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Effects of Input Variables in Radiological Accident Consequence Assessment

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Abstract

The importance of input variables of real-time accident consequence assessment model has been analyzed. Partial correlation coefficients of input variables related to the plume and the ingestion exposure have been estimated using Latine hypercube sampling technique. It is known that wind speed and growth dilution rate are the most important variable in plume and ingestion exposure, respectively.

I. Introduction

The main task of a radiological accident consequence assessment(ACA) model is to predict the radiological situation and to provide a reliable quantitative data base for making decisions on countermeasures. There are two types of ACA models. One is real-time ACA and the other is probabilistic ACA model. Real-time ACA models are important tool for decision processes on countermeasures in case of large-scale radioactive contamination of the environment. Probabilistic ACA models have been applied to risk assessments for nuclear installations, assessing the merit of different design options, safety goals, siting and emergency planning. These models should be fast-running models. Therefore probabilistic ACA models adopt simple and fast modules for the estimation of radiological exposure. The adoption of simple and fast modules may result in the production of unrealistic consequence assessment.

Real-time ACA models adopt more precise numerical modules and are able to produce realistic consequence assessment. The importance analysis of input variables in a real-time ACA model provides the information which can be used as an useful guidance for the development of a more reliable probabilistic ACA model. In this study, the importance analysis of input variables of real-time ACA models FADAS[1] and DYNACON[2] has been conducted using the environmental information of Korea.

The main objectives of this study are to analyze the importance of input variables in a real-time ACA model taking into account the environmental characteristics of Korea, and to provide the information necessary for the development of the site-specific probabilistic ACA model.

II. Approach

II.1 Applied Models

For the estimation of plume exposure, site-specific meteorological and geographical conditions should be considered. In this study, the estimation of plume exposure has been conducted on Ul-chin nuclear site with FADAS model over the domain of 17 km x 17km area. For the ingestion pathway analysis, the information from national statistics were analyzed. Figure 1 shows the characteristics of main modules of FADAS.

Wind Field Generation	Site Specific Mass Consistent 3-Dim. Wind Filed Generation
Dynamic Diffusion	Random Walk Diffusion Model Concentration Distribution
Dose Assessment	Numerical Integration Method for Cloud- and Groundshine[3]

Figure 1. Configuration of FADAS

DYNACON is used for estimating the long term exposure dose given through the ingestion pathways. It is a compartment model in which the environmental elements are regarded as compartments. The rate of change of the concentration of radionuclide in each compartment is represented as the difference of inflow and outflow rate. Equation (1) represents the change of the concentration of radionuclide in each compartment.

$$\frac{dY_i}{dt} = \sum_{j=1}^{n} k_{ji} Y_j - \left(\sum_{j=1}^{n} k_{ij}\right) Y_i - \lambda_i Y_i + P_i \qquad (1)$$

where, Y is the concentration of radionuclide, k is the transfer coefficient between two compartments, λ represents the loss of concentration, and P represents the inflow rate.

II.2 Importance Analysis

In relation to the interpretation of the results of the accident consequence assessment, it is important to specify the effect of each input variable. The technique generally used in the sensitivity analysis was adopted to determine the importance of each variable related to an ACA model. In this study, Latin hypercube sampling technique was used for making the sets of input variables and partial correlation coefficients which represent the importance of each variable on the consequences, have been calculated[4].

II.3 Distributions of Input Variables

The meteorological data measured for 10 years around Ul-chin site have been statistically analyzed. The land use around the site was obtained from the statistical data of Ul-chin[5]. Table 1 represents the distribution and applicable range of three input variables of FADAS. In this model, surface roughness z_0 is related to wind profile by the following Equation.

$$u = (u_*/k) \ln(z/z_0) \qquad (2)$$

where, u is wind speed, u_* is frictional velocity, k is the von Karman constant and z is the height at which wind speed is considered[6].

Table 1. Information of Input variables related to short-term exposure

Variable	Range	Distribution Type
Wind speed (m/sec)	0.5 - 14.	Lognormal
Release Height (m)	10 - 70	Uniform
Surface Roughness (m)	0.2 - 0.9	Triangular

Table 2 represents the distribution and applicable range of 9 variables related to the ingestion pathway[7,8,9].

III. Results and Discussions

III.1 Effects on Plume Exposure

The external exposure given from radioactive plume is proportional to the concentration of the effluent around the ground. The concentration distributions obtained for 50 sampled input data sets were analyzed for calculating the importance of three input variables. Every 10 minutes, wind field over the domain of 17km x 17km on Ul-chin site was generated. For the calculation of concentration distribution, the release rate of 181.43 kg/hr of SF_6 gas was assumed. The release rate was actually adopted when the field tracer experiment was conducted over Ul-chin site on 1997.

Table 2 Input variables related to long-term exposure

Variables	Units	Range of value		Distribution type
		^{137}Cs	^{90}Sr	
Weathering Removal Rate	1/day	1.81×10^{-2} - 4.24×10^{-2}	1.81×10^{-2} - 4.24×10^{-2}	Lognormal
Growth Dilution Rate	1/day	2.27×10^{-2} - 5.30×10^{-2}	2.27×10^{-2} - 5.30×10^{-2}	Lognormal
Translocation Rate	1/day	3.9×10^{-3} - 7.2×10^{-3}	7.8×10^{-4} - 1.4×10^{-3}	Triangular
Plant to Soil Concentration Ratio	-	1.0×10^{-3} - 1.0×10^{-1}	2.2×10^{-2} - 6.6×10^{-1}	Lognormal
Resuspension Factor	1/m	1.0×10^{-6} - 1.0×10^{-4}	1.0×10^{-6} - 1.0×10^{-4}	Lognormal
Deposition Velocity	m/day	2.9 - 4900	2.9 - 4900	Lognormal
Foliar Interception Constant	m^2/kg	1.0 - 4.0	1.0 - 4.0	Lognormal
Soil-Water Distribution Coefficient	mL/g	36.5 - 30000	2.0 - 1000	Lognormal

The most influential variable in plume exposure was wind speed with partial correlation coefficient(PCC) of -0.691. The second one is release height with PCC of -0.485. The PCC of surface roughness is 0.132. From these results, the followings can be observed:

1) Weather is the most important condition on the atmospheric transport of effluents.
2) The importance of surface roughness is about 19% of that of wind speed. Therefore, the land use should be considered in ACA for realistic estimation.

III.2 Effects on Ingestion Pathway

Rice is the main foodstuff with the consumption rate of 122 kg yr^{-1} for adults in Korea. Due to the lack of experimental data for rice in Korea as well as foreign countries. It is known that the growth characteristics of cereals is very similar to that of rice. In this study, cereal was used as the foodstuff for the analysis of ingestion exposure. It is known that the growth characteristics of cereals is very similar to that of rice. The time-integrated radionuclide concentrations in cereal for both 2 and 50 years as a function of the date of deposition were calculated with the sampled 200 sets of 9 parameters. Two radionuclides ^{90}Sr and ^{137}Cs were assumed to be deposited uniformly with the concentration of 1 Bq/m^2. Figures 2 and 3 show the absolute partial correlation coefficients obtained for ^{90}Sr and ^{137}Cs, respectively. In the figures, G and N represent deposition during growing season and non-growing sean, respectively. From these figures, authors could find the followings:

1) The importance of parameters is strongly dependent on radionuclides and the dates of deposition.
2) The growth dilution rate was the most sensitive parameter.
3) In case of ^{137}Cs, there is no difference between 2 and 50 years integrated radionuclide concentrations. While, the PCCs for ^{90}Sr shows distinct differences. It is due to high root uptake and low translocation of ^{90}Sr as compared with ^{137}Cs.
4) The PCCs for translocation rate shows the largest difference between the two radionuclides. It means that the translocation is a dominant process of contamination in the early stage (within 2 years) after deposition.

IV. Conclusions

The importance of input variables of accident consequence assessment models for plume and ingestion exposure pathways has been estimated. A short term real-time ACA model FADAS and a long term dynamic food chain model DYNACON were used for the plume and ingestion exposure analysis, respectively. Wind speed is known to be the most effective variable in short term exposure. The effects of surface roughness can not be ignored. It was found that there are several influential variables such as growth dilution rate and translocation rate for ingestion exposure analysis. These variables are site-specific. Therefore it is very important to obtain site-specific data for the influential variables through filed experiments for realistic evaluation of the transport of radionuclides in the environment.

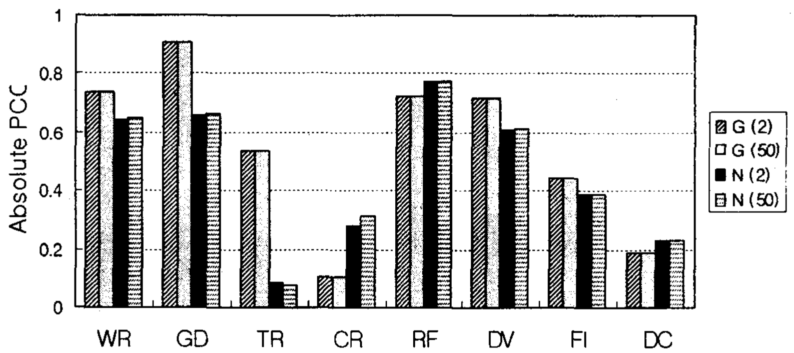

Figure 2. Pccs for cereals for Cs-137

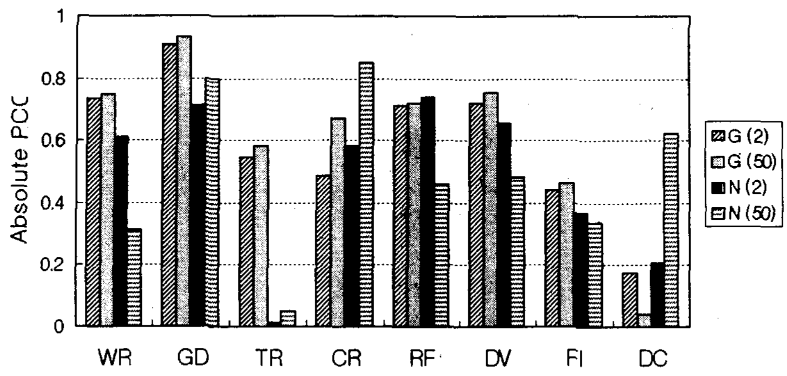

Figure 3. Pccs for cereals for Sr-90

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