Assessment of the radiation dose for the domestic human and environment resulting from the Fukushima nuclear accident

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1. Introduction

A severe nuclear accident occurred at the nuclear power plant in Fukushima, Japan on 11 March, 2011, and a significant amount of gaseous radioactive materials, which was estimated to approximately 10% of that released by the Chernobyl nuclear accident in 1986, was released to the atmosphere and dispersed by wind. About two weeks after the accident, the air activity of I-131, Cs-137, Cs-134 and Xe-133 higher than the usual level was observed in a wide region of the Korea. The radionuclides dispersed into the environment have potential of giving the radiological risk to human health and the environment through the various pathways, and therefore the assessment of the radiological impact by the accident is essential to keep the human health safe and to protect the environment from the effect of ionizing radiation.

The purpose of this study is to assess the radiation dose for the domestic human and environment as consequences of the Fukushima nuclear accident.

2. Assessment method

2.1 Exposure pathways to human

The present model took into account four exposure pathways to predict the human dose; 1) the internal exposure due to ingestion of contaminated foodstuffs, 2) the internal exposure due to the inhalation of airborne radionuclides, 3) the external exposure from the radionuclides in the passing cloud, and 4) the external exposure from radionuclides deposited on the ground (Fig.1).

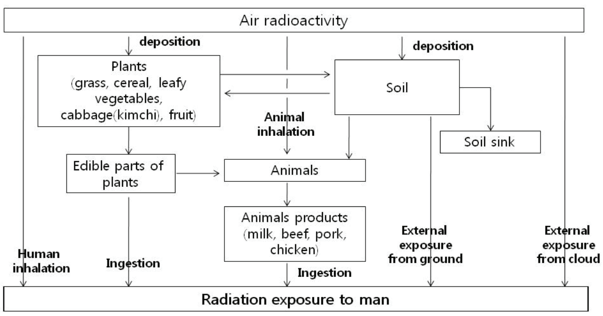

Fig.1 Exposure pathways to human

Four radionuclides of I-131, Cs-137, Cs-134, and Xe-133 that were detected in the airborne samples after the Fukushima nuclear accident were considered in the dose calculation. The airborne monitoring result measured by the KINS (Korea Institute of Nuclear Safety) showed that the airborne activity higher than normal level was first detected at the local monitoring stations on 28 March, and the highest peak was on April 6. By using the observed airborne radionuclide concentration, the time-integrated air activity for each local monitoring site was calculated, and the highest value among them was selected as the reference time-integrated airborne activity for the human dose calculation (Table 1).

Table 1 Time-integrated air activity used for the human dose the calculation

R/N	Time-integrated activity in air (Bq d/m^3)	local sites
I-131	0.0318	Gangreong
Cs-134	0.00524	Gunsan
Cs-137	0.00465	Suwon
Xe-133	12.5	Goseong

The fallout deposition during about 3 months after the Fukushima nuclear accident was reported to be 2.35 Bq/m^2 for I-131, 1.43 Bq/m^2 for Cs-134, and 1.58 Bq/m^2 for Cs-137, respectively [1]. These values incorporate both the dry and wet deposition.

Ingestion and inhalation dose conversion factor were taken from ICRP 67 [2] and 71 [3], respectively. The dose conversion factor for the external exposure from the cloud and ground was taken from the GSF-12 [4]. The age-dependent breathing rate was taken from the literature [5]. The daily food consumption of the Korean for the ingestion dose calculation was taken from an ODCM [6] for the domestic nuclear facilities.

2.2 Non-human species dose assessment

The whole body absorbed dose rate (D_{tot}) for a specified organism in a reference ecosystem is calculated by

$$D_{tot} = \sum_i (CR_i \times DCC_{\mathrm{int},i} + DCC_{ext,i}) C_{i,m} \qquad (1)$$

where CR_i (Bq/kg organism per Bq/kg medium) is the concentration ratio of radionuclide i, $C_{i,m}$ (Bq/kg medium) is the average concentration of radionuclide i in the environmental media, and $DCC_{int,i}$ (μGy/d per Bq/kg organism) and $DCC_{ext,i}$ (μGy/d per Bq/kg medium) are the internal and external dose conversion coefficients of radionuclide i for the reference organism.

In the present study, two different set of target organisms were considered. One is the eight draft Korean reference animals and plant (RAPs), the other is the limiting organisms being used for the screening level assessment, which is defined as the biota that receives the highest dose for a specific radionuclide in an ecosystem. For example, in the ERICA tool [7] the limiting terrestrial organisms were the bird egg for I-131, the mammal (deer) for Cs-134 and Cs-137, and the limiting freshwater organisms were the phytoplankton for I-131 and the insect larvae for Cs-134 and Cs-137

3. Result

3.1 Projected human dose

Fig. 2 shows the accumulated effective dose for adult with time following the Fukushima nuclear accident. During the initial few months after the accident, the internal exposures due to the inhalation and ingestion were the highest contributors to the total dose. The effect of external exposure from ground appeared to increase with time. The effect of the external exposure from cloud turned out to be very minor for the entire period.

The first year total human effective dose resulting from the Fukushima nuclear accident was estimated to less than 1.4E-4mSv. It accounts for about 0.006% of the annual dose (2.3mSv) received from the natural radioactivity through the normal life of human. The total life-time effective dose for an adult was estimated to less than 3.3E-4mSv. Consequently, there was no practically radiological impact on the domestic human as result of the Fukushima nuclear accident.

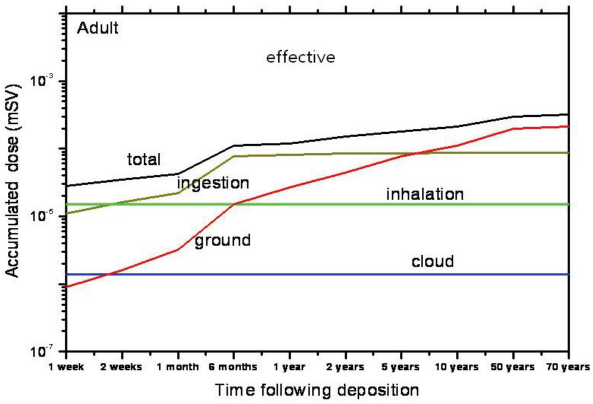

Fig.2 Projected effective dose for adult

3.2 Environmental effect

To assess the whole body dose rate for the reference organisms, the K-BIOTA (the Korean computer code to assess the risk of radioactivity to wildlife) was used. Fig.3 and Table 2 shows the whole body absorbed dose rate for the draft Korean RAPs and the ERICA limiting organisms, respectively. The higher dose rate was obtained for the ERICA limiting organism because it is more conservative approach. The total whole body dose rate for the ERICA terrestrial and the freshwater organism was estimated to 2.34E-5 and 6.32E-3mGy/d, respectively. These values were both far less than the IAEA standard (1mGy/d for the terrestrial animal, and 10mGy/d for the freshwater animal) to protect the environment from the ionizing radiation. The result indicates that the radioactivity released by the Fukushima nuclear accident would not give the harmfulness almost to the environment in the republic of Korea.

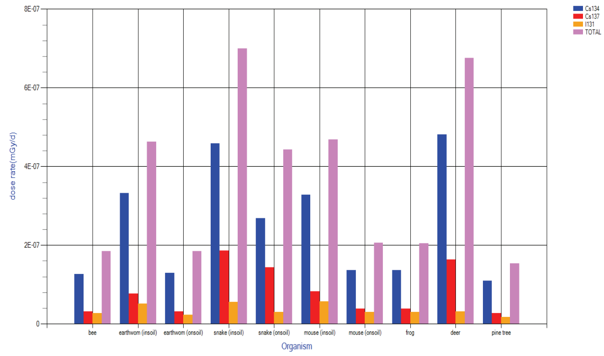

Fig.3 Whole body absorbed dose rate for the draft Korean RAPs

Table 2 Whole body dose rate for the ERICA limiting organisms

R/N	Terrestrial organism (mGy/d)	Fresh water organism (mGy/d)
I-131	2.13E-5	7.1.E-5
Cs-137	1.44E-6	5.20E-3
Cs-134	7.27E-7	1.05E-3
total	2.34E-5	6.32E-3

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