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A Study on the Application of Countermeasure for the Reduction of the Ingestion Dose After Nuclear Accidents

Won Tae Hwang · Kyung Suk Suh · Eun Han Kim · Young Gil Choi ·
Moon Hee Han
Korea Atomic Energy Research Institute

Gyuseong Cho
Korea Advanced Institute of Science and Technology

Abstract

The effectiveness of dose reduction resulting from the application of countermeasures for ingestion pathways after nuclear accidents was investigated together with the derivation of optimized intervention levels for Korean foodstuffs. The radioactivity in foodstuffs was predicted from a dynamic food chain model DYNACON for the date which the deposition occurs. The effectiveness of countermeasures strongly depended on radionuclides, foodstuffs and date of deposition.

1. Introduction

In the event of a nuclear emergency, the countermeasure may need to be taken to control the radiation exposure of the public through the prediction of the present and future radiological consequences. A dynamic food chain model DYNACON has been developed for the radiological consequence analysis resulting from the consumption of contaminated foodstuffs [1]. The available countermeasures to protect the ingestion pathways in earlier phase (in the first year) after an accident are follows : 1) restriction of food consumption 2) change in the processing of foodstuffs 3) application of additives such as ammonium ferric hexacyano ferrate (II) and bentonite to reduce the Cs activity in milk and meat effectively 4) change in the feeding regimes of domestic animals 5) feeding until the time of slaughtering with uncontaminated fodder. In general, the decision of countermeasures may be done on the basis of radioactivity on the ground or radioactivity in the foodstuffs.

In this study, the effectiveness of dose reduction resulting from the restriction of contaminated foodstuffs after accidents was investigated. The optimized intervention levels (ILs) for Korean foodstuffs were derived using cost-benefit analysis with a human capital approach.

2. Derivation of Optimized Intervention Levels for Foodstuffs

The two general principles of the system for accident management are justification and optimization [2]. The simple cost-benefit analysis, which is a well-established method in economic theory, is a useful tool for decision-making, although other and more extended methods exist. It only considers averted dose by implementing the countermeasure and monetary cost of implementing the countermeasure. The optimized IL (Bq kg^{-1}) for the foodstuff, which is based on cost-benefit analysis with the general principles, is given by [3] :

$$IL = \frac{b}{a \cdot DF} \tag{1}$$

where b is the cost per unit mass of a given foodstuffs, a is monetary value of the unit dose, and DF is committed effective dose per unit intake. The optimized duration of the foodban (T_{opt}, days) can be derived from radioactivity at harvest or production of foodstuffs (C_0 , Bq kg^{-1}).

$$T_{opt} = -\frac{1}{\lambda}\ln\left(\frac{b}{a\ C_0\ DF}\right) \tag{2}$$

where λ is the decay constant of radionuclide in days.

3. Results and Discussion

The effectiveness of countermeasures for the potential reduction of ingestion dose after nuclear accidents was investigated. A dynamic food chain model DYNACON was used for the prediction of radioactivity in foodstuffs from radioactivity on the ground. It was assumed that a deposition occurs on Aug. 15, which is the growing season of many plants. The α value of 10,000 \$ (Sv · man)$^{-1}$ on the basis of human capital approach, and economical and social data in 1996 were applied to derive the optimized ILs for Korean foodstuffs.

Table 1 shows the optimized ILs for foodstuffs and the resulting committed effective doses. The optimized IL was relatively high for rice, legumes and beef due to the cost per unit mass of foodstuffs. The optimized ILs for ^{90}Sr and ^{131}I were a factor of 3 lower than ^{137}Cs due to the higher dose factors. The optimized annual dose from the consumption of contaminated foodstuffs was approximately 34 mSv yr^{-1}.

Fig. 1 shows the reduction of ingestion dose resulting from the introduction of optimized ILs as a function of ^{90}Sr concentration on the ground. The ban on consumption of milk was required through the whole radioactivities on the ground (*i.e.*, from 10 to 300 kBq m^{-2}). The duration of ban depends on the radioactivity on the ground. In addition to milk, the ban on consumption of legumes was required for the higher radioactivity on the ground (300 kBq m^{-2}). With increasing the radioactivity on the ground, more and more foodstuffs were contaminated with radioactivity above the optimized ILs leading to increasing absolute and relative reductions of the ingestion dose.

Fig. 2 shows the the optimized duration of the ban as a function of initial concentration of ^{131}I. When the initial radioactivity increases twice, the optimized duration of the ban was prolonged for 8 days, which is equivalent to ^{131}I half-life.

Figs' 3 and 4 show the reduction of ingestion dose for milk as a function of duration of the ban and delay between the deposition and the start of the ban for ^{137}Cs and ^{131}I, respectively. In case of ^{137}Cs, the ban for 50 days starting after 7 days was equal to the ban for 23 days starting immediately after deposition in effectiveness of dose reduction (dose reduction of 40%). In case of ^{131}I, the ban for 14 days starting after 3 days was equal to the ban for 7 days starting immediately after deposition (dose reduction of 60%). It is obvious that the fast reaction after the deposition is important in the effectiveness of dose reduction, especially for short-lived radionuclides ^{131}I.

4. Conclusions

The effectiveness of dose reduction resulting from the application of countermeasures for ingestion pathways after nuclear accidents was investigated together with the derivation of optimized intervention levels for Korean foodstuffs. Some flexibility in optimized intervention levels shall be left to the decision-maker to allow considerations of some additional factors such as social and political factors. The effectiveness of countermeasures strongly depended on radionuclides, foodstuffs and date of deposition. Therefore, a detailed radioecological situation-specific analysis is needed for the *optimization of the decisions* to be taken in emergency situations.

References

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3. IAEA, International Criteria in a Nuclear or Radiation Emergency, Safety Series No. 109, 1994.
4. 통계청, 한국통계월보, 1997.
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Table 1. Optimized ILs for foodstuffs and the resulting committed effecive doses

Foodstuffs	Cost (Won kg^{-1})	Consumption rate ($kg\ yr^{-1}$)					ILs for foodstuffs ($Bq\ kg^{-1}$)			Dose** ($mSv\ yr^{-1}$)
		Infant	Child	Teenager	Adult	Average*	^{137}Cs	^{90}Sr	^{131}I	
Rice	1674	0	81.35	127.45	122.02	112.53	13000	3900	4500	19.3
Cereals	621	0	8.23	12.89	12.34	11.38	4900	1500	1700	0.73
Legumes	1760	0	12.90	20.22	19.36	17.86	14000	4100	4800	3.23
Leafy vegetables	167	0	30.79	48.24	46.18	42.59	1300	400	500	0.73
Root vegetables	161	0	15.54	24.35	23.31	21.50	1300	400	400	0.36
Fruit vegetables	504	0	11.87	18.60	17.81	16.43	4000	1200	1400	0.85
Potatoes	520	0	11.31	17.72	16.96	15.64	4100	1200	1400	0.84
Fruits	941	0	11.03	17.27	16.54	15.25	7400	2200	2500	1.47
Eggs	673	0	5.10	7.98	7.64	7.05	5300	1600	1800	0.49
Pork	1517	0	4.92	7.71	7.38	6.81	12000	3600	4100	1.06
Poultry	1313	0	0.99	1.56	1.49	1.38	10000	3000	3600	0.19
Milk	455	183.2	13.04	20.43	19.56	18.04	3600	1000	1200	1.0
Beef	6753	0	4.43	6.96	6.65	6.13	53000	16000	18000	4.26
Sum		183.2	211.50	331.38	317.24	303.37				33.9

* Average consumption rates were obtained by considering the Korean population constitution.
(infant :1.6%, child : 13.3%, teenager : 16.6%, adult : 68.5%) [4]

** Committed effective dose per unit intake was taken from Ref. [5].

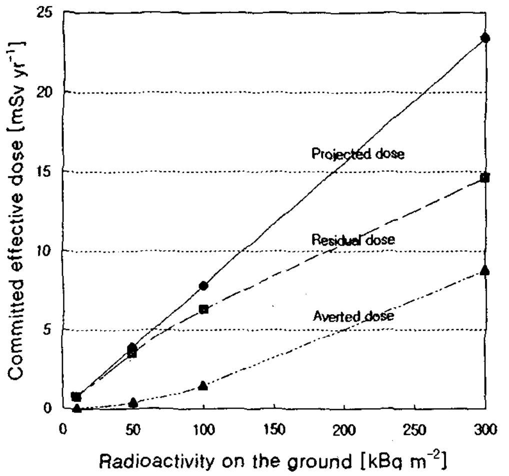

Fig. 1. Reduction of ingestion dose resulting from the introduction of optimized ILs as a function of ^{90}Sr concentration on the ground.

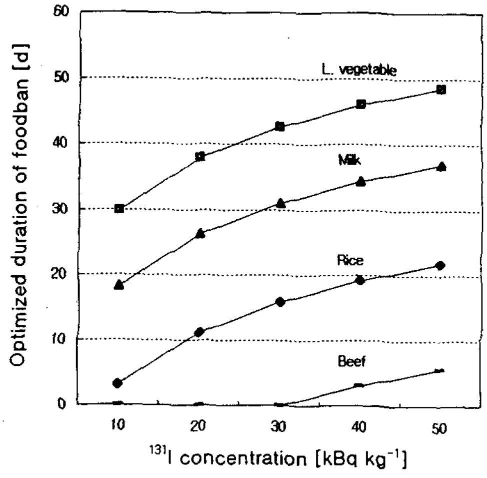

Fig. 2. Optimized duration of the ban as a function of initial concentration of ^{131}I.

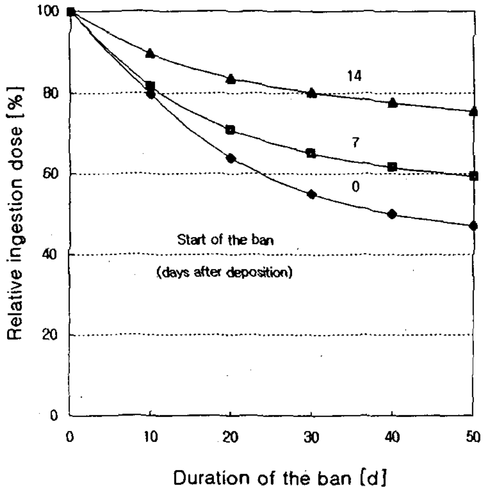

Fig. 3. Reduction of ingestion dose for milk as a function of duration of the ban and delay between the deposition and the start of the ban for ^{137}Cs.

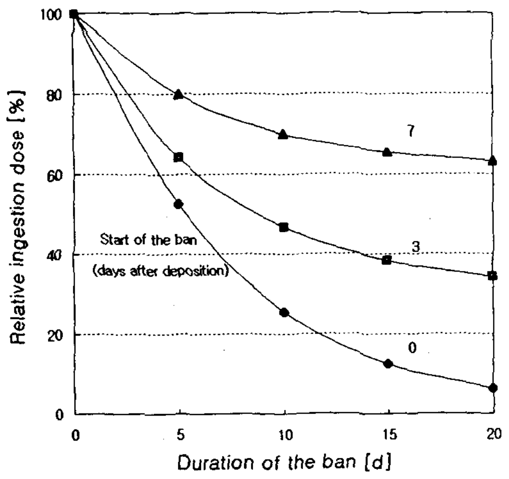

Fig. 4. Reduction of ingestion dose for milk as a function of duration of the ban and delay between the deposition and the start of the ban for ^{131}I.