A Study on the Contaminated Food Interdiction for the Public following a Severe Accident of Nuclear Power Plants

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1. Introduction

When the radionuclides are released to the offsite the nuclear power plants (NPPs) during a severe accident, the nearby ground is easily contaminated and so are the growing crops. In this case, the food interdiction criteria in the regulation for the public can be applied. To decide the protective actions following the severe accident, it is important to predict the activity concentration of the food.

Thus, in this study the activity concentrations of the growing crops were calculated when the offsite ground contamination occurs by a severe accident. The agricultural features of Korea were reflected by the parameters. These calculated values were for the unit deposition of unit area. By comparing these with the food interdiction criteria, we derived the allowable ground concentrations of activity. The cumulative activity concentrations for 10 years were also obtained for each food category and radionuclide.

2. Methods and Results

To estimate the activity concentrations of crops for unit deposition of unit area, we used COMIDA2 program. This program is mainly used to evaluate the ingestion dose for intermediate or long-term in Level 3 Probabilistic Safety Assessment (PSA) and it calculates the activity concentration and the ingestion dose over time. In this study, we derived the activity concentrations of foodstuffs for 9 accident dates, except for the ingestion dose.

2.1 Agricultural Features of Korea

The reflected agricultural features of Korea were wet-to-dry ratio (FD), the feedstuff consumption rates for each livestock, the specific dates for agricultural events, and the transfer coefficients of pork (TCO). Pork is an added food category because the consumption rate of pork is highest among all kinds of the meat in Korea. The FDs were taken from a report[1]. The feedstuff consumption rates for each livestock were analyzed by using the statistics from government. In this calculation, the degree of self-sufficiency for each feedstuff was considered and the consumption of pasture and soil in grazing season was neglected by considering livestock industry environment in Korea. The specific dates for agricultural events were taken from a paper[2] and the pork TCOs for each radionuclides were taken from a report[3].

2.2 Food Interdiction Criteria in regulations

The food interdiction criteria in regulations are shown in Table 1. These are applicable for the public in emergency periods following the severe accident of NPPs.

Table 1. Food Interdiction Criteria

Radionuclide Group		Food Category			
		Meat, Fish, Grain (Bq/kg)	Vege.*, Fruit (Bq/kg)	Water, Milk (Bq/l)	Baby Food (Bq/kg)
Ⅰ	Cs-134, Cs-137, Ru-103, Ru-106, Sr-89	2000	1000	200	100
Ⅱ	I-131, Sr-90	1000	500	100	10
Ⅲ	U-235, U-238	100	100	20	10
Ⅳ	Am-241, Pu-238, Pu-239, Pu-240, Pu-242	10	10	10	1
Ⅴ	H-3	-	-	100 kBq/l	-

*Vege. means vegetables including leafy vegetables and root vegetables.

In this study, we evaluated the activity concentrations of meat, grains, legumes, vegetable, fruit, and milk for each of radionuclide in group Ⅰ~Ⅳ by COMIDA2. The value of legume was added to 'meat, fish, grain' food category.

2.3 Activity Concentrations of Food Categories

The activity concentrations of foodstuffs in the first year along with 9 accident dates were derived and depicted in Fig. 1. For all radionuclides and foodstuff, as the accident date became closer with the harvest date (273rd Julian day), the activity concentrations were increased. Therefore the maximum was that of 271st Julian day, while the minimum was that of 301st Julian day. In case of accident on 271st Julian day, the crops are almost fully developed so that the most of released radionuclides are directly deposited on the vegetation surface. The activity concentrations of meat and milk were also high because the livestock eating the highly contaminated crops produces animal products.

Unlike other food categories, the value of milk was temporarily decreased with accident on 181st Julian day and 241st Julian day. The reason of decrease was the hay cutoff, so the amount of cut hay was removed.

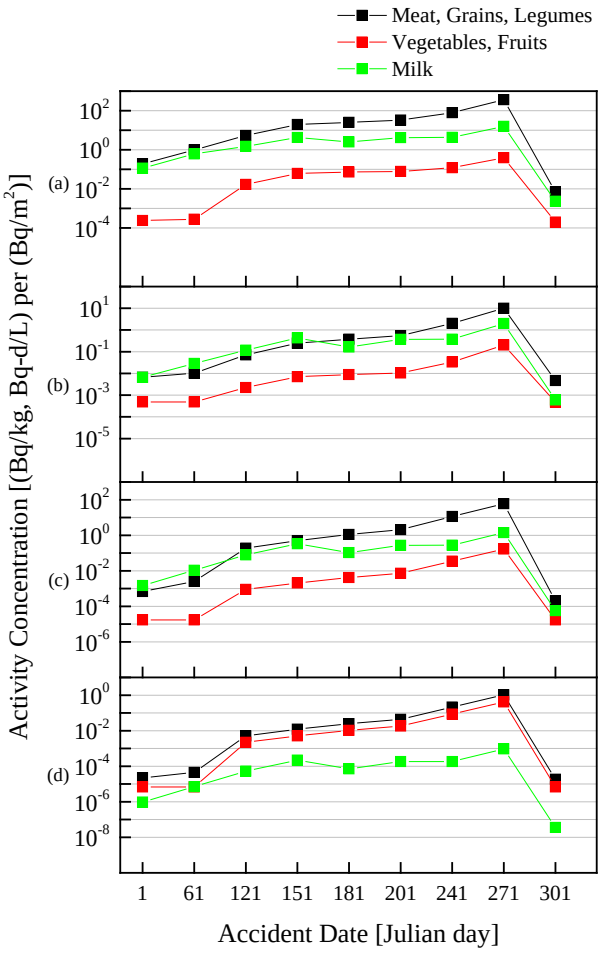

Fig. 1. Activity concentrations of food categories along with 9 accident dates in the first year, for radionuclide in (a) group Ⅰ, (b) group Ⅱ, (c) group Ⅲ, and (d) group Ⅳ.

2.4 Allowable Ground Concentrations

Since the given values in Fig. 1 are for unit deposition of unit area, to compare them with the values in Table 1, we should multiply the contaminated area and the ground concentration. The ground concentration depends on the distance from the release point and the amount of released radionuclides. To find out the range of allowable ground concentration which meets the regulation criteria, we calculated the minimum and maximum. These are shown in table 2.

Table 2. Allowable Ground Concentration for each radionuclide group and food category

Radio-nuclide Group	Food Category	Allowable Ground Concentration (Bq/m²)	
		Min.	Max.
Ⅰ	Meat, Grain	5.46E+00	2.90E+05
	Vege., Fruits	2.55E+03	5.06E+06
	Milk	1.26E+01	8.66E+04
Ⅱ	Meat, Grain	9.90E+01	2.14E+05
	Vege., Fruits	2.48E+03	1.05E+06
	Milk	5.03E+01	1.68E+05
Ⅲ	Meat, Grain	1.67E+00	4.96E+05
	Vege., Fruits	5.97E+02	5.80E+06
	Milk	1.41E+01	3.47E+05
Ⅳ	Meat, Grain	9.55E+00	5.42E+05
	Vege., Fruits	2.39E+01	1.47E+06
	Milk	1.06E+04	2.81E+08

The minimum was about 5.5 Bq/m² for ‘Meat, Grain’ category of radionuclide group Ⅰ, and the maximum was about 2.81×10^{8} Bq/m² for ‘Milk’ category of radionuclide group Ⅳ. While the contamination from the released gaseous materials was reflected, the activity concentrations of fish and water are required for more accurate analysis.

2.5 Cumulative Activity Concentration

The cumulative activity concentrations for 10 years were obtained to figure out the contribution of each foodstuff and radionuclide, and then depicted in Fig. 2. The accident date was assumed to be 271st Julian day because it was the highest in Fig. 1.

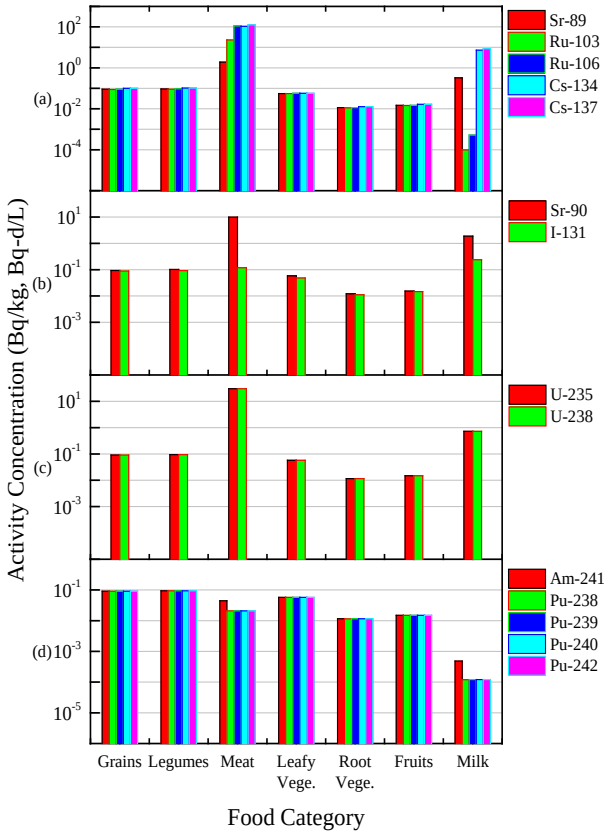

Fig. 2. Activity concentrations accumulated for 10 years by food categories when the release occurs on 271st Julian day for radionuclides in (a) group Ⅰ, (b) group Ⅱ, (c) group Ⅲ, and (d) group Ⅳ.

The activity concentrations of crop products including grains, legumes, leafy vegetables, root vegetables and fruits were derived by the identical dynamic model. It made a similar tendency for all foodstuffs and radionuclides in (a)~(d) of Fig.2. However those of animal products including meat and milk were distinct from those of crop products. Since they were derived by equilibrium model, they were calculated by multiplication of the feedstuff activity concentration, TCO, and the feedstuff consumption rate for each livestock. Therefore the activity concentrations of animal products were dependent on the TCOs.

3. Conclusions

In this study, when the contamination by a unit deposition of unit area occurs by the released gaseous materials during a severe accident of NPP, the activity concentrations of foodstuffs for each radionuclide were calculated.

As the accident date gets closer to the harvest date, the activity concentrations of foodstuffs were increased for all radionuclides and most foodstuffs. But unlike other foodstuff, the value of milk was temporarily decreased by the date of hay cutoff.

The range of allowable ground concentration was calculated to meet the food interdiction criteria in regulations. The maximum was around 5.1×10^{7} times higher than the minimum.

The cumulative activity concentration for 10 years was obtained for each foodstuff and radionuclide. While the values of crop products had similar tendency by identical dynamic model, those of animal products were distinct. The activity concentrations for each radionuclide and crop product were similar, but those for animal products were differed from the TCO for each radionuclide.

For more reliable data, the detailed calculation for the growing season of each crop and the experiments for the coefficients of each foodstuff and radionuclide are required. Additionally the activity concentrations of fish and water should be considered to figure out the more reliable allowable ground concentration.

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