Improvement of the dose assessment tools on the basis of dispersion of the ^{99}Tc in the Nordic Seas and the Arctic Ocean

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INTRODUCTION

Compartment models are widely used for evaluation of radiological consequences to man and biota in marine environment with spatial and temporal scales of several thousand kilometres and millenniums, respectively (EC, 2003). The compartment modelling uses two rigid general assumptions for dispersion of radionuclides in oceanic space: (a) uniform and (b) instantaneous mixing in each compartment. The second assumption leads, in practical calculations, to instantaneous mixing in the whole ocean space and, therefore, inserts an additional systematic uncertainty into calculated results. The developed in Norwegian Radiation Protection Authority (NRPA) during last years model is based on a compartment modelling approach, which includes terms describing the radionuclide dispersion into oceanic space with time (non-instantaneous mixing in oceanic space). It showed that the modified approach provides more realistic results compared to traditional compartment modelling and this approach is more sensitive to processes near the sources of contamination and during the initial time of radionuclides dispersion (Iosjpe *et al*., 2002). Results between modified and traditional approaches can differ widely, especially for scenarios where redistribution of radionuclides between different marine areas was important (Iosjpe, 2006).

The present paper will present the new modification of the NRPA model, in which the main improvement concerns the parameters for describing non-instantaneous mixing in oceanic space and a corresponding set of water fluxes between compartments.

MODEL DESCRIPTION

The equations describing transfer of radionuclides between the compartments are of the form

$$\frac{dA_i}{dt} = \sum_{j=1}^{n} k_{ji}\gamma(t \geq T_{ji})A_j - \sum_{j=1}^{n} k_{ij}A_i\gamma(t \geq T_j) - k_i A_i + Q_i, \quad t \geq T_i$$
$$A_i = 0, \quad t < T_i$$

where $k_{ii}=0$ for all i, A_i and A_j are activities (Bq) at time t in compartments i and j; k_{ij} and k_{ji} are transfer rates (y^{-1}) between compartments i and j; k_i is an effective activity transfer rate (y^{-1}) from compartment i taking into account loss of material from the compartment without transfer to another, for example radioactive decay; Q_i is a source of input into compartment i ($Bq\ y^{-1}$); n is the number of compartments in the system. T_i is the time of availability for compartment i (the first times when compartment i is open for dispersion of radionuclides) and γ is an unit function:

$$\gamma(t \geq T_i) = \begin{cases} 1, t \geq T_i \\ 0, t < T_i \end{cases}, \qquad \gamma(t \geq T_{ij}) = \begin{cases} 1, t \geq T_{ij} \\ 0, t < T_{ij} \end{cases}$$

Methods for evaluation of "times of availability" $\{T_i\}$ and more detailed description of the model are discussed in the (Iosjpe *et al*., 2002; Iosjpe, 2006).

Under the present modification, the model parameters $\{T_{ij}\}$ (T_{ij} is the time required before the transfer of radionuclides from the box i to the box j can begin without any way through other boxes) are used not only for evaluation of parameters $\{T_i\}$, but are directly included into the main equation describing transfer of radionuclides.

Traditional box modelling is a particular case of the present approach when all different times of availability $\{T_i\}$ and $\{T_{ij}\}$ are zero.

METHODS AND RESULTS

The main consequences after the present modification of the model are non-instantaneous water fluxes between boxes, which unlike the previous version of the model are "open" for dispersion of radionuclides.

The term "water fluxes" here includes water streams as well as diffusion processes. Traditional models with instantaneous mixing of radionucludes in oceanic space have optimised a set of water fluxes with purpose to better describe existing experimental data as for instance in Nielsen (1995). Apparently the present modification of the model also needs a similar procedure. This is also particularly important because of possible changes within the water fluxes system itself as a result of global climate changing.

^{99}Tc is anthropogenic radionuclide with low sediment distribution coefficient and physical half-life $2 \cdot 10^5$ years. Due to conservative features of ^{99}Tc and well-known history of discharges of ^{99}Tc into marine environment (mainly from nuclear facilities at Sellafield and Cap la Hague) ^{99}Tc can be easily used for evaluation and corroboration of the model parameters.

The modification has been provided on the basis of comprehensive ^{99}Tc data set (approximately, three thousand experimental points) collected under the course of the project "RADNOR", supported by the Norwegian Research Council (Gerlald *et al*., 2005; Karcher *et al*., 2005).

Examples of ^{99}Tc data points for year 1994 are shown in Figure 1 (Gwynn, 2007). It is necessary to note that even comprehensive data set cannot cover all actual marine regions especially with time series.

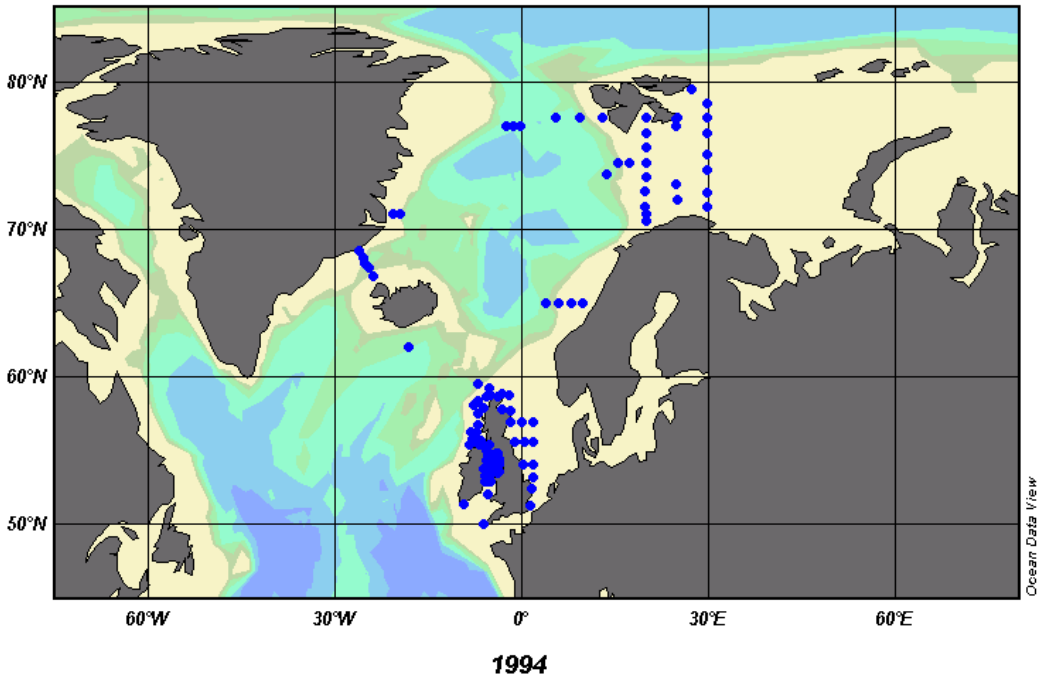

Figure 1. Experimental ^{99}Tc data points for year 1994.

Improvement of the parameters (water fluxes and times of availability) was provided with as minimal changing as possible with preliminary local sensitivity analysis of adjacent marine regions with regards to water fluxes balance.

Sensitivity analysis was provided by the expression

$$S^{(L)} = \frac{dA_i}{dP}\frac{P^{(0)}}{A_i^{(0)}},$$

where P corresponds to investigated parameters and *"0"* corresponds to the basis variant.

Possibility to use comparing of the results of simulation between the NRPA model and the *3D* hydrodynamic NAOSIM model for model improvement was demonstrated by Karcher *et al*. (2005). This comparison between models is also made in the present paper as an important source for model corroboration and parameter modification. One of results is shown in Fig. 2 where the previous (without parameter modification) and the present versions of the NRPA model are compared with experimental data.

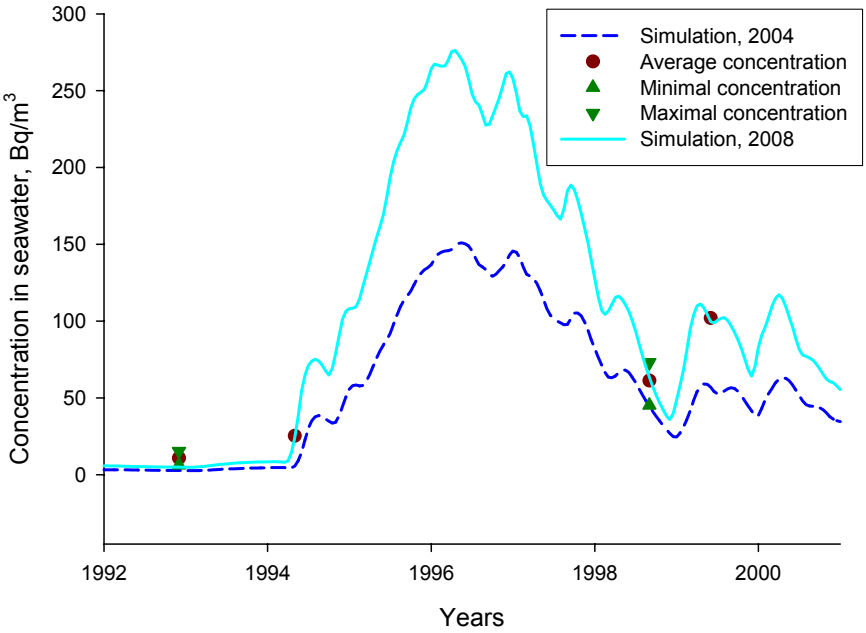

Figure 2. Comparison of simulations of previous and present versions of the model (the Liverpool and Morcambre Bay)

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