Statens strålevern
Norwegian Radiation Protection Authority

Radioecological sensitivity of the coastal marine regions

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Environmental sensitivity of the marine regions

EMRAS II Programme

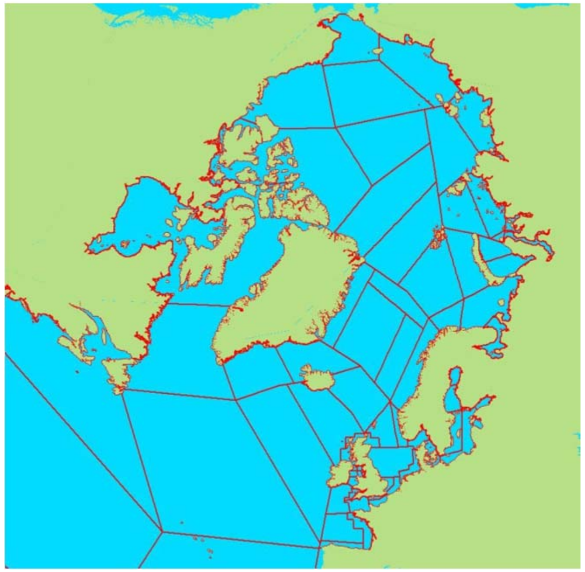
Environmental sensitivity working group

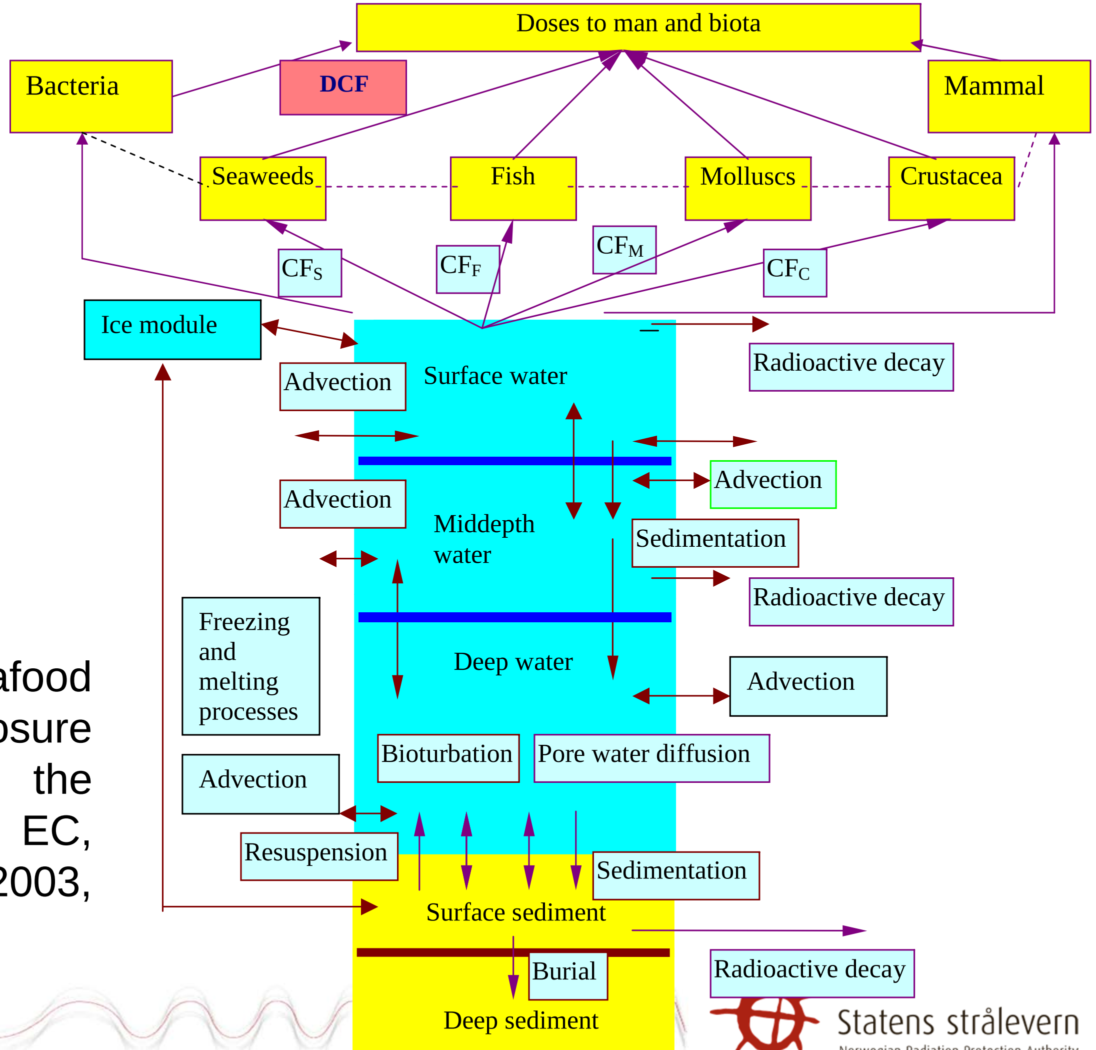
The environmental sensitivity has been considered as a dose to adults

Release scenario:

a single deposition of 1000 Bq/m2 of radionuclides in each marine region

NRPA box model: schematic structure of the processes involved in modelling





Comparison of the contribution to individual dose to man from seafood ingestion and external exposure indicates a clear domination of the ingestion pathway (MARINA-Med EC, 1994; IAEA-TECDOC-1330, 2003, Iosjpe et al., 2009)

NRPA box model: equations of the transfer of radionuclides between the boxes (Iosjpe et al., 2009)

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

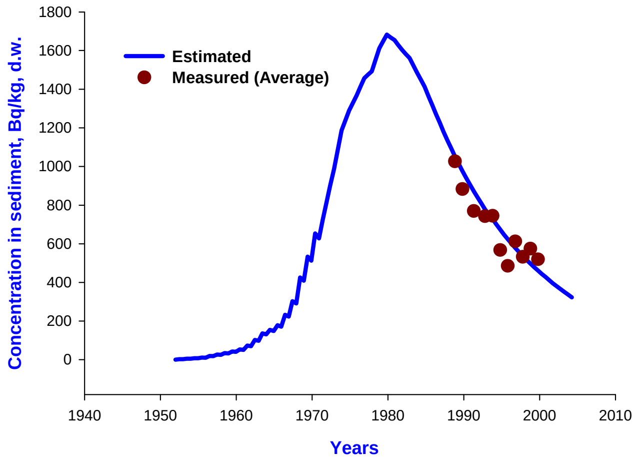
$$A_i = 0, \quad t < T_i$$

$$T_i = \min_{\mu_m(v_0, v_i) \in M_i} \sum_{j,k} w_{jk} \qquad \gamma(t \geq T_i) = \begin{cases} 1, & t \geq T_i \\ 0, & t < T_i \end{cases}$$

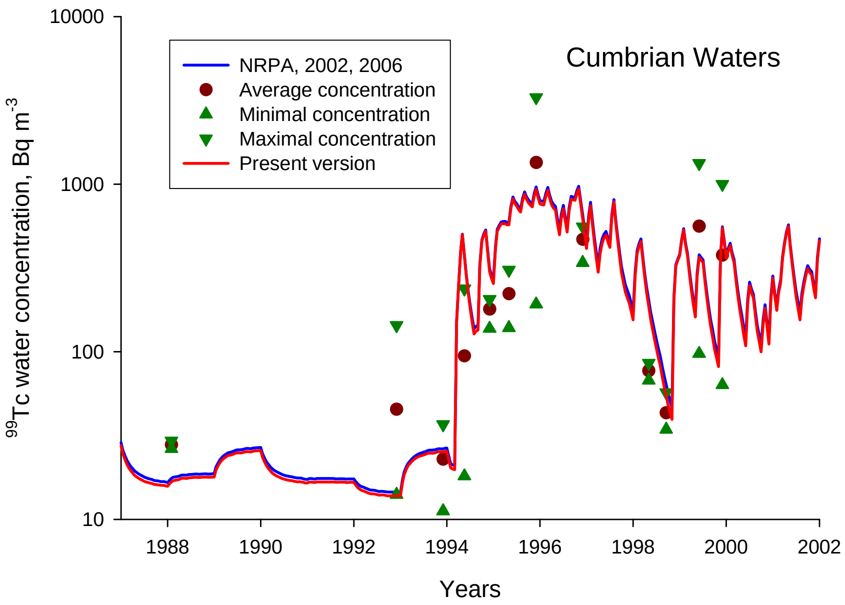
Non-nstantaneous mixing in oceanic space

Model Corroboration (Iosjpe, 2006; Iosjpe et al., 2009)

Pu-239



Tc-99



Selected radionuclides

IAEA, 2004: sediment distribution coefficients Kd, and concentration factors for fish (CFf), crustaceans (CFc), molluscs (CFm) and seaweeds (CFs)

	^{137}Cs	^{90}Sr	^{131}I	^{239}Pu
Kd	4000	8	70	100000
CFf	100	3	9	100
CFc	50	5	3	200
CFm	60	10	10	3000
CFs	50	10	10000	4000

Selected marine regions

Cumbrian waters of the Irish Sea (CW)

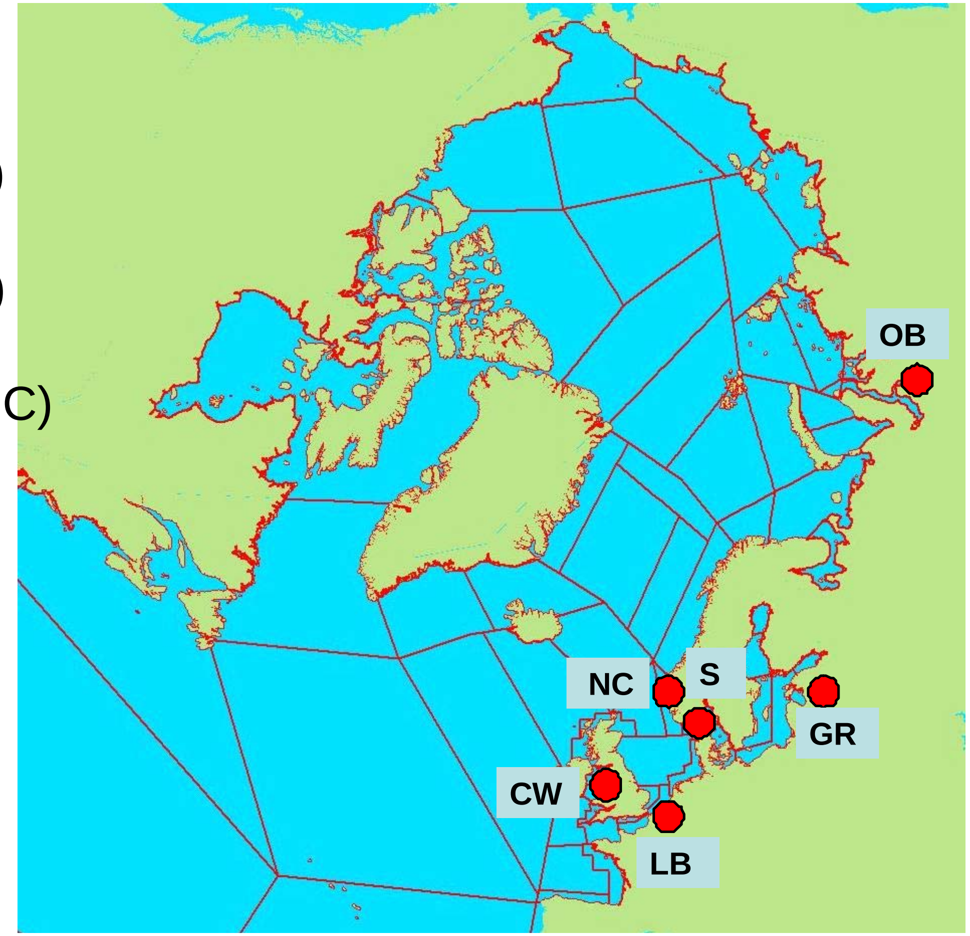
Lyme Bay on the English Channel (LB)

North Sea of the Norwegian coasts (NC)

Skagerrak (S)

Gulf of Riga on the Baltic Sea (GR)

Ob Bay on the Kara Sea (OB)



Selected marine regions

Name	Volume, m3	Depth, m	Surface area, m2
Irish Sea: Cumbrian Waters	3,80E+10	2,80E+01	1,36E+09
English Channel: Lyme Bay	2,01E+11	3,95E+01	5,09E+09
North Sea: Norwegian Current Surface	9,20E+12	1,56E+02	5,90E+10
Skagerrak	6,78E+12	2,10E+02	3,23E+10
Baltic Sea: Gulf of Riga	4,05E+11	2,30E+01	1,76E+10
Kara Sea: Ob Bay	3,19E+11	1,10E+01	2,90E+10

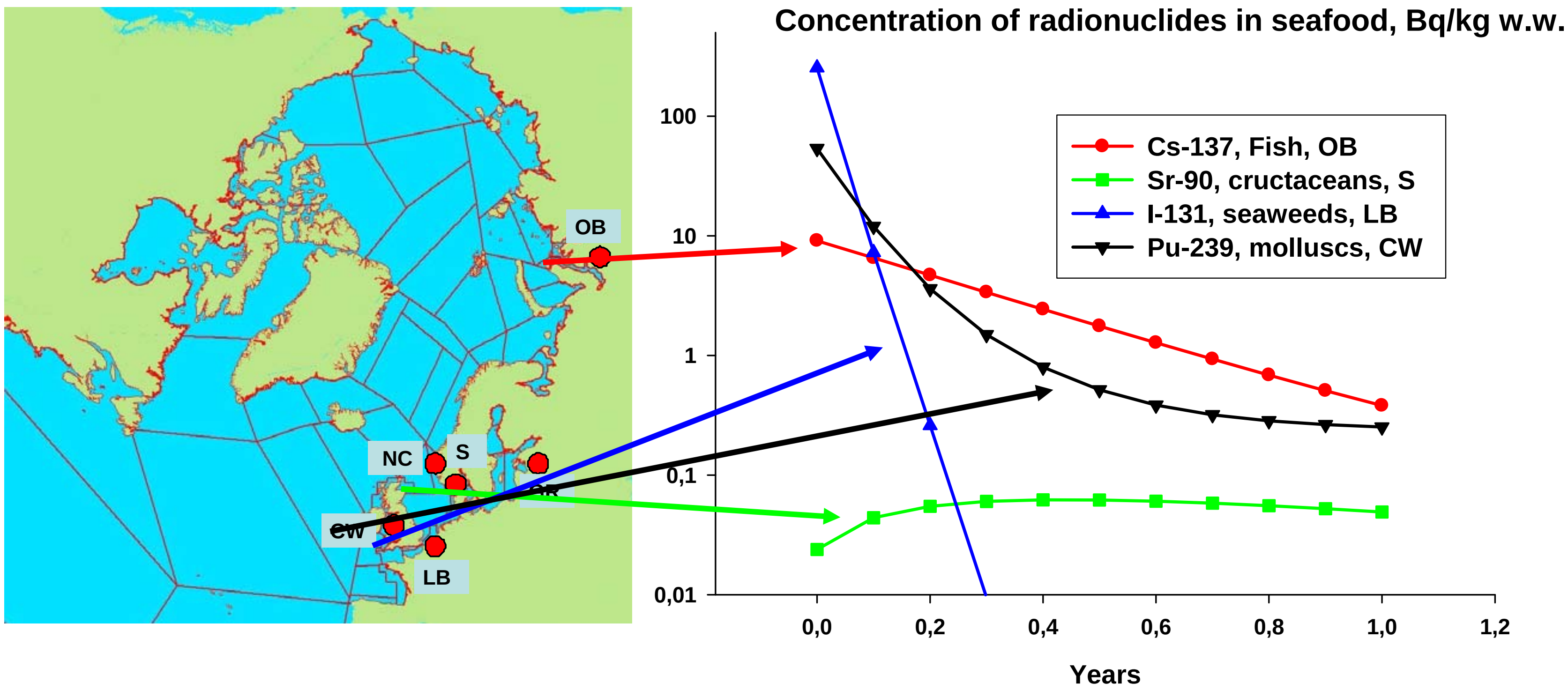
Selected marine regions: *SSL* (suspended sediment load) and *SR* (the mass sedimentation rate)

Name	SSL t/m^3	SR, t/m^2/y
Irish Sea: Cumbrian Waters	1,0E-05	6,0E-03
English Channel: Lyme Bay	3,0E-06	1,0E-04
North Sea: Norwegian Current Surface	6,6E-06	1,0E-04
Skagerrak	1,0E-06	5,0E-03
Baltic Sea: Gulf of Riga	1,0E-06	5,0E-04
Kara Sea: Ob Bay	5,0E-05	1,0E-03

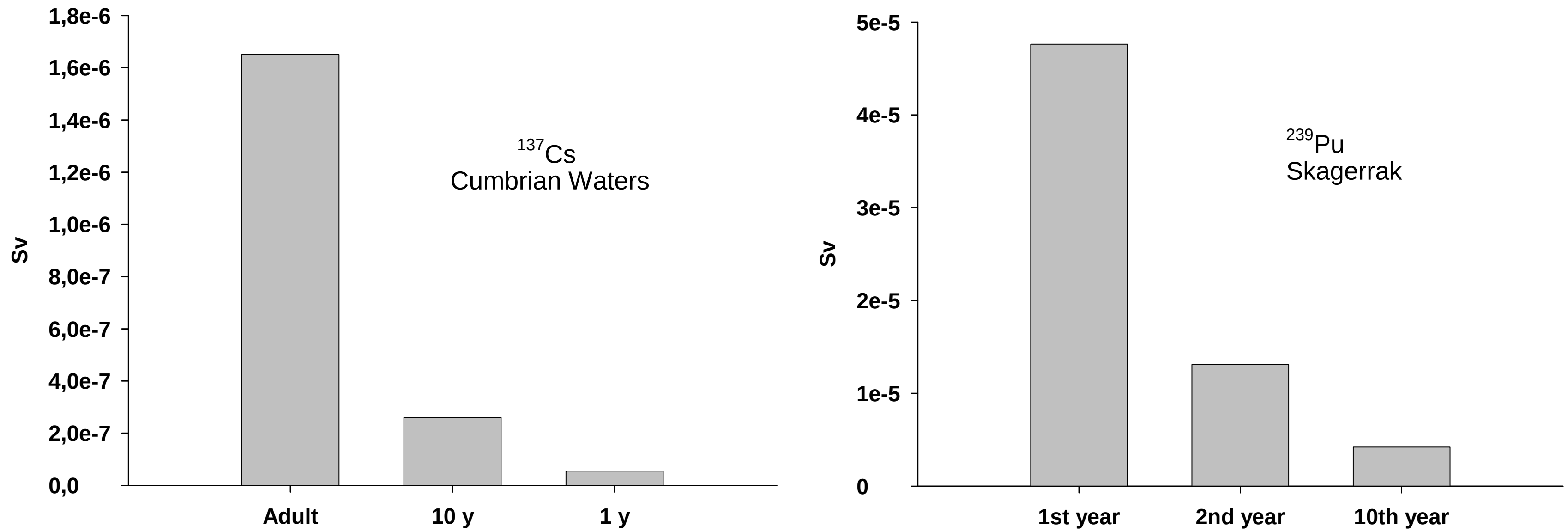
Seafood consumption (Smith & Jones, 2003) corresponds to results for the population of the coastal regions

	Group 1 (adult)	Group 2 (child)	Group 3 (infant)
Fish	51	10.2	2.5
Crustacean	17	2.25	0
Molluscs	14	3.5	0
Seaweeds	5	0	0

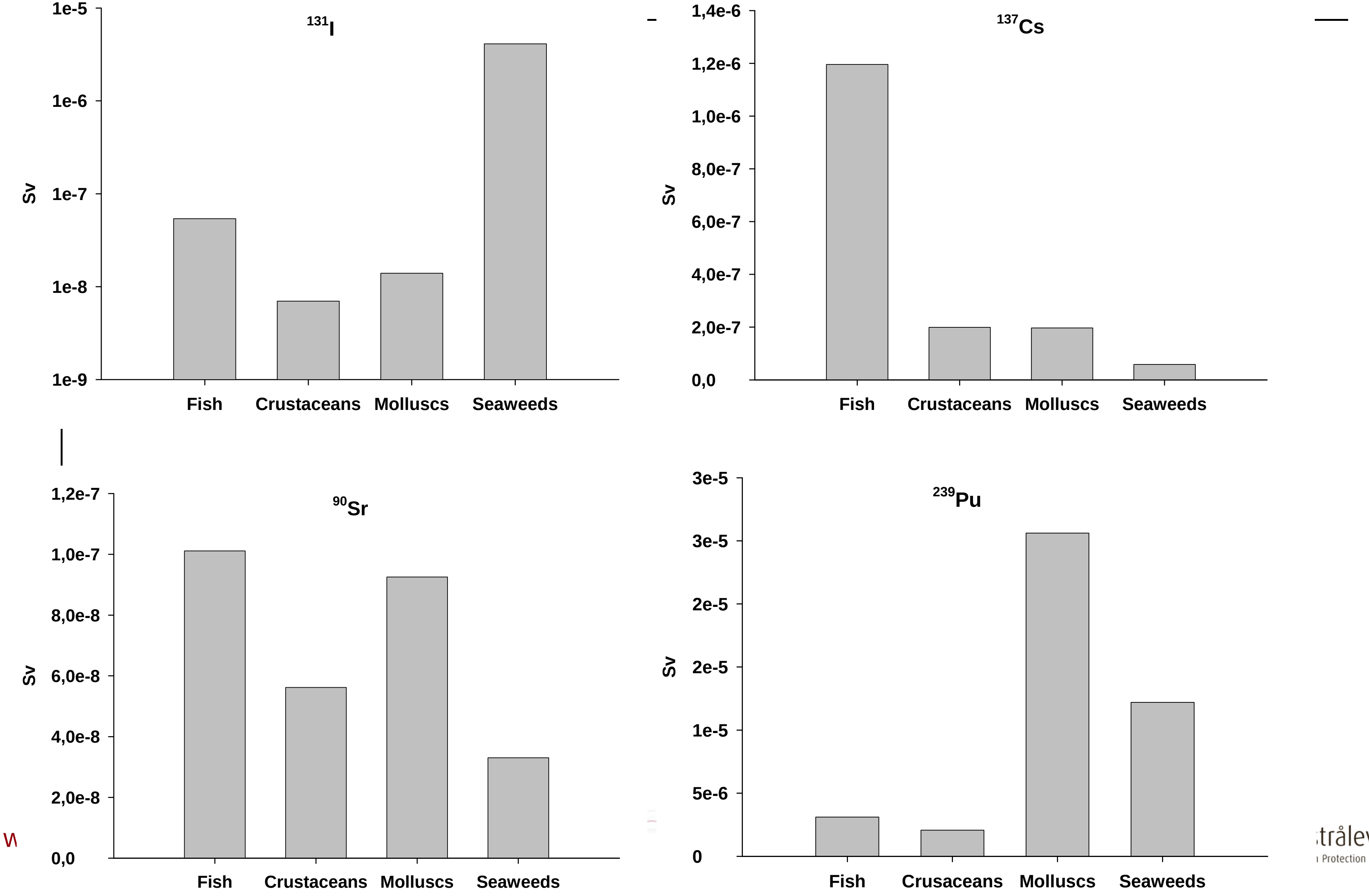
Radionuclides concentration in seafood



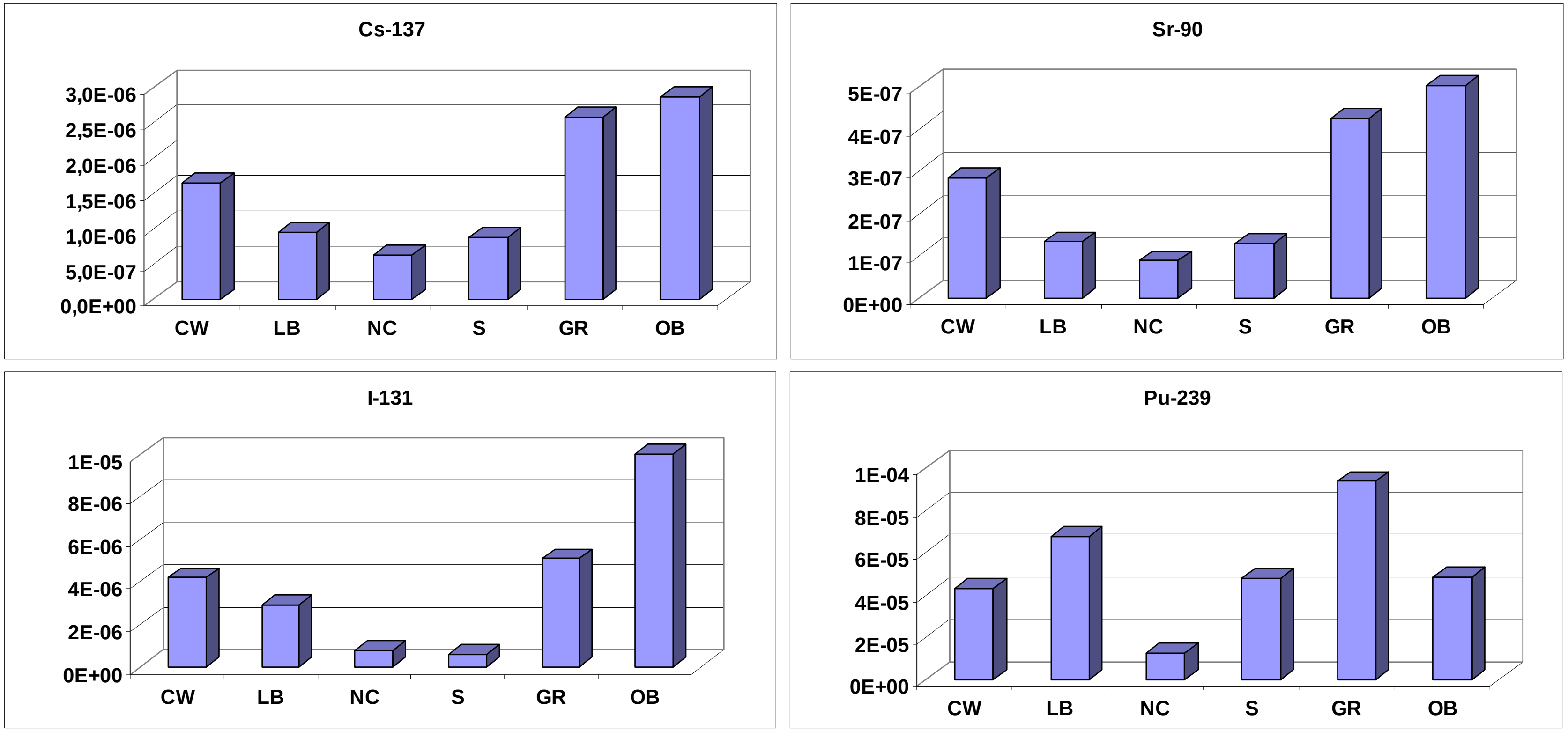
Dose (Sv) for different age from 137Cs (Cumbrian Waters), and during different times from 239Pu for adult (Skagerrak).



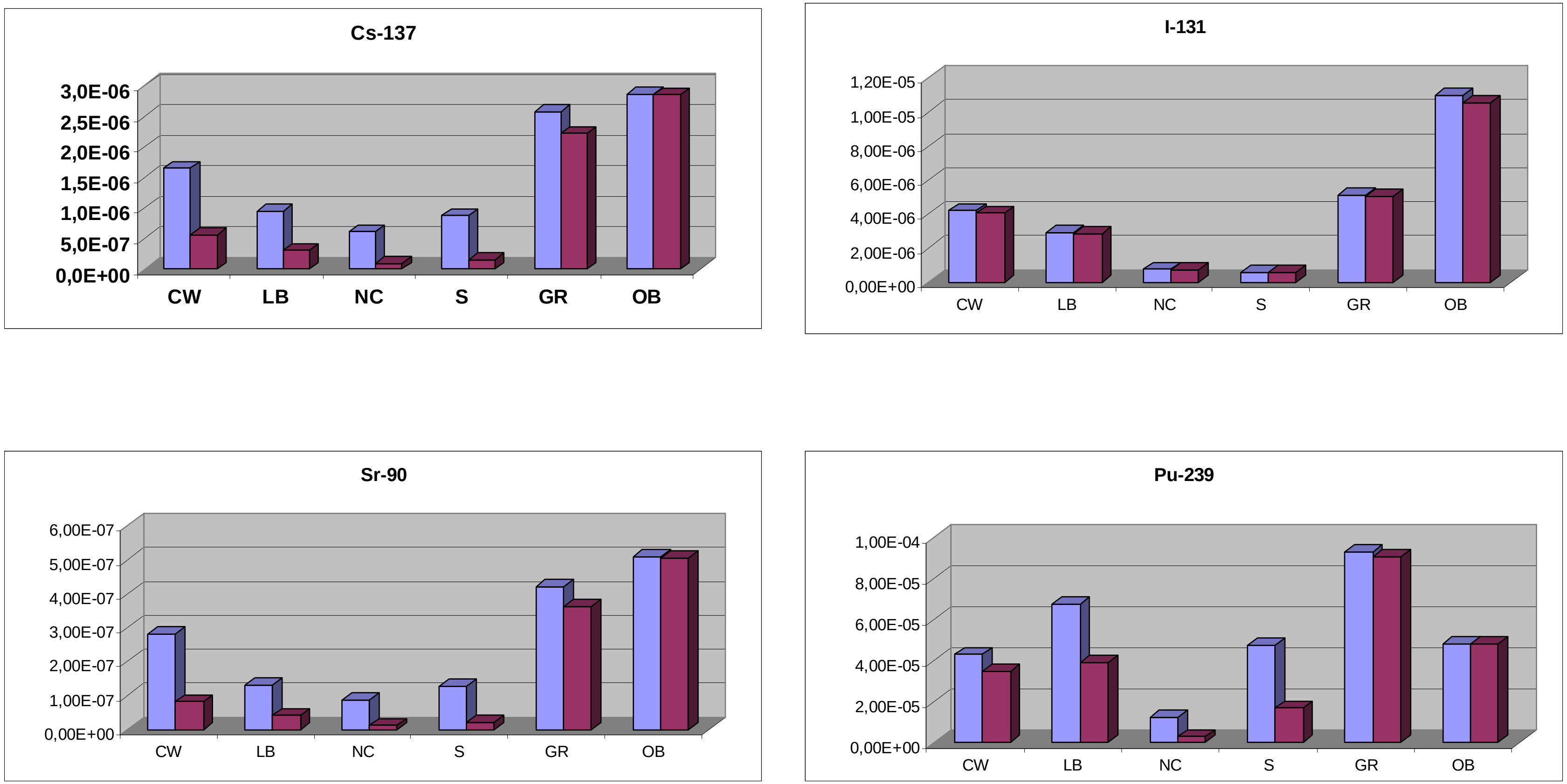
Doses (Sv) from one year of consumption of I-131, Cs-137, Sr-90, and Pu-239 in fish, crustaceans, molluscs, and seaweed.



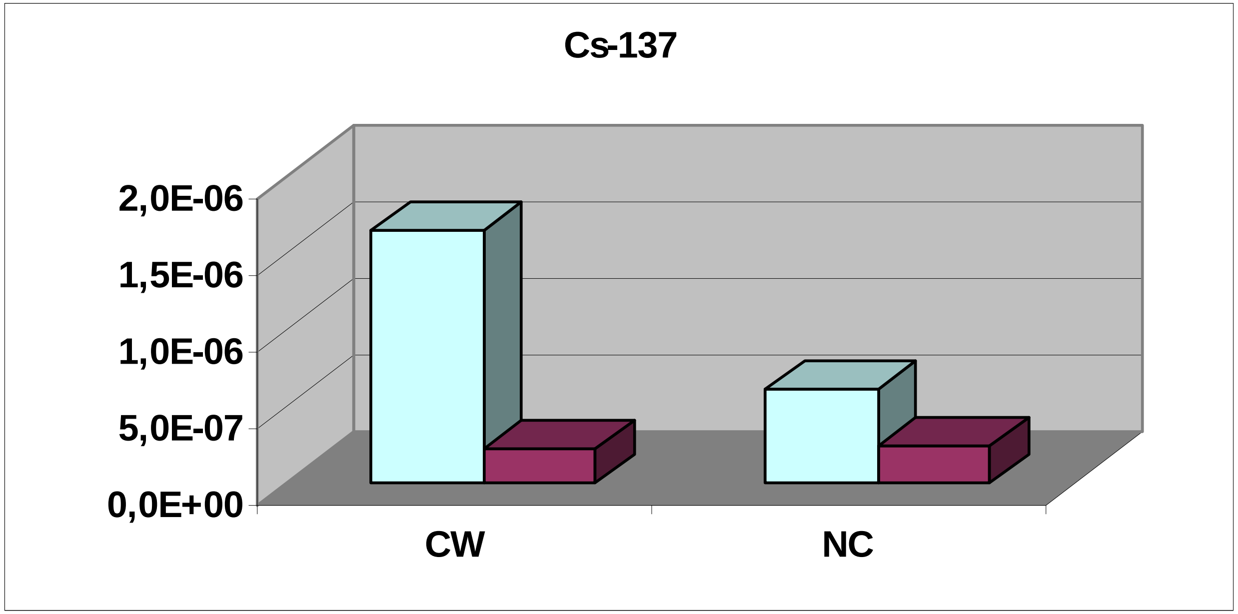
Doses, Sv


Cs-137
3,0E-06
2,5E-06
2,0E-06
1,5E-06
1,0E-06
5,0E-07
0,0E+00
CW LB NC S GR OB
Sr-90
5E-07
4E-07
3E-07
2E-07
1E-07
0E+00
CW LB NC S GR OB
I-131
1E-05
8E-06
6E-06
4E-06
2E-06
0E+00
CW LB NC S GR OB
Pu-239
1E-04
8E-05
6E-05
4E-05
2E-05
0E+00
CW LB NC S GR OB

Potential improvement: comparison of scenarios: releases in the local environments



Potential improvement:
IMPACT OF ASSUMPTIONS ABOUT SEAFOOD CONSUMPTION



The green color corresponds to the results of dose calculations from Cs-137 release, where the same assumptions about the levels of seafood consumption for the population of the coastal regions, provided by Smith & Jones, (2003) have been used in all marine locations, while the red color corresponds to calculations where site specific information about average seafood consumption, provided by Smith & Jones, (2003) and by Bergsten (2003) have been used for the Cumbrian waters (CW) and for the Norwegian coastal waters (NC), respectively.

PARAMETERS AND PROCESSES CONTROLLING THE VULNERABILITY OF THE MARINE REGIONS

The local sensitivity index

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

V(S) and P correspond to state variables (for example, doses to man) 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). In the present paper the values for P_0 and V_0(S) correspond to results provided by

PARAMETERS

fl - maximum water exchange for the compartment
SR - sedimentation rate
SSL - suspended sediment load in water column
RW - sediment reworking rate
RT - pore-water turnover rate
Kd - sediment distribution coefficient
D - molecular diffusion coefficient
CF - radionuclide concentration factors for seafood

Results

- Doses to adults for all selected radionuclides and marine locations have low sensitivity to the molecular diffusion coefficient (D) and pore-water turnover rate (RT).
- Sr-90: sensitivity index is low for parameters describing water-sediment interactions
- I-131: only one parameter, namely the concentration factor for seaweeds, has a high sensitivity index value
- Doses to man are most sensitive to the process of bioaccumulation (parameter CF)
- Doses to man are sensitive to the process of the particle mixing (parameters Kd, Rw, SSL), but only for the radionuclides with relatively high sediment distribution coefficient (Pu-239, Cs-137)

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

Locations	OB	CW	LB	S	GR	NC
^{137}Cs	0.26	0.10	0.06	0.21	0.10	0.22
^{90}Sr	0.39	0.16	0.06	0.21	0.13	0.23
^{239}Pu	0.11	0.02	0.04	0.12	0.00	0.15

Absolute values of the local sensitivity index for sediment reworking rate (RW), sediment distribution coefficient (Kd), suspended sediment load in water column (SSL), sedimentation rate (SR).

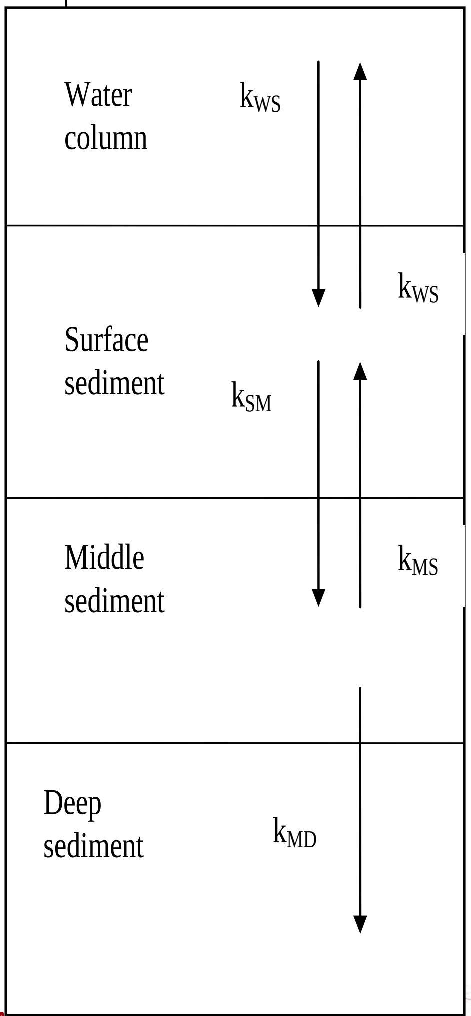
		OB	CW	LB	S	GR	NC
^{137}Cs	Rw	0.19	0.11	0.06	0.08	0.17	0.07
^{239}Pu	Rw	0.33	0.23	0.39	0.28	0.33	0.18
^{137}Cs	K_d	0.21	0.22	0.06	0.09	0.21	0.07
^{239}Pu	K_d	0.07	0.27	0.36	0.20	0.37	0.13
^{239}Pu	SSL	0.39	0.13	0.04	0.04	0.04	0.00
^{239}Pu	SR	0.11	0.16	0.01	0.29	0.06	0.00

Absolute values of the local sensitivity index for concentration factors for fish (CFf), crustaceans (CFc), molluscs (CFm) and seaweeds (CFs).

	^{137}Cs	^{90}Sr	^{131}I	^{239}Pu
CFf	0.72	0.36	0.01	0.07
CFc	0.12	0.20	0.00	0.05
CFm	0.12	0.33	0.00	0.60
CFs	0.04	0.12	0.99	0.28

Potential improvement: evaluation of the key environmental parameters (Poster, ICRER2011 –sensitivity analysis of the model parameters, f. ex., CF, Kd, …)

Water-sediment interaction



$$k_{WS} = \frac{SR\cdot k_d}{d\cdot(1+k_d\cdot SSL)} + \frac{D}{d\cdot h_S(1+k_d\cdot SSL)} + \frac{R_T\cdot\omega\cdot h_S}{d\cdot(1+k_d\cdot SSL)} + \frac{R_W\cdot\rho\cdot k_d\cdot(1-\omega)}{d\cdot(1+k_d\cdot SSL)}$$

$$k_{SW} = \frac{D}{h_S^2\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]} + \frac{R_T\cdot\omega}{\omega+k_d\cdot\rho\cdot(1-\omega)} + \frac{R_W\cdot\rho\cdot k_d\cdot(1-\omega)}{h_S\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]}$$

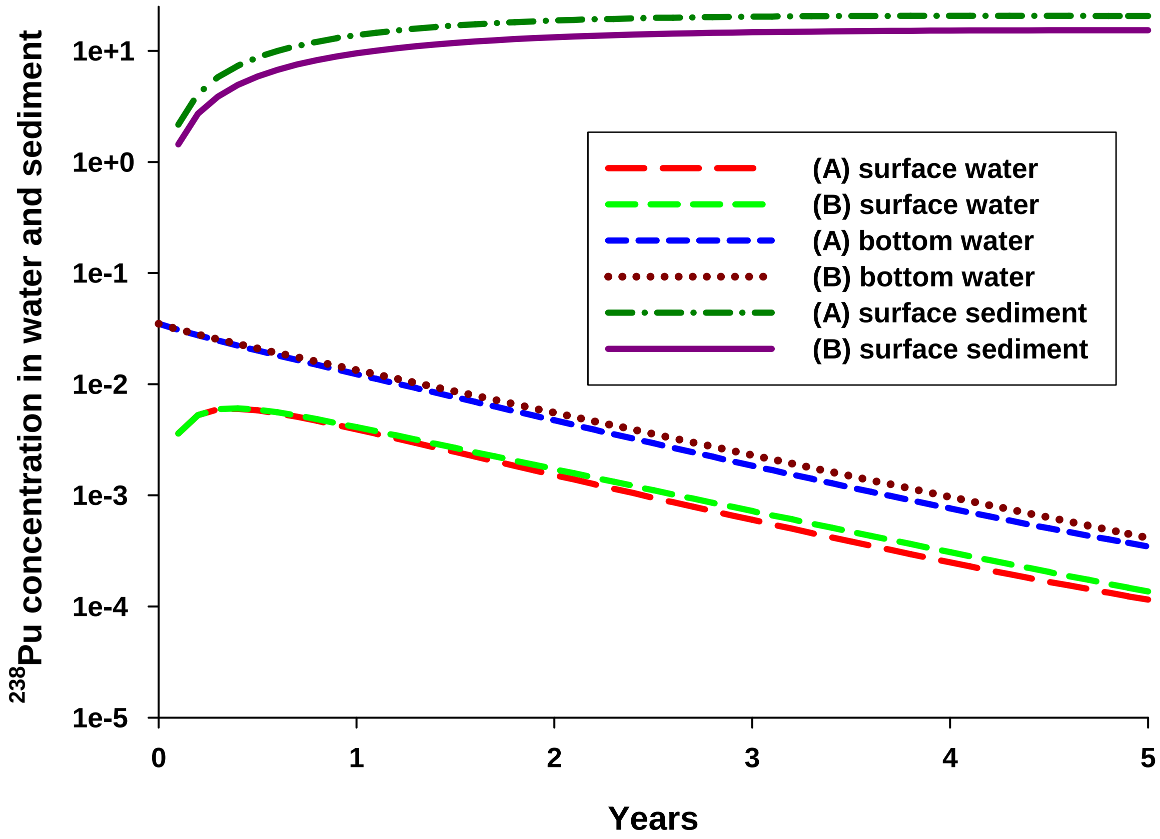
$$k_{SM} = \frac{D\cdot\omega}{h_S^2\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]} + \frac{k_d\cdot SR}{h_S\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]}$$

$$k_{MS} = \frac{D\cdot\omega}{h_S\cdot h_{SM}\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]}$$

$$k_{MD} = \frac{k_d\cdot SR}{h_{SM}\cdot[\omega+k_d\cdot\rho\cdot(1-\omega)]}.$$

Definition of parameters is not a trivial task: concentrations (Iosjpe, 2011)

Pu-238 bulk concentrations in surface water, bottom water and sediment compartments: (A) the basic scenario; (B) *Kd* increased by a factor of 5, *Rw* decreased by a factor of 5, in comparison to (A). Results correspond to the southern part of the Norwegian Current.



Practical results: half-life in sediment (Iosjpe, 2011)