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Olivier Radakovitch, Adrien Delaval, Céline Duffa, P. Boyer, Léonore Flipo, et al.. 137 CS Desorption within an estuary: modelling and experiments. International Estuarine Biogeochemistry symposium, Rutgers Boskovic Institute, May 2023, Sibenik, Croatia. hal-04139316

HAL Id: hal-04139316

<https://hal.science/hal-04139316>

Submitted on 23 Jun 2023

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^{137}Cs DESORPTION WITHIN AN ESTUARY: MODELLING AND EXPERIMENTS

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ADICT solutions, France





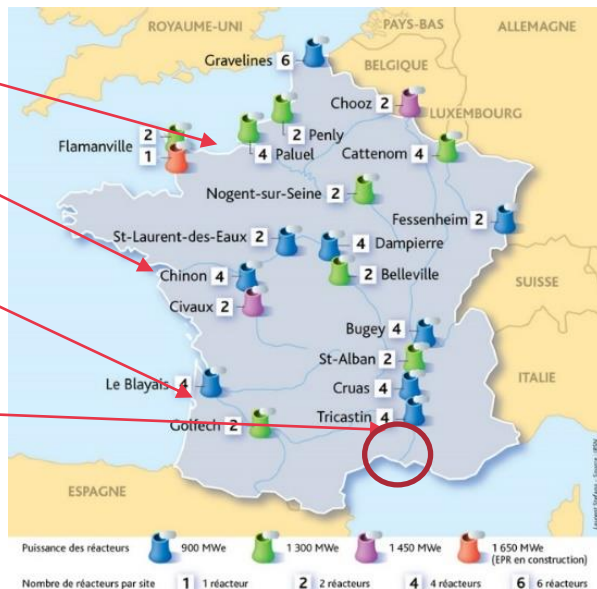
Estuaries are hot spot areas for the transfer of radionuclides

Seine 380 m³/s

Loire 825 m³/s

Garonne 545 m³/s

Rhône, 1700 m³/s



- 13 nuclear plants installed in France along four rivers.
- Scenario of accidental releases of radionuclides must take into account the coastal areas.
- Estuaries are hot spot areas where specific physico-chemical processes (**particles cycle, salinity changes, desorption...**) may change speciation and fluxes.
- They must be correctly simulated to predict the fluxes transferred to the sea and potential impact on the ecosystems.

¹³⁷Cs

Emitted in most accidental scenarios

Half-life: 30 years

Gamma emitter → internal and external irradiation

Bioaccumulation within the trophic chain

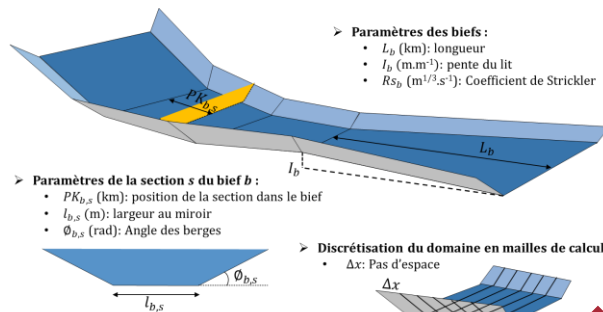


IRSN Numerical models for radionuclide transfers in aquatic systems

CASTEAUR: 1D numerical model for radionuclides transfer in rivers

Inputs:

- Hydrographic parameters
- Chronics of :
 - water and suspended particles
 - Radionuclides releases (various inputs)
 - Sediments and radionuclides properties



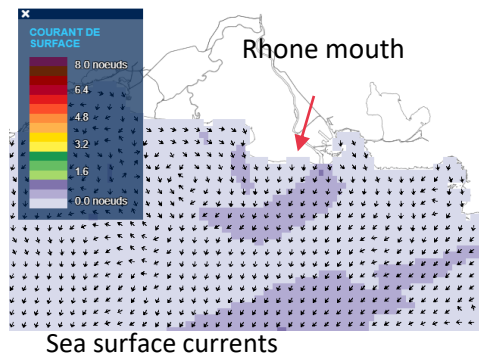
Outputs:

- Water flow, water height, ...
- Suspended particulate matter content and sediment deposition.
- Dissolved and particulate Radionuclides concentrations and fluxes in water column and sediments**

STERNE: 3D numerical model for radionuclides dispersion in the ocean

Inputs:

- Hydrodynamic data from oceanographic model (SHOM)
- Chronics of :
 - Radionuclides by direct releases or atmospheric deposition
 - Chemical and radioecological parameters (FC, Tp, Tb_{1/2}...)



Outputs:

Radionuclides concentrations in water , particles and biota



Model need for the different estuaries (well mixed to salt-wedge)



DRACAR : Désorption des RAdionuCléides à l'interfAce littoRale

DRACAR

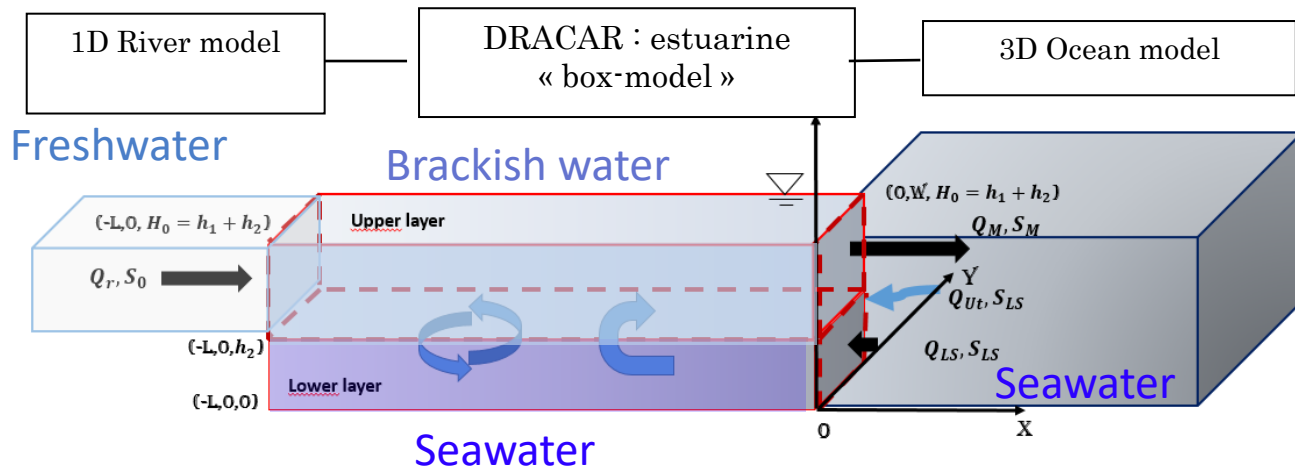
Based on

Physical outputs

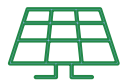
Box-model for freshwater-seawater mixing within estuary and structure of water masses.

- Solving salt, volume and potential energy budgets.
- Knudsen's theorem.

- Physical structure of the water masses
- Water residence time in the estuary
- 2D salinity
- Water and salinity fluxes at sea



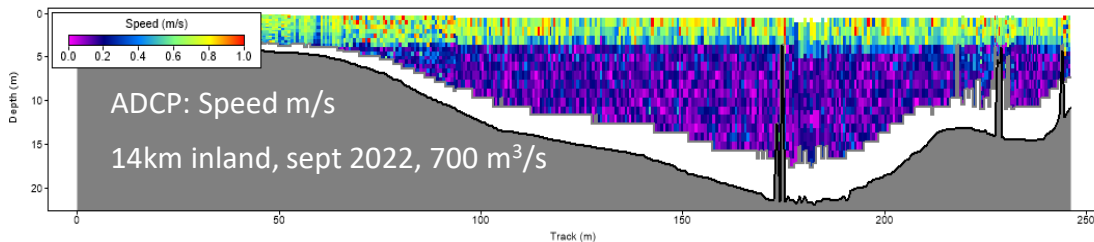
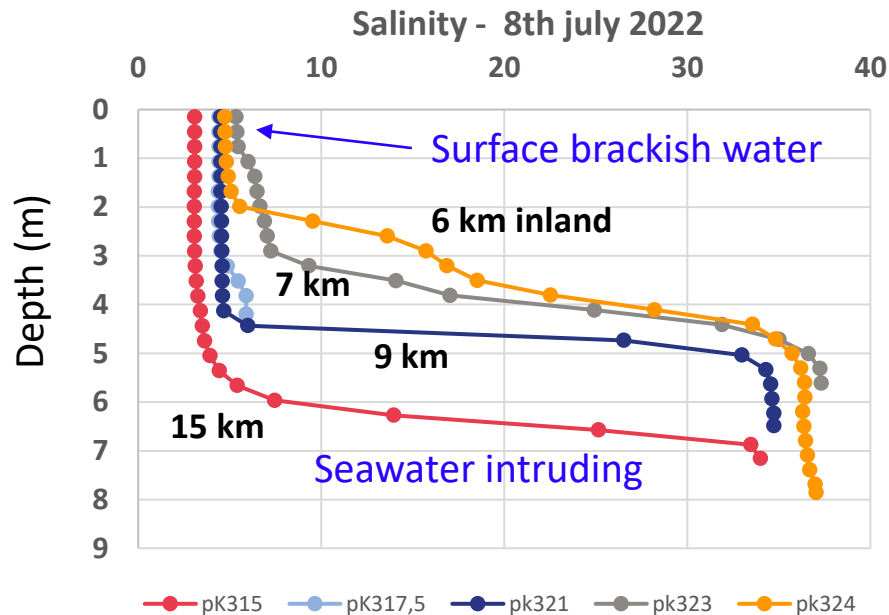
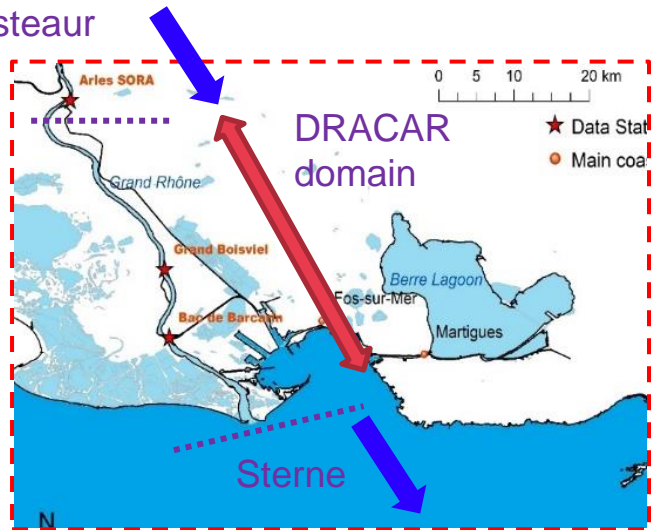
Delaval et al 2022



The Rhone Salt-wedge estuary

Below $1500 \text{ m}^3/\text{s}$, a salt-wedge intrudes up to 30 km, in relation with water discharge.

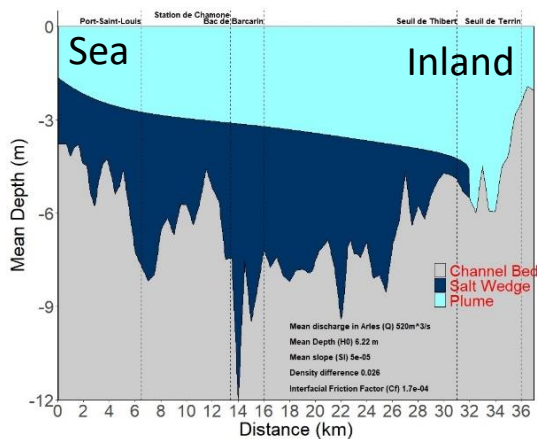
Casteaur





DRACAR simulation

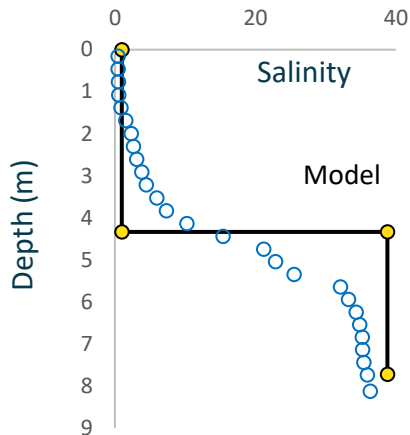
Salt-wedge structure



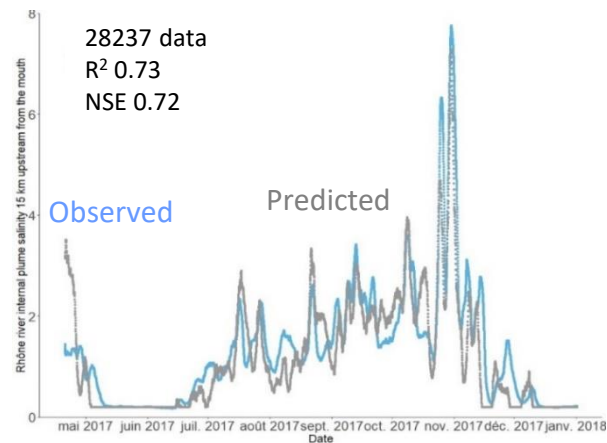
- ✓ More realistic value for river flux to the sea.
- ✓ Flushing time for particles between 0 and 37 g/L.



Salinity profile - 8 km inland

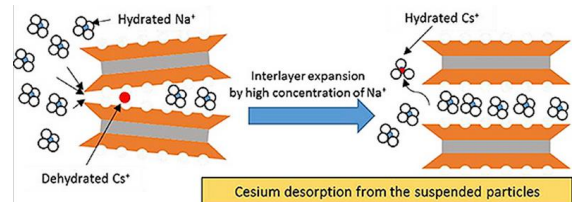


Surface salinity - 15km inland



Integration of desorption process

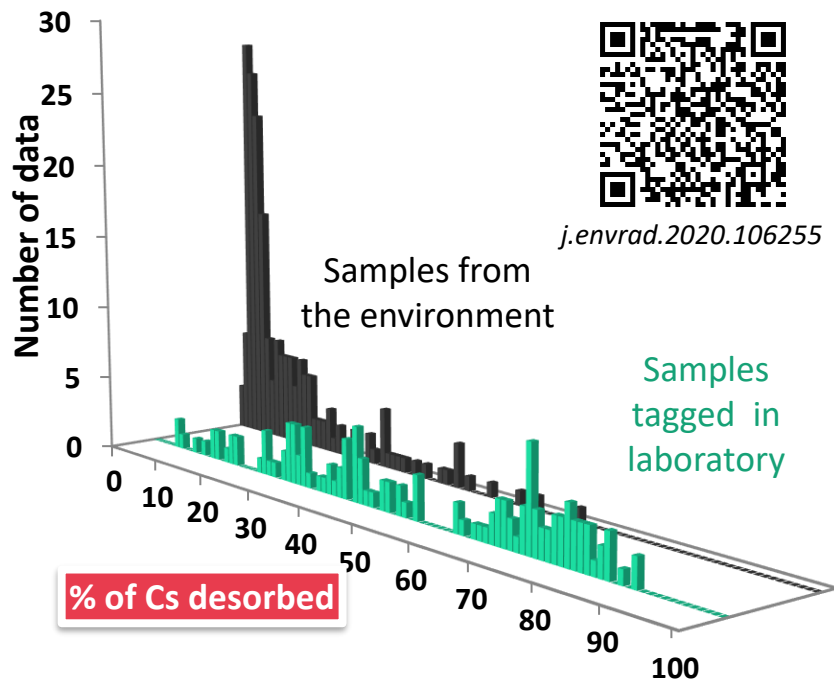
Intensity of particulate ^{137}Cs desorption due to the exchange with dissolved seawater cations (K^+ , Na^+)





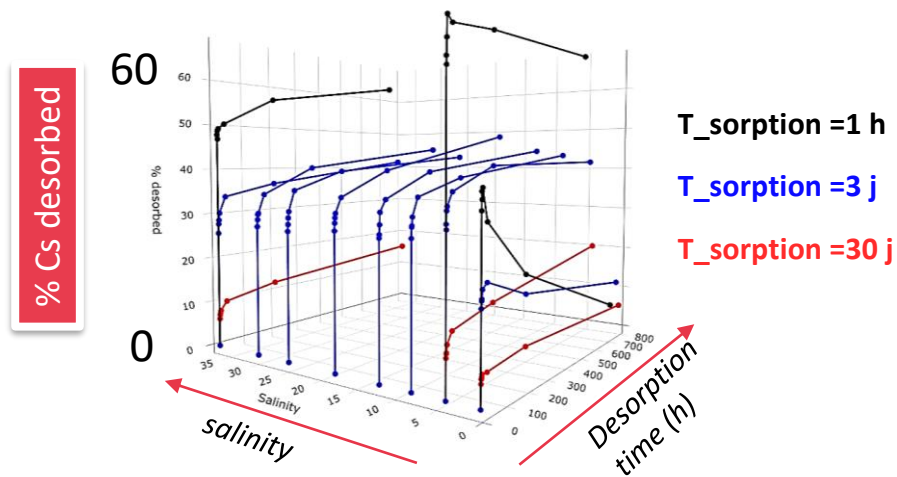
Desorption of ^{137}Cs at the fresh-seawater interface

Compilation of 32 studies from 1963 to 2017

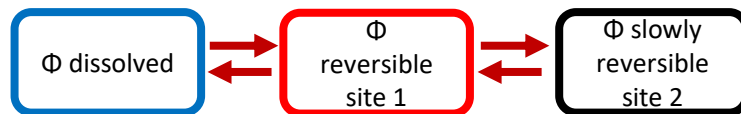


- No clear trend with salinity
- Existence of an « ageing » effect

Desorption in laboratory to test the influence of salinity and ageing effects



- Desorption initiates at 0,2-4 g/L salt
- Ageing effect influences desorption
- A two kinetics model simulates well the process








Simulation of Cs flux (Bq/s) along the continuum

Release of dissolved ^{137}Cs

Rhône flood

$Q = 2300 \text{ m}^3/\text{s}$
 $\text{SPM} = 1 \text{ g/L}$



Dissolved 
Reversible site 
Slowly reversible 

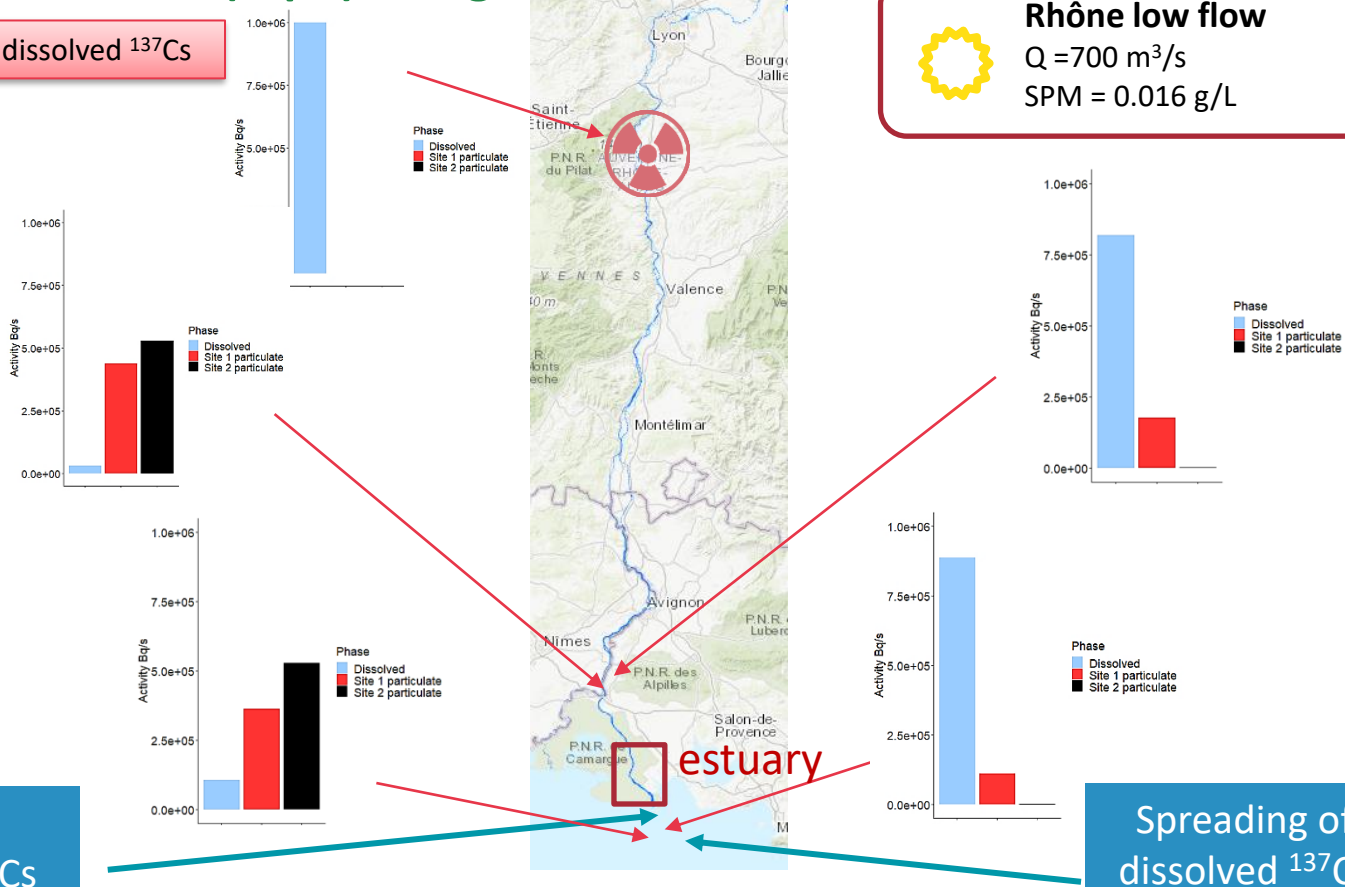
Settling of
particulate ^{137}Cs

Rhône low flow

$Q = 700 \text{ m}^3/\text{s}$
 $\text{SPM} = 0.016 \text{ g/L}$



Spreading of
dissolved ^{137}Cs

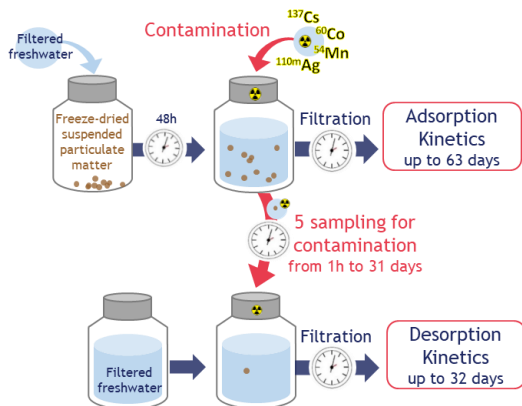
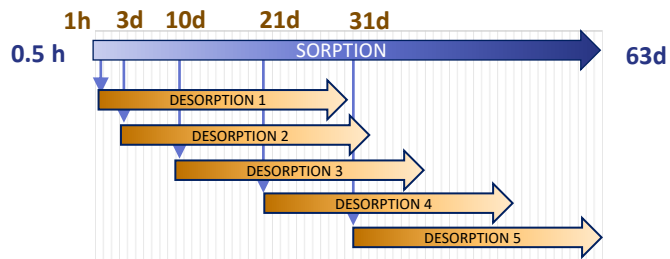




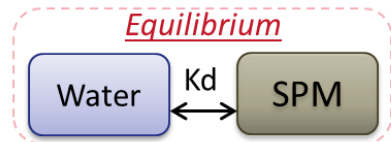
Adsorption-desorption experiments for Cs, Co, Mn and Ag

- ^{137}Cs $^{110\text{m}}\text{Ag}$ ^{60}Co ^{54}Mn onto Rhone suspended particulate matter
- Desorption after 30 min to 2 months**

- Define which sorption-desorption model is most suited to described changes in the river continuum (transit time, chemical changes...)



dataset



Equilibrium and kinetic



Two kinetics

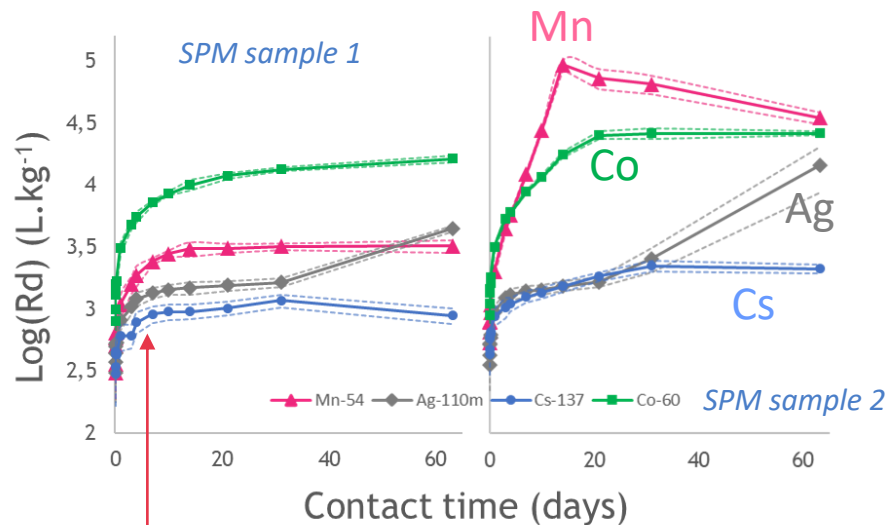


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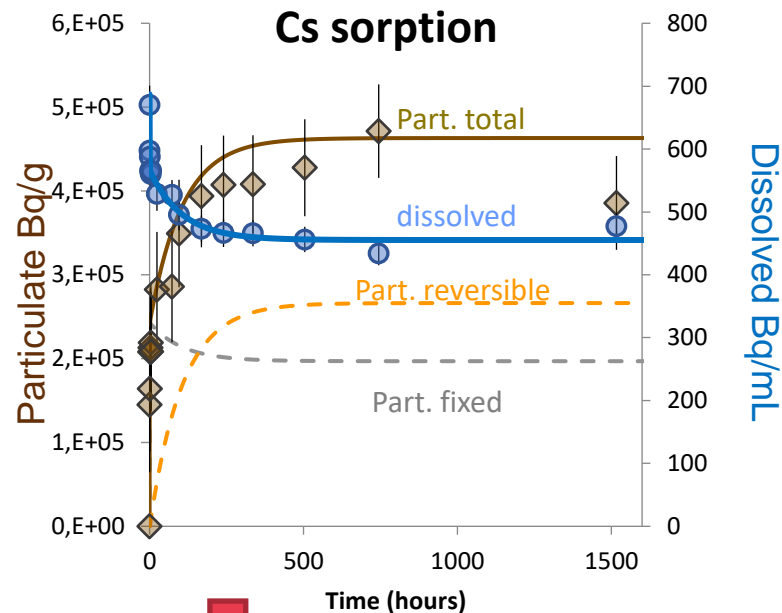


First results of the experiment

Solid/dissolved activities



Transit time in the Rhone from nuclear plant locations to the sea is less than 6 days.



Conclusions

- The hydrodynamic of the water masses are well represented for a salt-wedge estuary, as well as water and salt budgets.
- The desorption of ^{137}Cs occurs very quickly (2 g/L) in brackishwater
- The duration of adsorption have an influence on the ^{137}Cs desorption, still difficult to constrain.
- Geochemical models including sorption – desorption kinetics are more realistic, but parameters are difficult to acquire.