DOSE ASSESSMENT TO MARINE BIOTA: EVALUATION OF KEY ENVIRONMENTAL PARAMETERS

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INTRODUCTION

The dose assessment to biota is an important part of radioecological analysis and one of the key factors in need of consideration for the development of response strategies to radionuclide release into marine regions. Such assessment has to simultaneously describe the dispersion of radionuclides in water and sediment phases; bioaccumulation of radionuclides in biota and finally, calculation of doses to different marine organisms. It is obvious that such an approach comes up against the problem of complexity and the need for a large set of parameters.

The sensitivity analysis of the model parameters can contribute to a better understanding of experimental data as well as define parameters which can play a key role in the evaluation of doses to marine organisms for different scenarios of releases of radionuclides into marine environment.

METHODOLOGY

In the present paper the environmental sensitivity has been considered as a dose to marine organisms according to a release scenario developed under the EMRAS II program (EMRAS II, 2011) where a single deposition of 1000 Bq/m^2 of radionuclides (^{90}Sr, ^{137}Cs, ^{239}Pu and ^{241}Am) is released into selected marine regions.

Simulations have been carried out using the NRPA compartment model for dose assessment to man and biota, which includes the processes of advection of radioactivity between water compartments, sedimentation, diffusion of radioactivity through pore water in sediments, particle mixing, pore water mixing and a burial process of radioactivity in deep sediment layers (Iosjpe et al., 2002; Iosjpe, 2006). The model takes into account the fact that contaminants are partitioned between the water phase and suspended sediment material in the coastal environment. The contamination of biota is further calculated from the radionuclide concentrations in filtered seawater. Dose rates to biota are developed on the basis of calculated radionuclide concentrations in marine organisms, water and sediment, using dose conversion factors (Brown et al., 2006; Iosjpe, 2006).

The sensitivity parameter analysis has been provided on the basis of the local sensitivity index $S^{(L)}$ (Jørgensen, 1994):

$$S^{(L)}(P) = \left(\frac{dV^{(S)}}{dP} \right)_{P_0} \frac{P_0}{V_0^{(S)}}$$

where $V^{(S)}$ and P correspond to state variables (for example, doses to biota) and parameters which are under evaluation; P_0 and $V_0^{(S)}$ correspond to the basic values of the parameter P and the state variable $V^{(S)}$.

PARAMETERS

fl - water exchange for the compartment
SSL - suspended sediment load in water column
RT - pore-water turnover rate
CF - radionuclide concentration factors for biota
h - surface sediment thickness
SR - sedimentation rate
RW - sediment reworking rate
Kd - sediment distribution coefficient
D - molecular diffusion coefficient
ω - porosity of the bottom sediment
DCF_i and **DCF_e -** internal and external dose conversion factors

DYNAMIC OF THE LOCAL SENSITIVITY INDEX

The simulations clearly demonstrate the complexities encountered when modelling doses to biota. The results show that the doses to marine organisms can either increase or decrease with the increase of the evaluated parameters. It is also shown that the results can strongly depend on the time of analysis.

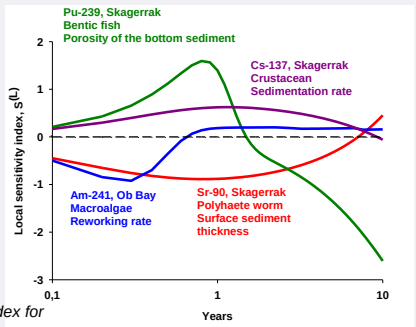
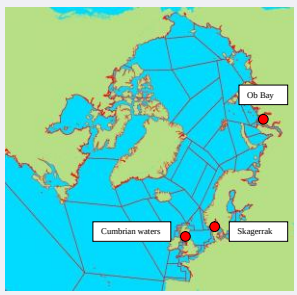


Table 1. Absolute values of the local sensitivity index for the advection rates (fl).

	Radionuclide	Location	fl
Sea bird	^{241}Am	CW	0.64
	^{137}Cs	S	3.49
Pelagic fish	^{239}Pu	OB	0.84
	^{90}Sr	CW	0.88
Phytoplankton	^{241}Am	S	0.58
	^{137}Cs	OB	1.84
Zooplanktone	^{239}Pu	CW	0.66
	^{90}Sr	S	3.30
Benthic fish	^{241}Am	OB	0.45
	^{137}Cs	CW	0.60
Benthic molluscs	^{137}Cs	OB	0.65
	^{90}Sr	CW	0.88
Crustacean	^{241}Am	S	0.55
	^{90}Sr	OB	3.62
Macroalgae	^{239}Pu	S	0.66
	^{137}Cs	OB	0.65
Polyhaete worm	^{241}Am	CW	0.75
	^{90}Sr	CW	0.73

SESITIVITY TO THE WATER EXCHANGE PARAMETERS

Some absolute values of the sensitivity indexes for the water exchange parameters are shown in Table 1. Results of the calculations indicates that doses to the marine organisms for all radionuclides and marine locations decrease with increasing of water exchange between marine compartments. Calculations show the high sensitivity to the water exchange parameters where marine organisms lives in the water column



SURFACE MODEL COMPARTMENTS AND SELECTED SHALLOW MARINE COASTAL ENVIRONMENTS:

- Cumbrian waters of the Irish Sea (CW)
- Skagerrak (S)
- Ob Bay on the Kara Sea (OB)

MARINE ORGANISMS

Sea bird	Pelagic fish
Phytoplankton	Zooplanktone
Benthic fish	Benthic molluscs
Crustacean	Macroalgae
Polyhaete worm	

SESITIVITY TO THE WATER-SEDIMENT INTERACTION PARAMETERS

Results of the calculations indicate that doses to marine organisms for selected radionuclides and marine locations have low sensitivity (the absolute values of S(L) are low) to the molecular diffusion coefficient (D) and pore-water turnover rate (RT).

Water-sediment interaction is a complicated process arising from combinations of many parameters. Nevertheless, results in Table 2 show that doses to marine organisms are, mainly, very sensitive to the process of water - sediment interactions, especially for ^{239}Pu and ^{241}Am (high values for the sediment distribution coefficient).

Table 2. Maximum absolute values of the local sensitivity index for environmental parameters controlling water-sediment interactions

	Radionuclide	Location	SSL	SR	RW	*ω*
Sea bird	^{241}Am	OB	2.86	1.66	1.63	9.45
Pelagic fish	^{239}Pu	OB	2.17	0.58	1.52	8.57
Phytoplankton	^{241}Am	S	2.74	2.50	0.80	4.20
Zooplanktone	^{239}Pu	CW	1.15	1.35	0.80	0.85
Benthic fish	^{241}Am	OB	1.37	0.33	0.92	9.25
Benthic molluscs	^{137}Cs	OB	0.12	0.12	0.58	2.31
Crustacean	^{241}Am	S	2.52	2.30	1.04	4.06
Macroalgae	^{239}Pu	S	0.17	1.28	1.49	0.85
Polyhaete worm	^{241}Am	CW	2.71	1.64	0.65	4.14

SESITIVITY TO THE CONCENTRATION ANDDOSE CONVERSION FACTORS

Results of the calculations indicate that doses to marine organisms for selected radionuclides and marine locations have high sensitivity to radionuclide concentration factors and intern and extern dose conversion factors (maximum values of the sensitivity indexes are approximately 1).

CONCLUSION

The sensitivity analysis shows that the influence of model parameters can vary widely depending on the concrete radionuclude and selected marine regions. It is shown that a sensitivity of doses to marine organisms to model parameters is a dynamic process where the results can strongly depend on the time

It is also shown that the results of the sensitivity parameter analysis can contribute to the process of defining which parameters can play an important role in the dose assessment. In particular, it is shown that doses to marine organisms are also sensitive to the processes of the water-sediment interactions for the radionuclides with high sediment distribution coefficient.

Additionally, it is shown that doses to marine organisms are high sensitive to processes of bioaccumulation for the present release scenario, selected radionuclides and the marine environments.

References

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