The Long-Term Simulation of ^{137}Cs in the North Atlantic Ocean Using the Lagrangian Particle Model

Byung-Il Min*, Kihyun Park, Sora Kim, Byung-Mo Yang, Jiyoon Kim, and Kyung-Suk Suh
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*bimin@kaeri.re.kr

1. Introduction

A number of researches on ^{137}Cs distributions in the Atlantic Ocean environment, release from nuclear fuel reprocessing at Sellafield (UK), have been published. The ocean dispersion models have been simulated the radionuclide concentration in the European Shelf and Atlantic oceans [1-2]. The purpose of this work is to improve a Lagrangian dispersion model for long-term numerical experiments for more than 50 years. The oceanic dispersion model used in this work was LORAS (Lagrangian Oceanic Radiological Assessment System) has been developed in Korea Atomic Energy Research Institute since 2011 [3].

2. Model Description

2.1 Marine dispersion model

A stochastic method is used to estimate the dispersion of non-conservative radionuclides and provide concentration in water, suspended matter and bottom sediments. The differential equations which describe transfers between the three phases are expressed the following.

$$\frac{\partial C_w}{\partial t} = -k_{1m}C_w - k_{1s}C_w, \frac{\partial C_s}{\partial t} = -k_2 C_s, \frac{\partial C_b}{\partial t} = -k_2 p C_b \quad (1)$$

Where C_w, C_s and C_b are radionuclide concentrations in seawater, suspend mater and bottom sediments respectively. K_{1m} is the kinetic coefficient describing radionuclide transfer from water to suspended matter, K_{1s} describes the transfer from water to bottom sediments and K_2 is the kinetic transfer coefficient which describes radionuclide release from suspended matter or bottom sediments to water. P is a correction factor which takes into account that some of the sediment particle surface may be hidden by other particles.

Radionuclide concentrations in seawater, suspended mater and seabed sediments are calculated in the domain of interest by counting the number of particles as follows.

$$C_w = \frac{I.N_w}{\Delta x \Delta y \Delta z}, C_s = \frac{I.N_s}{m \Delta x \Delta y \Delta z}, C_b = \frac{I.N_b}{\Delta x \Delta y H \rho_b} \quad (2)$$

Here $I=Q/NP$, where Q is the source term and NP is the number of particles used in the simulation $\Delta x\Delta y\Delta z$ is the volume of the each cell, m is suspended matter concentration, H is the mixing depth in the bottom sediment and ρ is sediment bulk density finally N_w, N_s and N_b are the number of particles in each phase.

2.2 Source Term

Annual ^{137}Cs releases from Sellafield and La Hague nuclear fuel reprocessing plants, presented in Fig. 1, are introduced from 1952 to 2009, which is the simulation period. These releases define the number of Bq corresponding to each released particle. It is considered that radionuclides are released in a dissolved form. Sellafield releases peaked in 1975, when 5200 TBq were released. In the case of La Hague releases, they started in 1966 and peaked in 1971, with 243 TBq. Later they were reduced by about two orders of magnitude (Fig. 1). Releases from both plants have been simulated by a total

number of 6×10^7 particles. The calculation time was a total of 5 days using a 160 cpu core. Atmospheric fallout and deposition from nuclear weapon tests and Chernobyl accident in 1986 are not included, since the deposition from Chernobyl accounts for a 10% (4) of the total cesium inventory in ocean.

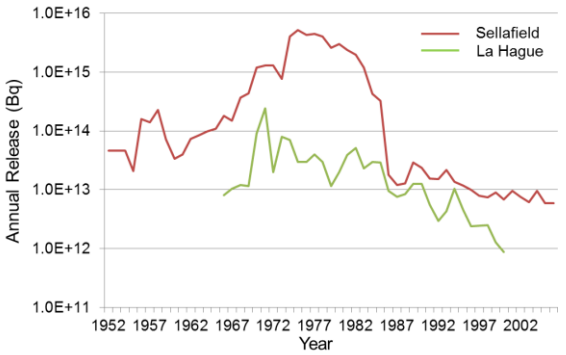

Fig. 1. Annual ^{137}Cs release from Sellafield and La Hague reprocessing plants.

3. Numerical Results

Fig. 2 shows the concentration of ^{137}Cs in the North Atlantic Ocean in seawater 50 years after the start of the 1952 calculations. The ^{137}Cs leaked from Sellafield spread mainly in the southwest of England. In the previous study ([4]), there was a very low concentration, but some of the northeastern propagation pattern passed through the northern coast of England, but this trend did not appear in this study. The main reason is due to the characteristics of the applied ocean circulation model. In this study, the effect of tide is not taken into consideration, so there are some differences.

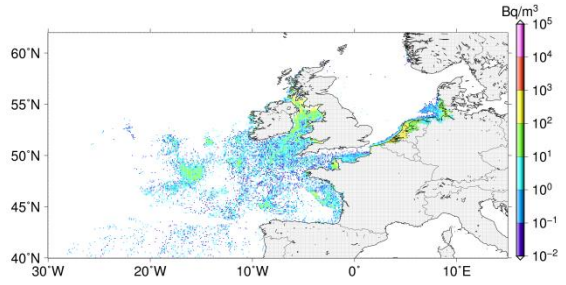

Fig. 2. Simulation results of ^{137}Cs concentration in ocean surface layer at the end of 2002.

The ^{137}Cs concentration of the English Channel located in the south of England is mainly influenced by runoff in the La Hague reprocessing plant. According to observational data [5], the concentration of this region was approximately 10 to 20 Bq/m^3, and the calculation results of this study showed similar 10 to 50 Bq/m^3. Concentrations tend to be overestimated when a large number of Lagrangian particles are located in areas with small volumes in the coast.

Future studies will use more particles and more detailed comparisons with observed data to improve some overestimated results.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation of Korea (NRF) and funded by the Korea government (MSIP) (MSIP: NRF-2017M2A8A4015253, NRF-2015M2A2B2034282).

REFERENCES

[1] D. Prandle, “A modelling study of the mixing of 137Cs in the seas of the European Continental Shelf Philos”, Trans. R. Soc. Lond. A, 310, 407-436 (1984).

[2] M. Villa, et al., “The behaviour of 129I released from nuclear fuel reprocessing factories in the North Atlantic Ocean and transport to the Arctic assessed from numerical modelling”, Mar. Pollut. Bull., 90, 15-24 (2015).

[3] B.I. Min, et al., “Marine dispersion assessment of 137Cs released from the Fukushima nuclear accident”, Mar. Pollut. Bull., 72(1), 22-33(2013).

[4] P.P. Povinec, et al., “Temporal and spatial trends in the distribution of 137Cs in surface waters of Northern European Seas a record of 40 years of investigations Deep Sea Res. Part II”, 50 2785-2801 (2003).

[5] J. Herrmann, et al., “The distribution of artificial radionuclides in the English Channel southern North Sea, Skagerrak and Kattegat 1990–1993”, J. Mar. Syst., 6, 427-456 (1995).