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Use of COMIDA2 for Evaluating Korean Ingestion Doses During Severe Accidents

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1. Introduction

If radioactive material is released into the environment due to severe accident of nuclear power plant, internal exposure resulting from ingesting contaminated food is important for assessing the chronic health impact of accident. In the level 3 probabilistic safety assessment of severe accidents, the intake of radioactive materials through food is considered as one of the major routes of exposure. However, there is little evaluation of ingestion dose considering Korean eating habits and agricultural culture. Based on the applicability to the level 3 PSA and the key evaluation factors, it is necessary to select a suitable food intake model and develop a model that can reflect the domestic agricultural environment.

2. Methods and Results

2.1 COMIDA2

COMIDA2 is selected as the computer code for food intake dose assessment. COMIDA2 is an updated version of COMIDA that predicts the concentration of contaminant species in crops due to acute fallout. It is a computer code that calculates the food intake dose. Therefore, in the result file, it is possible to confirm both the contamination concentration of the nuclear species and the intake dose by each crop. Also, COMIDA2 can be analyzed independently of MACCS2, which is a code used for level 3 PSA, and the result of COMIDA2 can be used in MACCS2 calculation [1].

2.2 Improved and recalculated parameter

COMIDA2 requires a total of three input files for execution. A VAR file for inputting nuclide-related data, a PAR file for inputting data other than a nuclide, and an INP file for inputting additional parameters when COMIDA is upgraded to COMIDA2.

There are many input variables of COMIDA2, but the factors reflecting domestic characteristics are limited. First, the average annual food consumption and output of Koreans can be modified. This follows the food category in the computer code, assuming that 'other livestock' in the category of food is pork with the highest consumption of meat in Korea. In the existing COMIDA2, eggs were treated as 'other livestock', which could be included in poultry. As other livestock become pork, the decay chain nuclear transfer coefficient of 'other livestock' in the VAR file has been changed to values for pork. In addition, feed consumption of various livestock in the PAR file is changed to match the domestic environment, and also entered the feed intake of pigs as ‘other livestock’.

Also, the representative crops in each food category were changed to suit the domestic food consumption environment, and the water content ratio for each crop was newly designated and the remaining percentage of the nuclide during cooking was changed among the input parameters of the INP file.

Table 1 shows the average annual food consumption per adult in 2015 provided by the Korea Health Industry Development Institute (KHIDI). The age group is designated as an adult because the MACCS2 and COMIDA2 computer codes perform an exclusion evaluation for only adults. A total of 19 food groups in the statistical data are composed of 13 vegetable foods and 6 animal foods. In this study, the consumption of grains and their products, potatoes and starchs, beans and their products, vegetables, fruits in the vegetable food according to the input of COMIDA2, and the consumption of beef, pork, chicken and egg, raw milk was extracted in the animal foods.

Table 1. Annual average consumption of Korean adults

Food Category	*Annual average consumption [kg·yr^{-1}]*
Grains	109.73
Potatoes and starch	13.96
Beans	14.12
Vegetable	119.64
Fruits	76.28
Beef	7.10
Pork	12.89
Chicken	8.41
Egg	9.72
Raw milk	17.28

In the consumption of animal foods, meat consumed pigs, eggs, chickens, and cows in order, reflecting the pork intake that was not present in the existing COMIDA2 food category. Food intake and production in COMIDA2 are assumed to be 100% self-sufficiency within the area, so they should be calculated by multiplying self-sufficiency rates by food groups in Korea. In the case of meat, only pure meat consumption was selected for the same reason. The food self-sufficiency rate of table 2 used in the calculation is based on the data from the report of the Korea Rural Economic Institute [2]. Egg was added to the poultry count to reflect the previous consideration of egg consumption in other livestock.

Table 2. Korean food self-sufficiency rate

Food Category	*food self-sufficiency rate [%]*
Grain	24
Potatoes	94
Beans	11
Vegetable	88
Fruits	79
Beef	46
Pork	73
Chicken	87

Table 3 shows the annual food consumption of adults considering Korean food self-sufficiency.

Table 3. Annual food consumption of adults considering Korea's food self-sufficiency rate

Food Category	*Annual average consumption* $[kg \cdot yr^{-1}]$
Grain	26.3
Leafy Veg.	73.7
Root Veg.	44.7
Legumes	1.6
Fruits	60.3
Beef	3.3
Milk	17.3
Poultry/Egg	15.8
Pork	9.4

In order to derive annual average food production, COMIDA2 was calculated by multiplying the estimated annual consumption of adults by '0.0024'.

The value of '0.0024' is 1.66×10^{10} m^2, which is the area used for food production in the Korea, divided by 40,291,121 people, the adult population over 20 years old, from the 'Resident Registration Population Statistics' of the Ministry of Public Administration and Security. The calculated annual average food production is shown in Table 4.

Table 4. Annual average food production

Food Category	*average food production* $[kg \cdot m^{-2}]$
Grain	0.06
Leafy Veg.	0.18
Root Veg.	0.11
Legumes	0.004
Fruits	0.14
Beef	0.01
Milk	0.04
Poultry	0.04
Pork	0.02

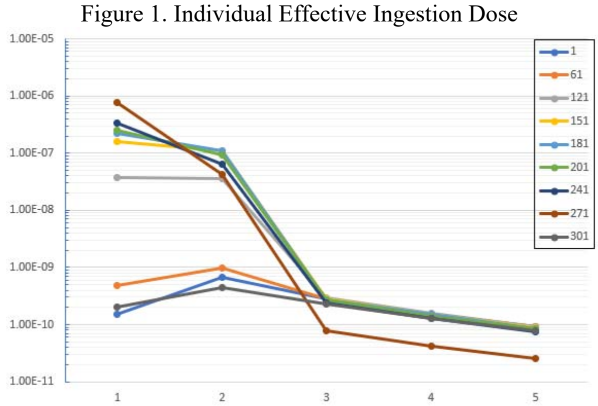
Since COMIDA2 considers human meat intake, and livestock grows and feeds on radioactive contaminated crops, it should also estimate the feed intake for each animal. It is assumed that grazing does not take place considering the domestic livestock environment. Hay, cereals, and legumes were calculated by referring to 'Agriculture, Forestry and Livestock Food Statistics'. In addition, there are time-related variables such as decay chain nuclear species transfer coefficient, moisture content ratio, food processing factors (cooking), and agricultural dates. Transition coefficients are referenced to the values listed in [3]. The differences in the moisture content ratios in the same food category were due to differences in the representative consumption of Korea and the United States. The water content ratio was extracted from the report published by the Korea Atomic Energy Research Institute [4].

The last time variable is the growth period of the crop, the grazing period of the livestock, the date of the cultivation, the beginning of the growth of the grass and hay. The average growth period and the harvest date of rice were set for the period of growth of the crops, assuming that the rice was the representative food of Korea. These values were extracted from the paper [5].

2.3 Result

Figure 1 shows the results of the improvement of the food intake dose assessment model. This is an assessment of the single nuclide, Cs-137, showing the individual effective dose ([mSv per (Bq · m^{-2})]) due to ingestion for 5 years following the accident date.

Figure 1. Individual Effective Ingestion Dose



The figure shows that if the incident occurred on days 1, 61, and 301, the dose for the first year was lower than for the second. Because days 1 and 61 are before sowing, radioactive material released by the accident has little direct impact on crops. On the other hand, since the accident at 301 days is after the harvest, radioactive materials have little direct impact on crops. Also, in case of accident with the highest dose of 271 days in the first year, it is very close to the harvest date of 273 days and the crops are almost fully grown, so there is a high probability that the released radioactive material is deposited on the crops. In other words, since the leaf interception coefficient is very large, the amount of deposition on the surface soil is relatively small compared to other accident days, so that the dose of the second year has decreased sharply. From the third after all accident days, the source of the crop depends only on root uptake and resuspension, and root uptake is dominant. Therefore, the dose after the third year is reduced due to the contamination concentration in the soil, which is gradually decreased by the half-life of the released radioactive material. An additional factor in the reduction of contamination concentration in the soil is the transition to cultivation, inside crops or adherent soils.

3. Conclusions

The food intake dose assessment model included the evaluation of the largest amount of pork in the meat and reevaluated it to reflect the dietary habits and agricultural environment of Koreans. The effective dose of an individual due to ingestion of contaminated food varies depending on the accident date, which is related to the sowing of agricultural products. The results of this study are expected to contribute to the improvement of the reliability of the level 3 probabilistic safety assessment.

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