Three Dimensional Dispersion of Tritium in the Sea around Shin-Wolsong Nuclear Power Plant Site

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1. Introduction

Recently, 3-dimensional models have been used in solving oceanic phenomena. This is because 2-dimensional model is difficult to give sufficient information about vertical profile of the current. 3-dimensional models are also applied in assessing the dispersion of radionuclides in aquatic environment. Where vertical variability is important component, 3-dimensional model should be used in order to obtain exact information about aquatic dispersion of radionuclides.

To better simulate oceanic dispersion of radionuclides, a representative dispersion model with rich information about the behavior characteristics of the nuclides is needed[1,2,3]. In the study, ocean circulation around Shin-Wolsong NPP in Korea was simulated with an ocean circulation model, and from the results, dissolved Tritium was predicted of its dispersion in the sea. Seasonal and annual oceanic dilution factor of Tritium, the major element of the liquid effluents from Shin-Wolsong unit 1 and 2 in Korea was calculated using 3-Dimensional dispersion model, and arrival time to specific distance were calculated.

2. Method and Result

2.1. Ocean circulation

Basically, POM(Princeton Ocean Model) was used as the ocean circulation model[4]. POM was a 3-dimensional model developed, solving the equation of continuity for incompressible flow in hydrostatic and Boussinesq assumptions, and Navier-Sotkes equation

Using Orthogonal curvilinear grid method, grids were composed along the coast to 160km to north and south from the Shin-Wolsong NPP, and 30km to the sea, as shown in Fig. 1. To 4km in radius from the NPP, they were square boxes($\Delta x = \Delta y$) of 100m in length, and then to the boundary, variable boxes of 200m~5km in length. Total number of the grids is 50x120.

Ocean circulation was simulated for spring tide and neap tide, respectively for spring, summer, fall, and winter. Calculation period was set to 7 days, the time period reaching quasi-steady state. External mode was given with 2 seconds, and internal mode, 60 seconds.

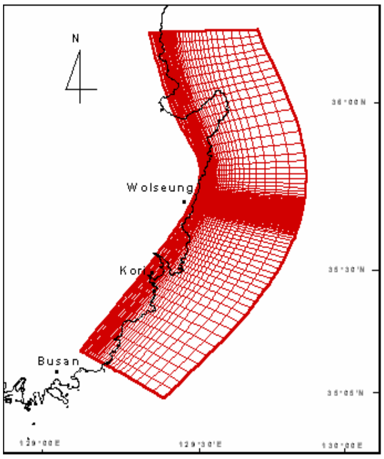

Fig. 1. Grid matrix used in the study on 3-dimensional oceanic dispersion of Tritium for Shin-Wolsong NPP

Around Wolsong NPP, Northbound current along the coast was prevalent, which is because northbound Daema warm current and downfall tide in NE direction in the north are faster in velocity and longer in duration than the tide in SE direction, and because WSW wind influences in spring.

As Daema warm current is the strongest in summer, so northbound current of 20 cm/sec was given on the south boundary. The summer season indicate stronger current than in spring season due to enhanced Daema warm current and wind in SW direction.

Wind in fall was almost like that in summer. Ocean circulation showed similar distribution to that in spring.

Strong wind in NE direction was prevalent and continuous in winter. In spring tide, meek northbound flow occurred since northbound flow, the normal for the tide, and southbound current due to wind in NW direction offset each other. In neap tide, meek southbound current occurred, which is resulted from wind-driven current more influential than the meek current in neap tide.

2.2. Oceanic dispersion

The equation for oceanic dispersion of Tritium used in the study is as below.

$$\frac{\partial c_w}{\partial t}+\frac{\partial(uc_w)}{\partial x}+\frac{\partial(vc_w)}{\partial x}+\frac{\partial(wc_w)}{\partial x}$$
$$=\frac{\partial}{\partial x}(\varepsilon_x\frac{\partial c_w}{\partial x})+\frac{\partial}{\partial x}(\varepsilon_x\frac{\partial c_w}{\partial x})+\frac{\partial}{\partial x}(\varepsilon_x\frac{\partial c_w}{\partial x})-\sum_i v_i C_i(F_i C_w)-Nc_w+S_w$$

Where, u, v, w is the velocity of x, y, z component. C_w is the concentration of dissolved radionuclides, and C_i is the concentration of radionuclide i. ε_x, ε_y, ε_z is the turbulent diffusivity of x, y, z component. v_i is sorption coefficient(m^3/(kg sec)). F_i is the distribution coefficient of component i. N is decay constant, and S_w is source term(including input at outfall and resuspension in submarine).

Based on the results of previous researches for Shin-Wolsong NPP, sorption coefficient, distribution coefficient, and source term for the equation of oceanic dispersion in this area were derived, and a finite difference model was established to simulate the dispersion of Tritium in the sea.

Simulation of oceanic dispersion of Tritium during normal operation was performed in the same way as in ocean circulation. Calculation time period was 7 days for spring tide and neap tide in spring, summer, fall, and winter. The following Fig 2. shows average dispersion and neap tide in spring. Under the assumption that the source is continuously discharged in unit amount from Wolsong NPP, mixing coefficient(M_p) is marked by 1/10 order of concentration from 10^{-1} to 10^{-10}. Oceanic dilution factor, D_f is the inverse number of mixing coefficient, M_p. Seasonal oceanic dilution factor of Tritium was calculated by distance, along the maximum axis on the oceanic dispersion map, and also its arrival time.

3. Conclusion

In the sea around Shin-Wolsong NPP in Korea, it was turned average current in spring tide is similar to that in neap tide. In summer, In spring tide, average distribution on the surface had meek northbound current, unlike in spring, summer, and fall. In neap tide, it had a meek southbound current.

Dilution factor of Tritium at the distance of 560m to the north from the Shin-Wolsong NPP in spring tide was 17, 13, 25, 17 respectively in spring, summer, fall, and winter. And, in neap tide, they were 15, 13, 83, 300, respectively for the 4 seasons. Seasonal variability is large. While, annual dilution factor at the distance of 560m was about 6.2, larger than 2.0, existing value used for the Shin-Wolsong NPP. This is because Korea has applied overly conservative assumption to oceanic dispersion. This updated annual dilution factor of Tritium derived from 3-D modeling of oceanic dispersion could be more rational and exact.

Reference

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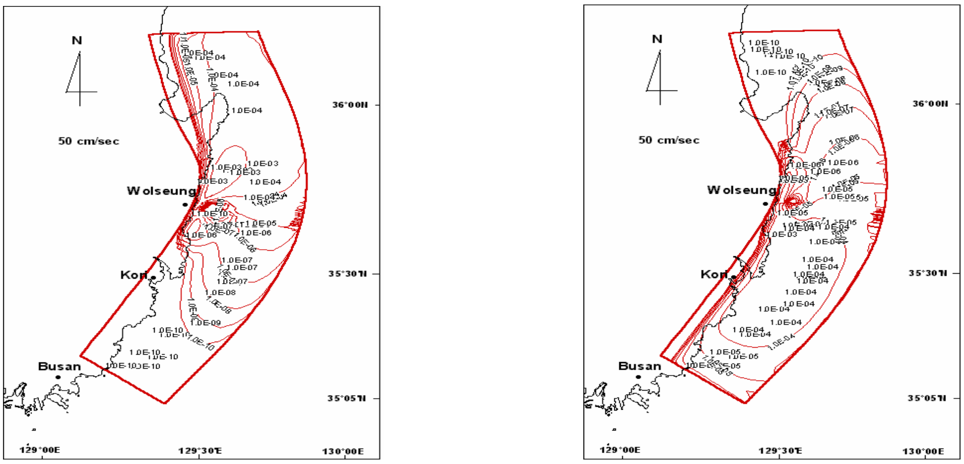

Fig. 2. Dispersion of Tritium in spring tide(left) and neap tide(right) in Spring around Shin -Wolsong NPP