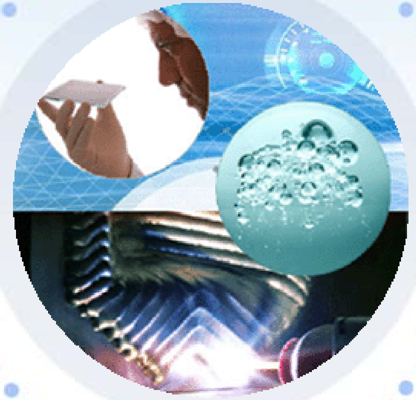

Modelling tritium in aquatic environment

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Why are we interested in dynamic models for the dose assessment of liquid releases ?

1. Some processes cannot be described by steady-state models : discontinuous process such as sediment deposit and resuspension

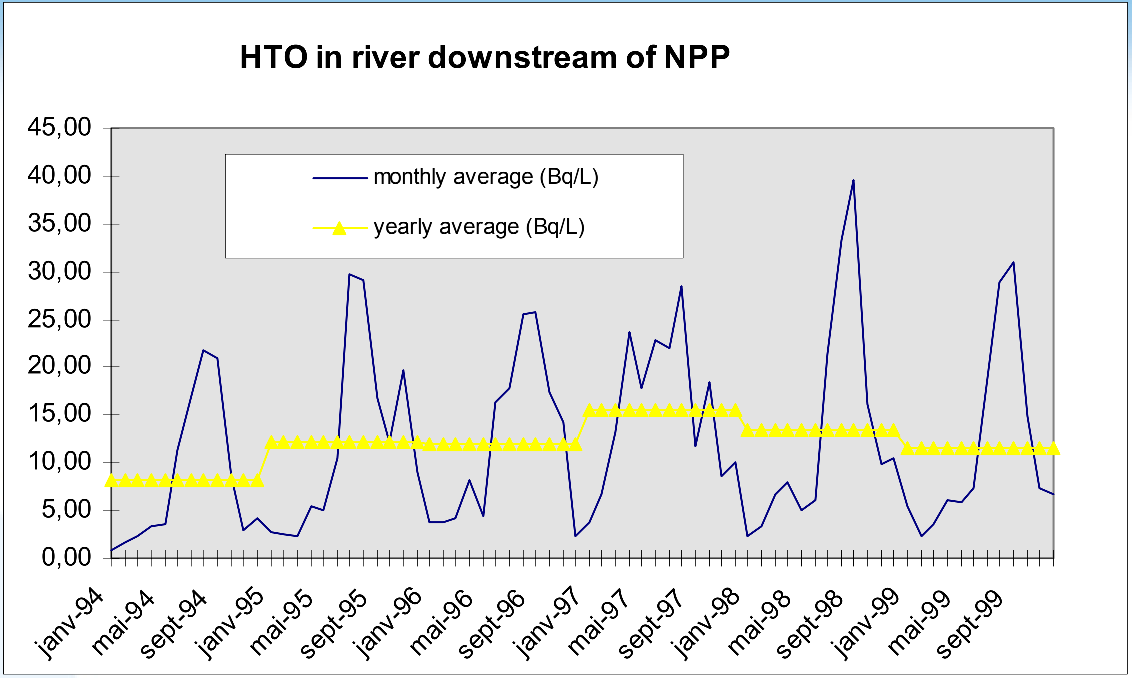
2. Steady state models, used to demonstrate compliance with regulatory dose limits, are difficult to validate in the environment where concentrations change according to time in the day, season, river discharge,…Case of NPP liquid releases, discontinuous process and time-dependent pathways (irrigation)

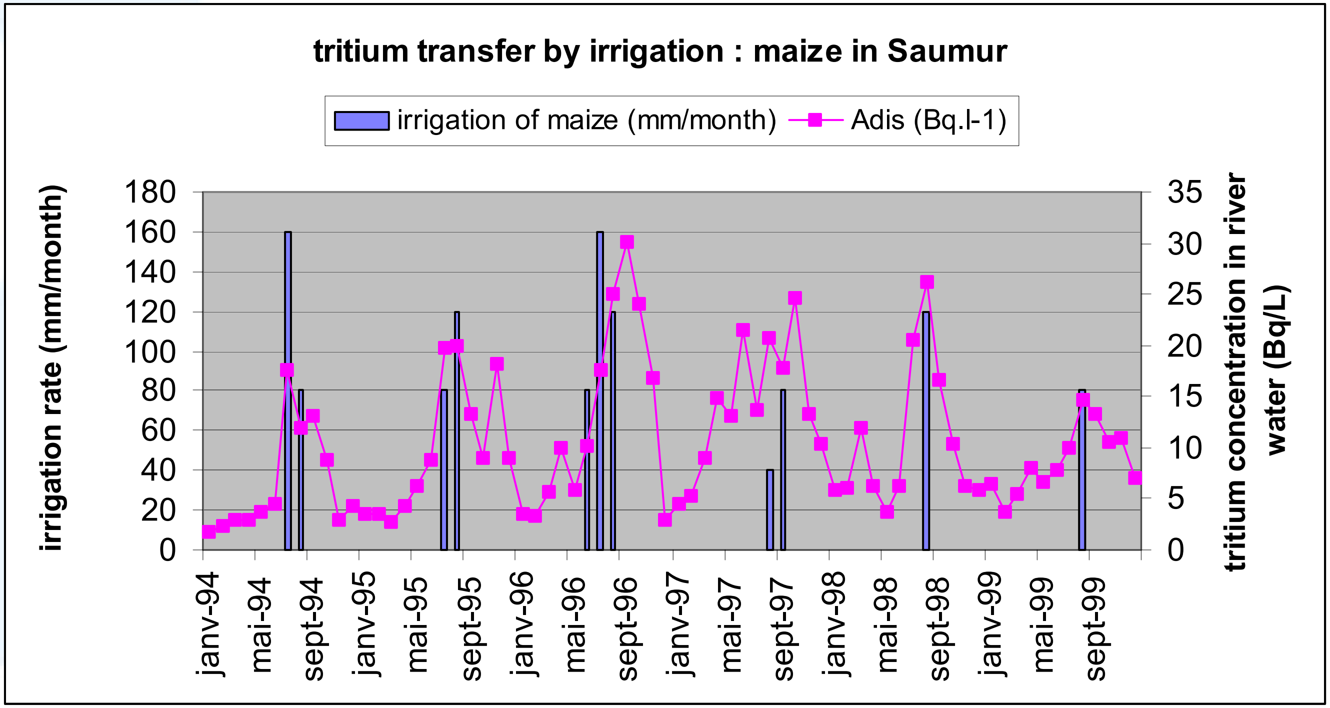
   Validation is possible by :

   - Comparing dynamic models to field data

   - Running dynamic models on a longer time range (year) and comparing yearly average results with steady state model to check that they are conservative

3. Dynamic models useful to demonstrate that different turn-over rates for HTO and OBT can explain observed OBT/HTO >1


HTO in river downstream of NPP
monthly average (Bq/L)
yearly average (Bq/L)
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
janv-94
mai-94
sept-94
janv-95
mai-95
sept-95
janv-96
mai-96
sept-96
janv-97
mai-97
sept-97
janv-98
mai-98
sept-98
janv-99
mai-99
sept-99


tritium transfer by irrigation : maize in Saumur
irrigation of maize (mm/month)
Adis (Bq.l-1)
irrigation rate (mm/month)
tritium concentration in river water (Bq/L)
180
160
140
120
100
80
60
40
20
0
35
30
25
20
15
10
5
0
janv-94
mai-94
sept-94
janv-95
mai-95
sept-95
janv-96
mai-96
sept-96
janv-97
mai-97
sept-97
janv-98
mai-98
sept-98
janv-99
mai-99
sept-99

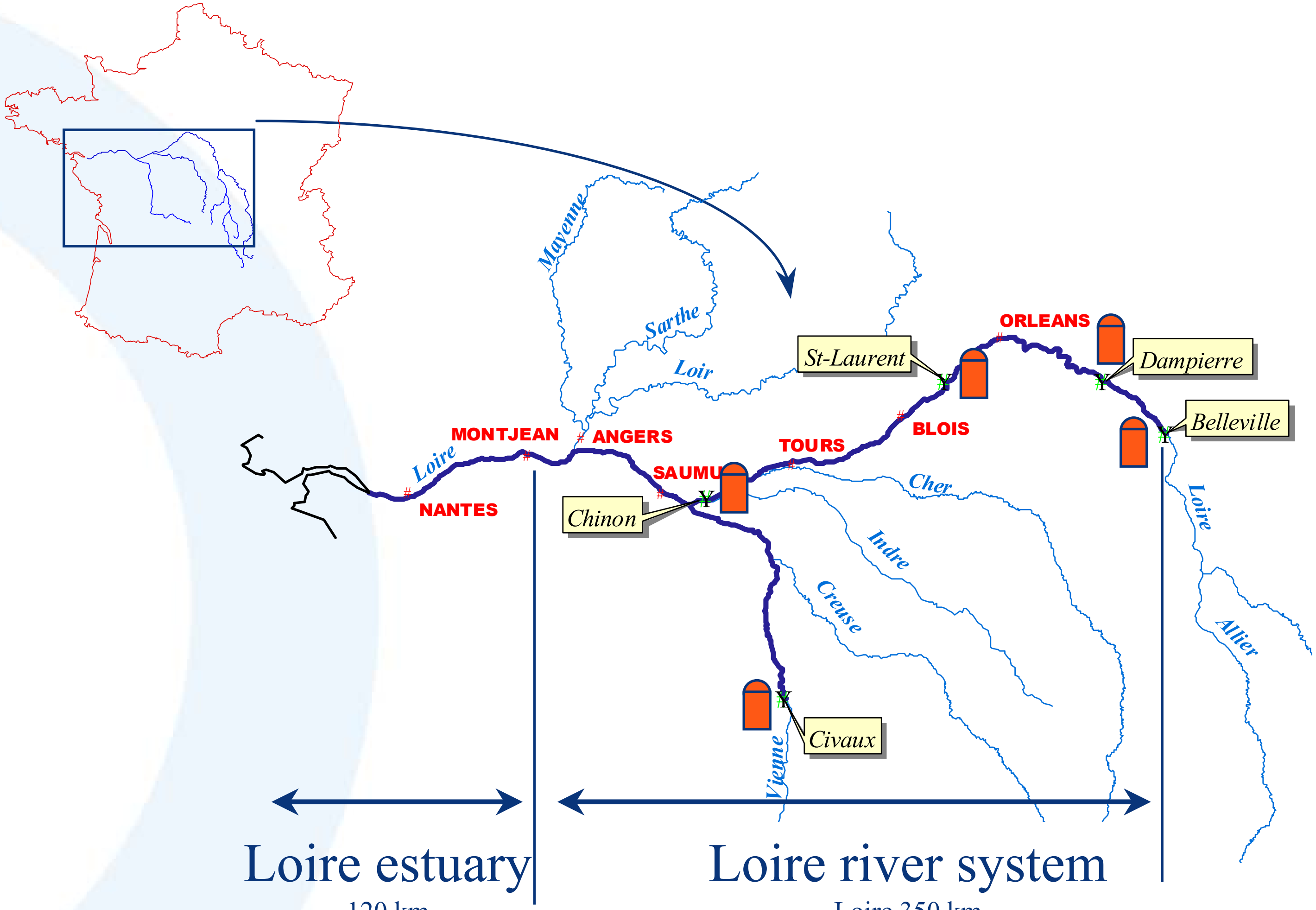
From discharge in water to man : review of existing tritium models

- Dispersion/transport in river or sea
- Transfer to aquatic organisms
- Transfer through irrigation to agricultural products

Review of aquatic tritium models

- Literature review in 2000 : Steady state specific activity models with or without OBT
- In 2000, CALVADOS (later called OURSON) dynamic model for tritium and carbon 14 in aquatic environment applied on the Loire river
- In 2004, IAEA EMRAS intercomparison exercises
  - dispersion /transport model → Loire river scenario
  - dynamic transfer to mussel → transplantation scenario in Perch lake
  - no scenario with irrigation

EMRAS - A comprehensive Loire river basin scenario from 1994 to 1999



Loire estuary
120 km

Loire river system
Loire 350 km
Vienne 120 km

EMRAS scenario on tritium migration in the Loire river

- Simulation of the dispersion of Tritium discharges in the whole Loire river system (~ 350 km)
- Reproduction of the real hydraulic conditions, from July to December 1999

↓

- Comparison between calculated tritium concentration and measurements at Angers
- Inter-comparison between the different models at different points along the river

Models tested on the Loire scenario

GOUTAL et al., 2008, Journal of Environmental Radioactivity

CASTEAUR	*IRSN, France*
MASCARET – TRACER module	*EDF, France*
MOIRA+ – MARTE module	*ENEA, Italy*
RIVTOX	*IMMSP, Ukraine*

Conclusions :

•Good agreement between model and measurements for average concentrations

•Performance of models controlled by appropriate estimates of water velocities and water fluxes : 1D hydrological models better adapted to sharp release or high hydraulic variability

Models tested on the mussel transplantation scenario

- *Model from NIRS, Japan*
- *Model from SRA, Japan*
- *OURSON EDF, France*
- *AQUATRIT IFIN, Romania*
- *BIOCHEM TUM, Germany*

Conclusions :

- Underestimation of OBT concentration in the first 24 h,overprediction after 88 days
- Understanding of processes involved in OBT dynamics need to be improved

General model for transfer to biota

- HTO
  - Rapid equilibrium between HTO in the organism and HTO in the surrounding media (air or water)
  - Turn-over rate controlled by ratio between water intake and body water content
- OBT
  - same general equation for OBT and carbon 14 in phytoplancton, fish, terrestrial plants and animals based on food intake rate or CO2 assimilation rate for photosynthetic organisms (Sheppard et al 2006)

$$\frac{d(A_{biota}^{C14}\cdot M_{biota}^{mass})}{dt}\cdot =$$

$$A_{biota}^{C14}(t)\cdot\frac{dM_{biota}^{mass}(t)}{dt}+M_{biota}^{mass}(t)\cdot\frac{dA_{biota}^{C14}(t)}{dt}=$$

$$-\lambda_{loss}\cdot A_{biota}^{C14}(t)\cdot M_{biota}^{mass}(t)+I\cdot K\cdot D\cdot A_{substrate}^{C14}(t)\cdot M_{biota}^{mass}(t)$$

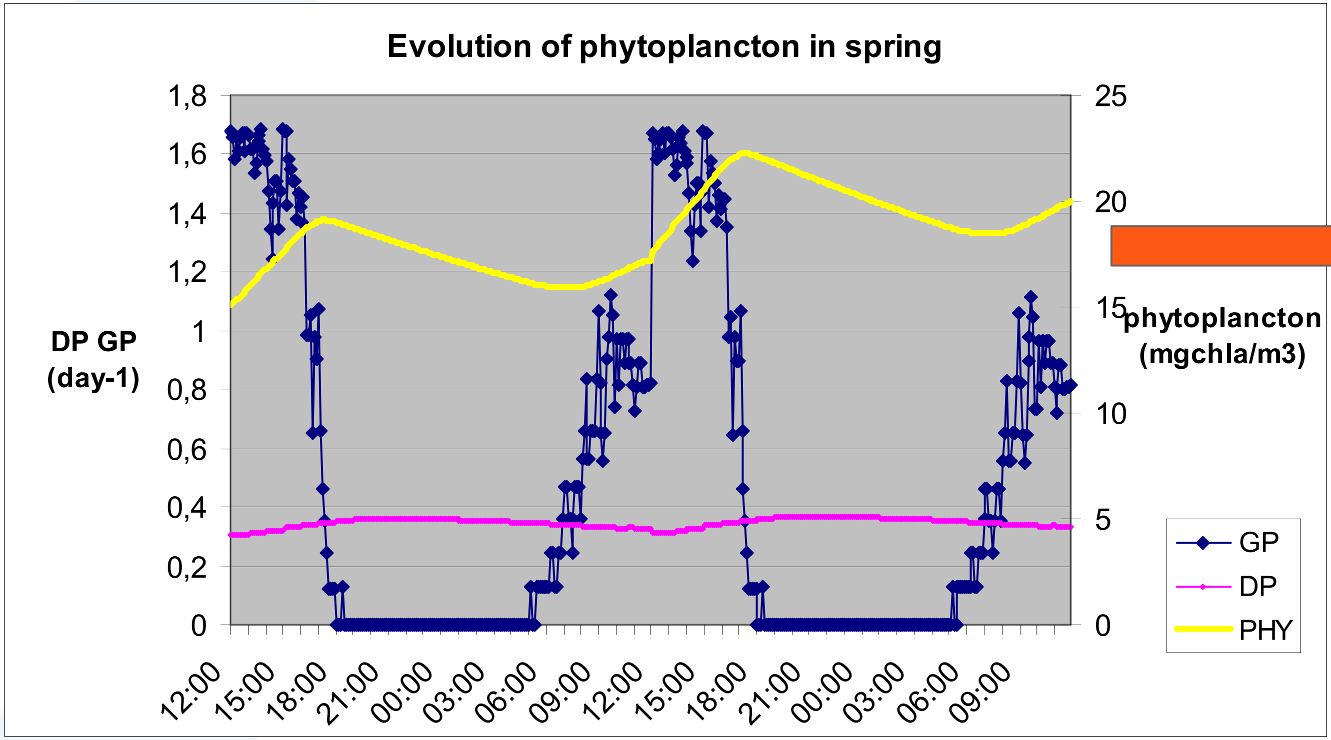
→

$$\frac{dA_{fish}^{C14}(t)}{dt}=-k_{ing}A_{fish}^{C14}(t)+k_{ing}.DF.\frac{C_{phyto}}{C_{fish}}.A_{eau}^{C14}(t)$$

Determination of turn-over rate of tritium in phytoplancton from phytoplancton growth model

•Phytoplancton growth model developped for eutrophication problem to predict O_2 evolution in aquatic environment :

- **Growth is a function of light (photosynthesis), water temperature and nutrient availability**
- **Disappearance (respiration and predation)**



Average relative growth rate : 0.5 day^{-1}

Phytoplancton model

$$\frac{dPHY}{dt} = (CP - DP)PHY$$

$$\begin{cases} g_1(T) = e^{a(T-T_{opt})}\left(\dfrac{T_{\max} - T}{T_{\max} - T_{opt}}\right)^{a(T_{\max}-T_{opt})} & ifT < T_{\max} \\ g_1(T) = 0 ifT \geq T_{\max} \end{cases}$$

$$CP(t) = \left(C_{\max} \times \underbrace{g_1(T)}_{\substack{\lim itation \\ by \\ température}} \times \underbrace{RAY}_{sunlight} \times LNUT(t) \right)$$

$$RAY = \frac{1}{Ke \times H}\left(e^{1-\frac{I_0}{I_S}e^{-Ke\times H}} - e^{1-\frac{I_0}{I_S}} \right)$$

$$\mathrm{LNUT} = \min\left(\frac{\mathrm{nut}_1}{\mathrm{nut}_1 + \mathrm{k}_{\mathrm{nut}_1}} ; \frac{\mathrm{nut}_2}{\mathrm{nut}_2 + \mathrm{k}_{\mathrm{nut2}}} ;... \right)$$

$$DP(t) = \left(\underbrace{RP}_{respiration} + \underbrace{MP(t)}_{mortality} \right) \times g_2(T)$$

Questions to be addressed

- For living organisms, single compartment model has the advantage of simplicity, two compartment model with a fast and slow turn-over rate might be more accurate but parameter values difficult to establish

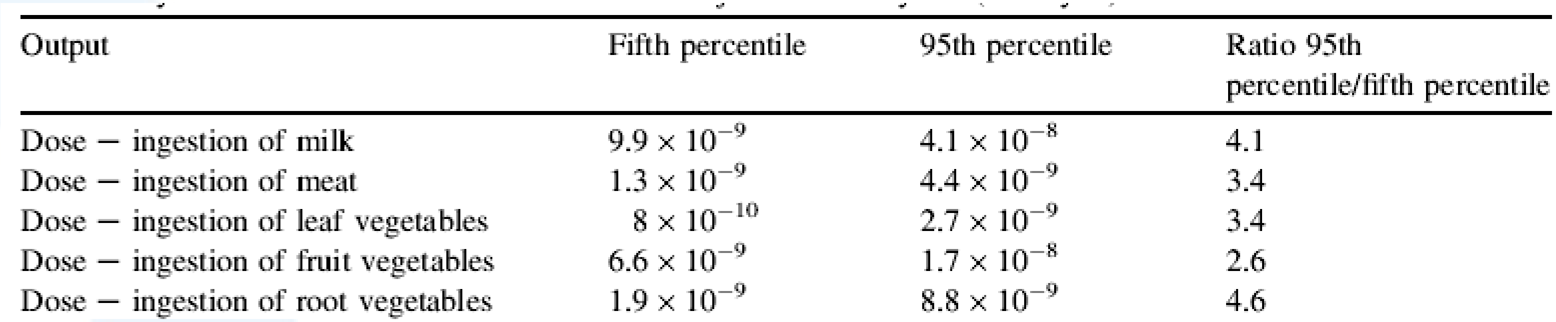
- Check the availability of food intake rate for different categories of aquatic organisms (molluscs, crustaceans, fish)

- Process to be included or not:
  - transfer from dissolved OBT(radiolabelled biomolecules) to aquatic organisms (done in AQUATRIT)
  - Transfer from sediment organic matter to bottom feeder - requires to determine the bioavailability of OBT
  - Transfer between atmosphere and water (done in MASCARET)

Compartments and pathways (including irrigation)for exposure to tritium from liquid releases (OURSON)

HTO riv	Éch. H_2O	Incorp.	Irrigation						Ingestion	Transformation	Ingestion
Éch. H_2O	HTO pois.										Ingestion
Elimin .bio		OBT pois.									Ingestion
			Sol - HTO	Infiltration	Evaporation	Prélèv. racinaire					
				Sol profond Nappe							
					Air						
					Transpir.	HTO – Feuil.	Photo-synthèse	Transloc.	Ingestion		Ingestion
							OBT – Feuil.			Assimilation	Ingestion
								OBT – grains	Ingestion	Assimilation	Ingestion
									HTO – Animal Part. com.		Ingestion
										OBT – Animal Part. com.	Ingestion
											Homme

Uncertainty of mean annual dose (Sv/an) in Montjean (OURSON results)

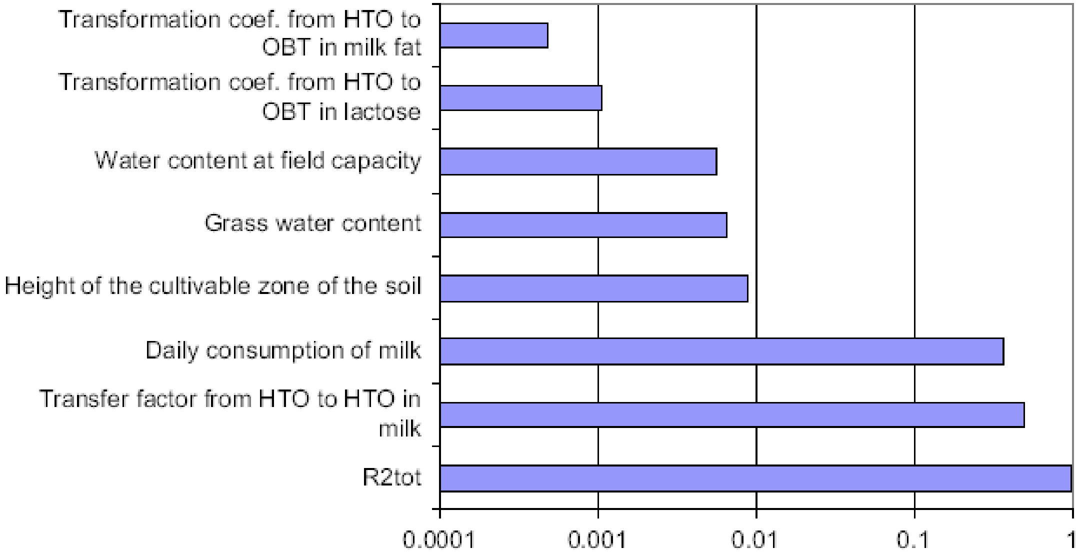


Output	Fifth percentile	95th percentile	Ratio 95th percentile/fifth percentile
Dose – ingestion of milk	9.9×10^{-9}	4.1×10^{-8}	4.1
Dose – ingestion of meat	1.3×10^{-9}	4.4×10^{-9}	3.4
Dose – ingestion of leaf vegetables	8×10^{-10}	2.7×10^{-9}	3.4
Dose – ingestion of fruit vegetables	6.6×10^{-9}	1.7×10^{-8}	2.6
Dose – ingestion of root vegetables	1.9×10^{-9}	8.8×10^{-9}	4.6

Source : Ciffroy ,Siclet et al , 2006, *Journal of Environmental Radioactivity*

Sensitivity analysis for ingestion of milk and ingestion of root vegetables

- Dose due to ingestion of milk – sensitivity index



Source : Ciffroy ,Siclet et al , 2006, *Journal of Environmental Radioactivity*

- Dose due to ingestion of root vegetables – sensitivity index