ESTIMATING RADIOCESIUM FLUX FROM CATCHMENT OF RIVERS TO THE OCEAN BY USING A COMPARTMENT MODEL

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Abstract

A dynamic compartment model has developed to estimate the redistribution of radiocesium in a river catchment including its flux to a receiving water body and the ocean. The model gives a well performance according to the values of correlation coefficient and Nash Coefficient efficiency which was calculated based on the comparison between estimated radiocesium flux to from Abukuma river to the Pacific ocean and its observed data. Moreover, we calculated the future radiocesium discharge from Abukuma river and the other 16 rivers in east coast of Fukushima prefecture. It was estimated that about 278 TBq of radiocesium will enter the Pacific ocean during 100 years after the accident. Such a significant amount compared to the direct discharge from the Fukushima Daiichi Nuclear Power Plant indicates that river catchment could be one of a major source of radiocesium contamination in the marine environmenment after a nuclear accident.

1. Introduction

According to a study conducted by Yamashiki et al., 2014, about 5.74 TBq of ^{137}Cs and 4.74 TBq of ^{134}Cs were discharged into the Pacific Ocean from Abukuma River during August 2011 to May 2012. In the other rives, 0.05 TBq and 0.3 TBq of ^{137}Cs were exported from Natsui and Same river respectively into the Pacific Ocean (Nagao et al., 2013). The amount of the exported radiocesium from Abukuma River during first year after the accident was estimated about 1.13% of the total deposited radiocesium on its catchment area. This situation means that there are still 98.87% of the deposited radiocesium stored in the catchment area. Though not all the deposited radiocesium is available for wash off process due to vertical migration, fixation and others phenomena, the flux of radiocesium into the ocean is still expected to be in a great amount for a long period considering the area of the rivers catchment, high precipitation rate in Japan and the half-life time of radiocesium. This condition requires a simulation of the transport process of the radionuclide from the basin area into the river, in order to allow further discharge to be predicted. A multi-compartment model of radiocesium movement in a catchment river based on wash off process has been developed in this studyThe present study aims to develop a model for migration of radiocesium from the catchment area of the river to the water body which incorporates both entrainment coefficient and transfer factor approach. Abukuma River and the other 16 rivers in Fukushima region were used as a case study. In addition, the future radiocesium flux from these eastern rivers was projected for the next 100 years after the accident occurred.

2. The Model

The model developed in this study consists of two sub-model, namely "BASIN" and "RIVER". Based on the land cover type on the surface of the catchment area, sub model BASIN is divided into Forest, Urban and Agriculture area. The governing equation used in this model is written as follows:

$$dA = \Big| \sum_{r=1} R_{r\to s} \Big|_{r} - \Big| \sum_{r=1} R_{s\to r} \Big|_{s} - \lambda_{s} {}_{s} + I_{s} \qquad (1)$$

Where As and Ar are the activity present in compartment s and r respectively at time t. Rr→s and Rs→r represent transfer rate from compartment r to s and s to r. The specific decay rate of radionuclide is represented by λ, and Is represents the initial input of radionuclide in the compartment. The detailed explanation of the model is described in our latest publication (Adhiraga Pratama, Yoneda, Shimada, Matsui, & Yamashiki, 2015)

3. Result and Discussion

For testing the accuracy of the model, the estimated data resulting from the model were compared to the observed data as presented in Figure 1a and 1b. An acceptable value of R^2 and Nash efficiency coefficient were obtained. The value of R^2 of 0.86 and the Nash efficiency coefficient value of 0.85 were achieved for both ^{137}Cs and ^{134}Cs indicating the model could accurately predict the seasonal variation and the amount of the flux. Based on the estimation, the flux of radiocesium was high in September 2011 in which about 6.5 x 10^{12} Bq of radiocesium was discharged into the Pacific Ocean through Sendai Bay. On the other hand, the flux of radiocesium reached the minimum level during winter season from December to February 2011. Moreover the discharge gradually increased from March to May of 2012 as the rainfall rate increased.

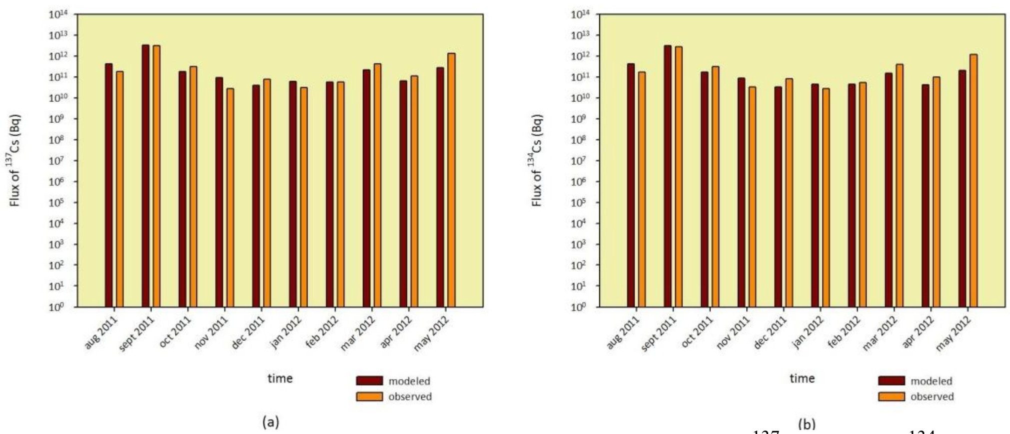

Figure 1. The comparison of modeled data and observed data for ^{137}Cs (a) and ^{134}Cs (b)

Figure 2a and 2b show the estimation of total accumulation of discharged radiocesium into the Pacific Ocean from Abukuma River and the eastern coast rivers. For 137Cs, the total accumulation of the flux are 66, 80 and 84 Tbq occurring 25, 50 and 75 years after the accident. For 134Cs, the total accumulation of the flux are 38, 39 and 39.7 Tbq occurring 25, 50 and 75 years after the accident. Summing up with the total accumulation of 137Cs flux from Abukuma River after 100 years which is 111 Tbq, it was estimated that about 195 Tbq would enter the Pacific Ocean during the 100 years following the accident. Moreover, since the total accumulation of 134Cs from Abukuma River is about 44 Tbq, the total discharge of 134Cs from Abukuma River and east coast rivers during the 100 years would be 83 Tbq. Thus, the total radiocesium that would be discharged into the Pacific Ocean was estimated at about 278 Tbq.

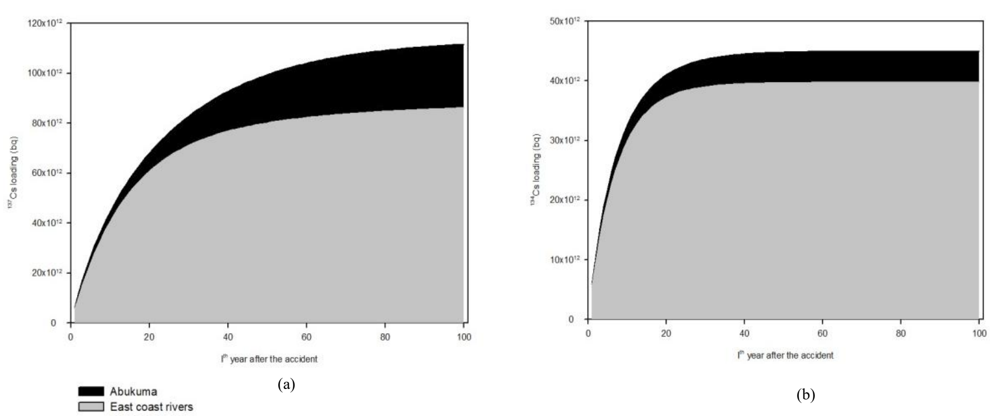

Figure 2. The total accumulation of of ^{137}Cs (a) and ^{134}Cs (b) for the next 100 years after the accident

Reference

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