desired for research on the medium-to long-term response and recovery from a nuclear accident, domestically and internationally. Put in place as it was for the technical base with respect to the initial accident response in Korea, quite shallow is the technical base for medium-to long-term accident response. In parallel, an efficient and economic environmental impact assessment technology has been deemed one of the core tools required to make any decisions for a nuclear accident response and recovery reasonable and commensurate with the legal stances and the lesson learned from the Fukushima, Japan.

Firstly, in Korea, we'd like to reveal the domestic model of ours and a program, NACC (Nuclear Power Plant Accident Cost Calculator) to calculate economic costs to be incurred during the activities relevant with response and recovery from nuclear accident. NACC implements the legal and environmental conditions in Korea and took the calculation result using L3 PSA for the accidental together with statistics for the nuclear power plant sites, which is provided by National Statistical Office. We divide the area around the nuclear power plant site into several sectors for the sake of analysis, and NACC uses sector-specific statistics and contamination information to calculate the decontamination cost of the entire site and the accident response economic cost factor for WinMACCS to calculate the accident response economic cost.

2. Methods and Results

2.1 accident response cost calculation model

In Fig.1, Task 1(T1) calculates the contamination concentration of radioactive material released into the environment according to the accident scenario for each unit at the nuclear power plant site using WinMACCS[1]. Task 2(T2) using the contamination information calculated for each unit using MURCC[2],[3],[4], the annual exposure dose for each sector for multiple nuclear power plant accidents is calculated. Task 3(T3) investigates the administrative district map of the nuclear power plant site and statistical information for each administrative district of the National Statistical Office. Task 4(T4) calculates the area fraction of administrative districts for each sector from the administrative district map and converts statistical information for each administrative district into statistical information for each sector. Task 5(T5) uses NACC to set decontamination work for each sector based on sector-specific contamination information and statistical information. Task 6(T6) calculates the WinMACCS input variable (economic cost factor) based on the decontamination work set for each sector in NACC. Task 7(T7) calculates the decontamination cost by sector using NACC and calculates the economic cost of simple accident response.

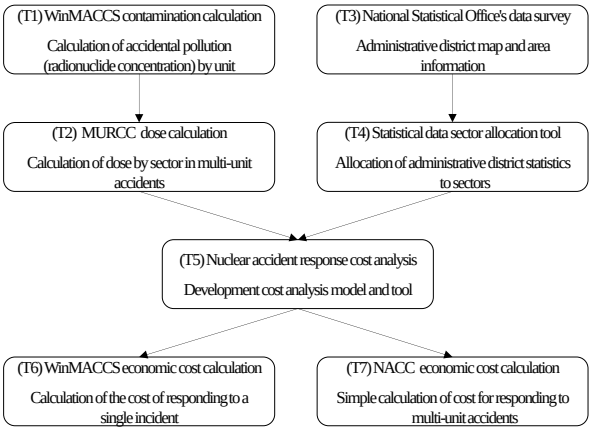

Fig. 1. Nuclear accident response cost calculation model.

2.2 Annual exposure dose calculation for Multi-unit nuclear power plant

Table I: annual exposure dose (Sv/yr) calculation results by sector

	13(W)	14(WNW)	15(NW)	16(NNW)	1(N)	2(NNE)	3(NE)	4(ENE)	5(E)
R1	3.70E-03	1.66E-04	2.56E+00	4.13E+02	1.92E+03	4.13E+02	2.56E+00	1.66E-04	3.70E-03
R2		9.99E-13	9.56E-02	1.26E+02	7.02E+02	1.26E+02	9.56E-02	9.99E-13	
R3		2.57E-14	2.36E-02	5.12E+01	3.18E+02	5.12E+01	2.36E-02	2.57E-14	
R4			8.18E-03	2.84E+01	1.92E+02	2.84E+01	8.18E-03		
R5			3.63E-03	1.78E+01	1.30E+02	1.78E+01	3.63E-03		
R6			7.18E-04	7.19E+00	6.00E+01	7.19E+00	7.18E-04		
R7			4.86E-05	1.53E+00	1.50E+01	1.53E+00	4.86E-05		
R8			3.31E-06	2.53E-01	2.79E+00	2.53E-01	3.31E-06		
R9			6.61E-07	4.97E-02	5.94E-01	4.97E-02	6.61E-07		
R10			6.36E-07	1.20E-02	1.44E-01	1.20E-02	6.36E-07		

2.3 Allocation of statistical data by sector

Statistical data from the National Statistical Office, such as population distribution and land use information are sorted by administrative district. However, since the administrative district is unstructured, it could be difficult to apply the radioactive material contamination information calculated in the previous section for each

administrative district. In this study statistical information by administrative district was converted into statistical information by sector. To show how this conversion can be carried out, in Figure 2, the administrative district map file and Python program were used to calculate the fraction of administrative districts in each sector, and NACC calculates the administrative district fraction and administrative district statistics and converts them into sector-specific statistical information.

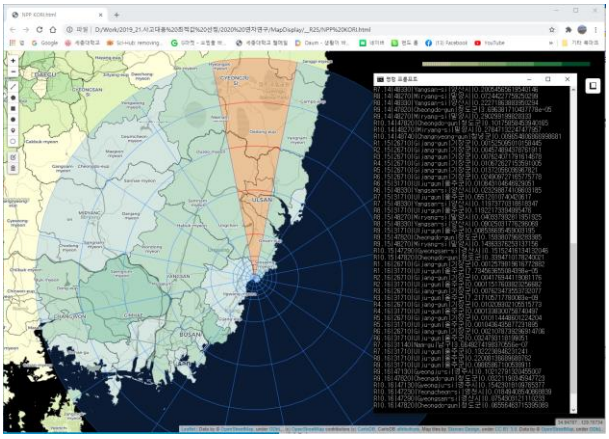

Fig. 2. Python and NACC to convert the administrative district-wise statistical information into one allocated for each Sectors for the accident analysis.

2.4 Configuring sector-specific decontamination operations

The contamination area is divided into three separate sub-areas as shown in Table II according to the degree of surface contamination[5].

Table II: site-contaminated sub-areas classification

	Description	decontamination
hard-to-return zone	Residents are restricted over a long period of time in areas with more than 50 mSv/yr.	Decontamination work is carried out after natural reduction.
restricted residential area	20-50mSv/yr area, if 20mSv/yr or less is certain, change to the evacuation order release preparation area.	It should be less than 20 mSv/yr in the short term.
Evacuation order release preparation area	area below 20 mSv/yr, the aim is to lift evacuation and return.	Reduce to less than 1 mSv/yr in the long term.

In Fig. 3, the decontamination work by sector was divided into four zones according to land use, and each zone was subdivided again according to characteristics. Accordingly, decontamination work is set for each part, and decontamination work is set in the same way for all sectors requiring decontamination work.

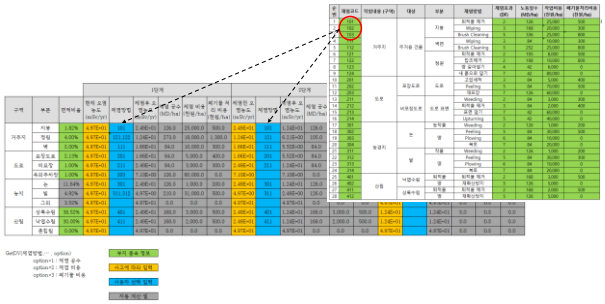

Fig. 3. Configuration of decontamination work by sector.

2.5 Calculation of economic cost to respond to and recover from of nuclear accidents

WinMACCS calculates the economic cost of responding to nuclear accidents in the CHRONC module[1]. In order to calculate economic costs, the economic cost factor value must be set as an input. The site-specific economic cost factor can be calculated by processing statistical information, but the decontamination cost factor for the period of mid- to long-term after accidents, depends on how decontamination work proceeds. Therefore, factors must be calculated after decontamination work is established. The formula for calculating the site decontamination efficiency factor is as follows.

$$DSREFC = \frac{\sum_{i=1}^{n}\{Sector\ Area_i \times (\sum_{j=1}^{4}\sum_{k=1}^{m_j} PartAreaRatio_{i,j,k} \times Contaimi1_{i,j,k})\}}{\sum_{i=1}^{n}\{Sector\ Area_i \times (\sum_{j=1}^{4}\sum_{k=1}^{m_j} PartAreaRatio_{i,j,k} \times Contaimi2_{i,j,k})\}}$$

$DSRECT$: *average decontamination efficiency of sites (unitless) at each decontamination stage*
i : *sector number*
n : *number of sectors on the site*
j : *sector area number (1: Residence, 2: Farmland, 3: Road, 4: Forest)*
k : *type of number that subdivides each area of a sector*
m : *the number of types that subdivide each area of a sector*
$SectorArea$: *sector area (ha)*
$Part\ Area\ Ratio$: *percentage of subdivision type area to sector (unitless)*
$Contami1$: *contamination concentration before decontamination (Sv/hr)*
$Contami2$: *contamination concentration after decontamination (Sv/hr)*

The results of calculating the decontamination cost factor in NACC and applying it to the WinMACCS input are as follows.

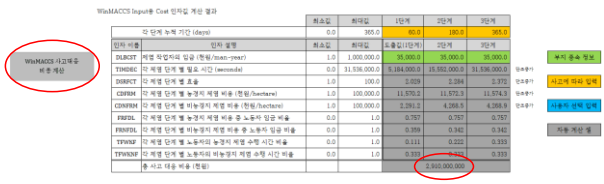

Fig. 4. Calculating the economic cost of a nuclear accident.

2.6 Simple accident response economic cost calculation

After setting up decontamination work for each sector, NACC is used to calculate decontamination costs and simple accident response economic costs. The formula for economic cost for simple accident response is as follows.

$$COST_{decon} = \sum_{i=1}^{n}\left\{Sector\,Area_i \times \left(\sum_{j=1}^{4}\sum_{k=1}^{m_j} Part\ Area\ Ratio_{i,j,k} \times Decon\ Cost_{i,j,k}\right)\right\}$$

$COST$: *total cost of decontamination at each decontamination stage* (KRW)
i : *sector number*
n : *number of sector on the site*
j : *sector area number* (1: *Residence*, 2: *Farmland*, 3: *Road*, 4: *Forest*)
k : *type of number that subdivides each area of a sector*
m : *the number of types that subdivide each area of a sector*
$Sector\ Area$: *sector area* (ha)
$Part\ Area\ Ratio$: *percentage of subdivision type area to sector* ($unitless$)
$Decon\ cost$: *Sector subdivison type decontamination cost* (KRW)

The results of calculating the decontamination cost for each sector are shown in Figure 5.

Sector ID	인구수 (명) POP	총 육지면적 (ha) LandArea	오염 정도 (mSv/yr) Contamination	제염 효율 (unitless) DeconFactor	제염 비용 (천원) DeconCost	제염 결과 (mSv/yr) DeconResult	제염 우선순위 DeconOrder
R1.1	247	50.542	1,923,730	6.605	58,070.6	291,233	
R1.2	233	50.558	412,795	2.116	23,877.7	195,027	
R1.3	240	50.550	2,558	2.118	23,915.8	1,208	
R1.5	388	52.269	4			4	
R1.13	398	50.375	4			4	
R1.15	398	50.371	2,558	2.161	24,606.0	1,184	
R1.16	328	50.449	412,795	2.142	24,415.2	192,693	
R2.1	529	151.841	702,106	2.101	23,551.7	334,110	
R2.2	446	151.938	126,002	2.094	23,395.8	60,167	
R2.3	446	151.946	96			96	
R2.15	1,192	151.096	96			96	
R2.16	1,190	151.091	126,002	2.161	24,797.3	58,302	
R3.1	815	253.101	318,310	2.098	23,471.1	151,729	
R3.2	744	253.189	51,245	2.094	23,392.0	24,470	
R3.3	744	253.212	24			24	
R3.15	1,987	251.798	24			24	
R7.1	404,794	15,200.392	14,975	2.282	31,404.9	6,561	
R7.2	385,333	12,700.447	1,525	2.318	28,338.6	658	
R7.16	44,542	15,159.587	1,525	2.094	23,343.1	728	
R8.1	94,482	25,114.381	2,793	2.097	23,918.3	1,332	
R8.2	92,937	13,501.725	253	2.110	12,592.9	120	
R8.16	63,929	25,181.327	253	2.092	22,999.1	121	
R9.1	76,899	35,053.969	594	2.092	22,505.7	284	
R9.2	40,292	14,466.753	50	2.098	9,461.3	24	
R9.16	71,208	35,068.547	50	2.093	22,346.5	24	
R10.1	148,346	42,772.514	144	2.104	22,174.7	69	
R10.2	79,773	13,592.500	12			12	
R10.16	82,006	44,947.115	12			12	
총 제염비용					723,431.5		

섹터별 제염 효율 및 비용 계산
제염작업 우선순위 결정
선택한 섹터 제염작업 시트로 이동
내용 지우기

Fig. 5. Calculation of decontamination costs and simple economic costs by sector.

3. Conclusions

We developed an economic cost calculation model reflecting the domestic environment for nuclear accident response and NACC, a calculation tool that calculates economic cost factors for WinMACCS and calculates economic cost for simple accident response.

ACKNOWLEDGMENTS

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