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Faire avancer la sûreté nucléaire

Evidencing the role of plants vs soils in the understanding of ^{137}Cs phyto-availability using a coupled experimental and modelling approach

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Région
PACA

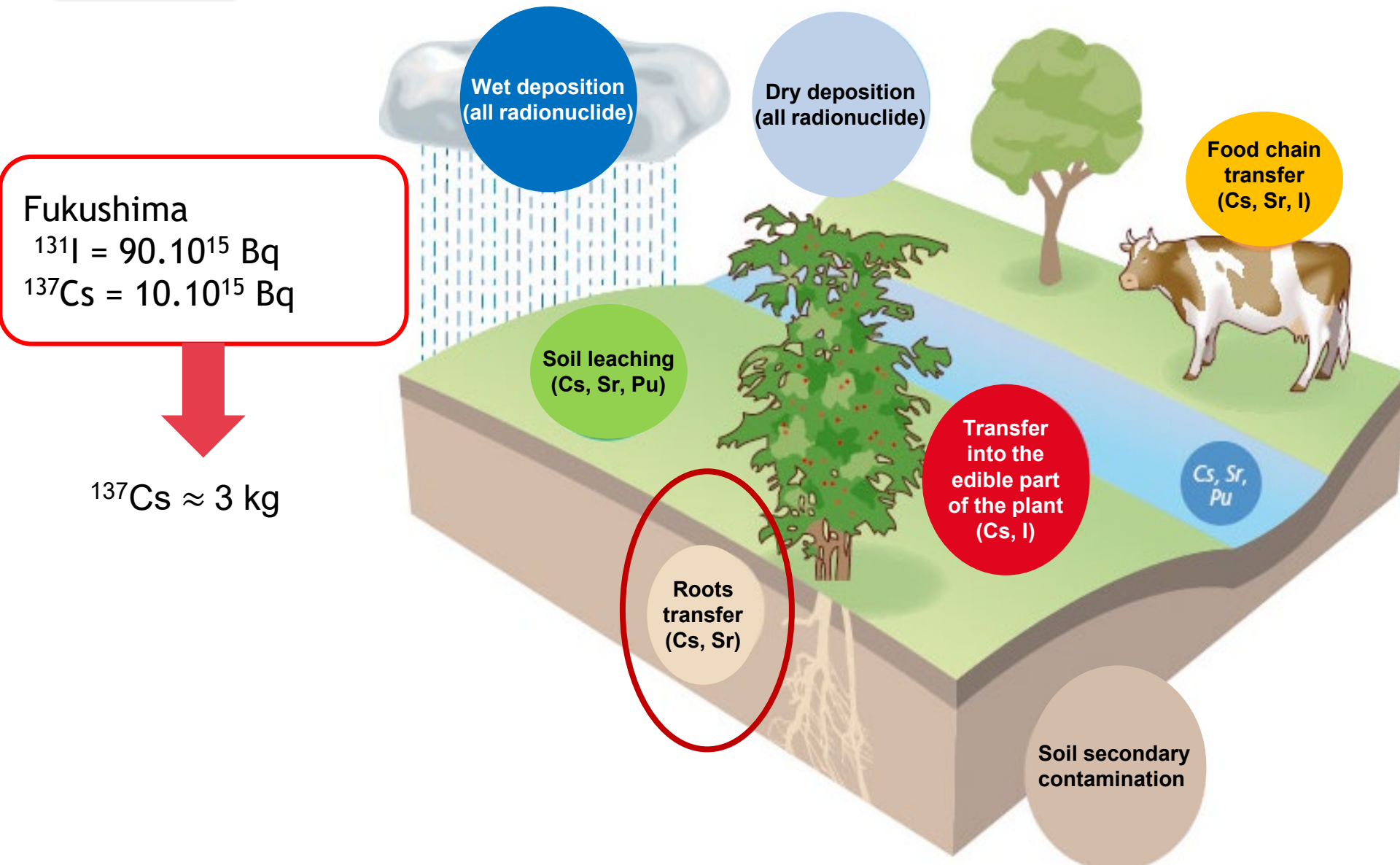


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MEMBRE DE

ETSON

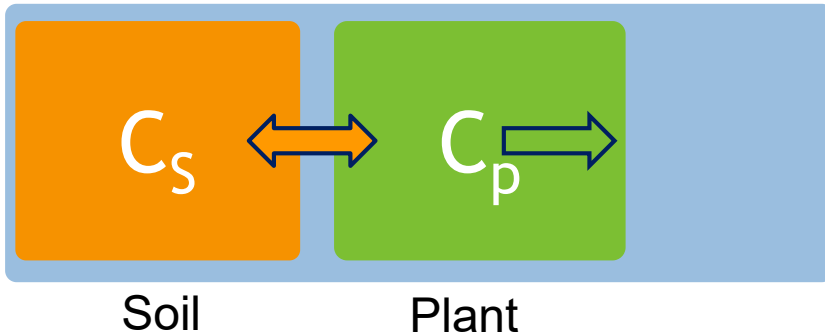
EUROPEAN
TECHNICAL SAFETY
ORGANISATIONS
NETWORK



(Transfert des principaux radionucléides dans les différents compartiments de l'environnement, <http://www.irsn.fr>)

Transfer factor model

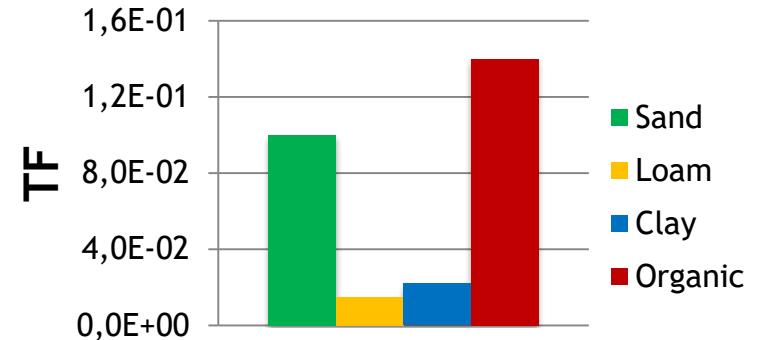
$$TF * C_s = C_p$$



Transfer factor limits

- Variability depending on the type of soil

Maize TF parameter



AIEA, 2009 – Tecdoc 1616

- Plant absorption of cesium is a linear function of soil concentration.
- All cesium in soil is considered available

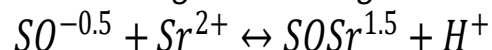
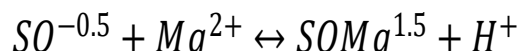
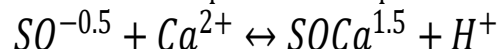
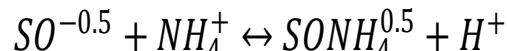
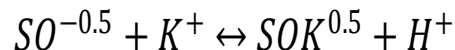
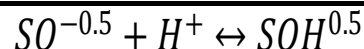
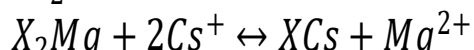
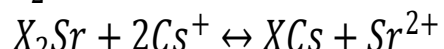
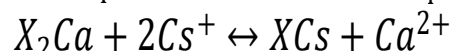
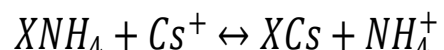
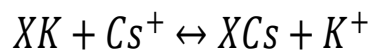
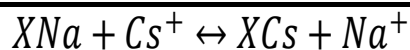
To Improve the modeling of cesium availability into the soil/solution/plant continuum

→ Operational for a large variety of soil and plant

Soil-Solution model

Solution-Plant model

Physio-chemical characteristics

Site capacity $\equiv X$ (meq/Kg)Site density $\equiv SOH$ (sites/nm²)Surface specific area (m²/g)Surface complexation reaction on $\equiv SOH$ sitesCation exchange reaction on $\equiv X$ - sites

Illite

225

 $2.7 \cdot 10^{-3}$

97

3.46

5.2

-1.8

0.6

1.5

-5

-5

-5

Montmorillonite

870

 $3.6 \cdot 10^{-5}$

800

3.4

4.3

-1.3

0.1

-1.4

-1.4

-1.4

-1.4

Kaolinite

20

 $1.5 \cdot 10^{-4}$

10

5

3

-3.6

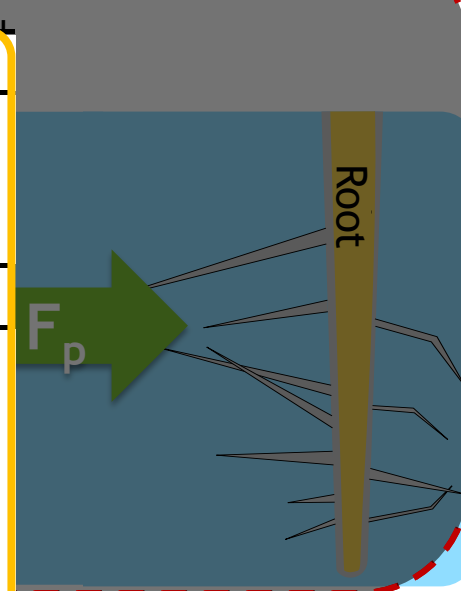
-1.75

-1.75

-5.9

-5.9

-5.9

LogK_{sc}LogK_c

$$F_p = \frac{F_{max} * C_w}{K_m + C_w}$$

plant flux $\rightarrow F_p$ (mol/g/d) $C_w < 1\text{mM}$

$F_{max} = F_{max1}$

$K_m = K_{m1}$

 $C_w > 1\text{mM}$

$F_{max} = F_{max2}$

$K_m = K_{m2}$

Material & Method

3 contrasted soils :

Soil	pH	CEC (meq/kg)	Organic carbon (g/kg)	Illite (g/kg)	Montmorillonite (g/kg)	Kaolinite (g/kg)
E	7,5	98,9	11,17	66,05	49,78	20,30
H	5,5	76,4	28,5	144,77	42,40	76,4
S	9,12	11,1	0,18	5,93	153,9	41,55

2 Plants :

- **Millet** → low absorption capacity
- **Mustard** → High absorption capacity

- 3 soils vs 2 plants = 6 experimentations

- ↪ RHIZOtest

- 6 sampling time,

- ↪ 3 RHIZOtest_plants

- ↪ 3 RHIZOtest_soils

Sequential batch desorption → ^{137}Cs environmental availability

RHIZOtest :

- Soil under total roots influence

- Low K nutrient solution

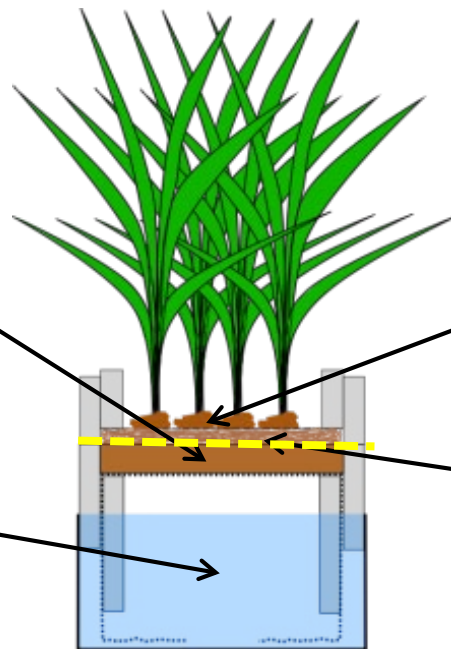
- ↪ Roots absorption → MAX

- No soil particles contamination onto the roots

^{137}Cs

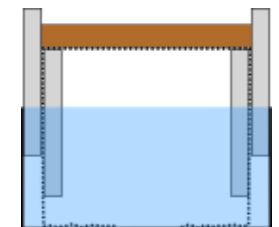
Contaminated soil

Low K nutrient solution



Root mat

Permeable grid



0h

48h

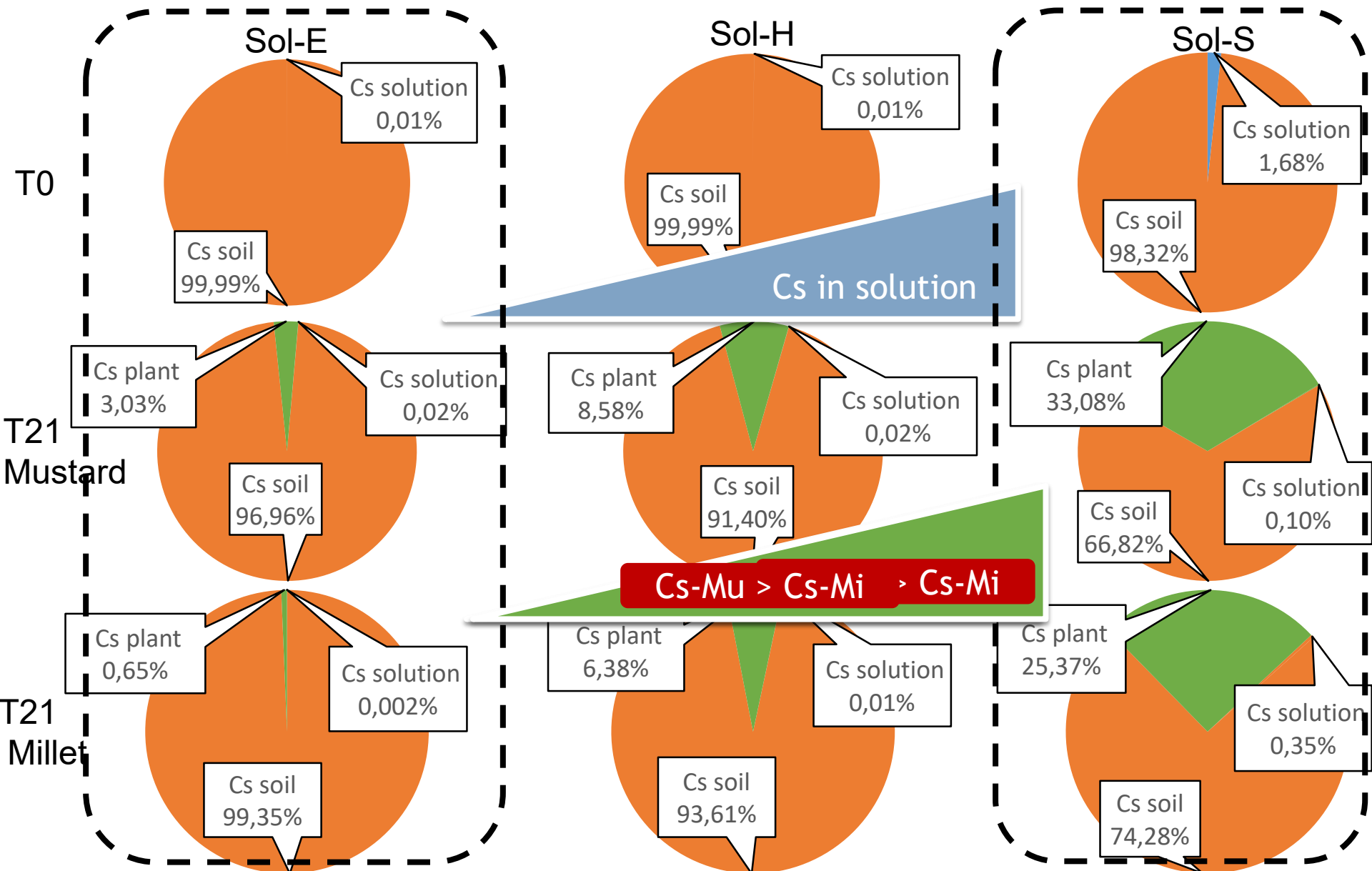
96h

7d

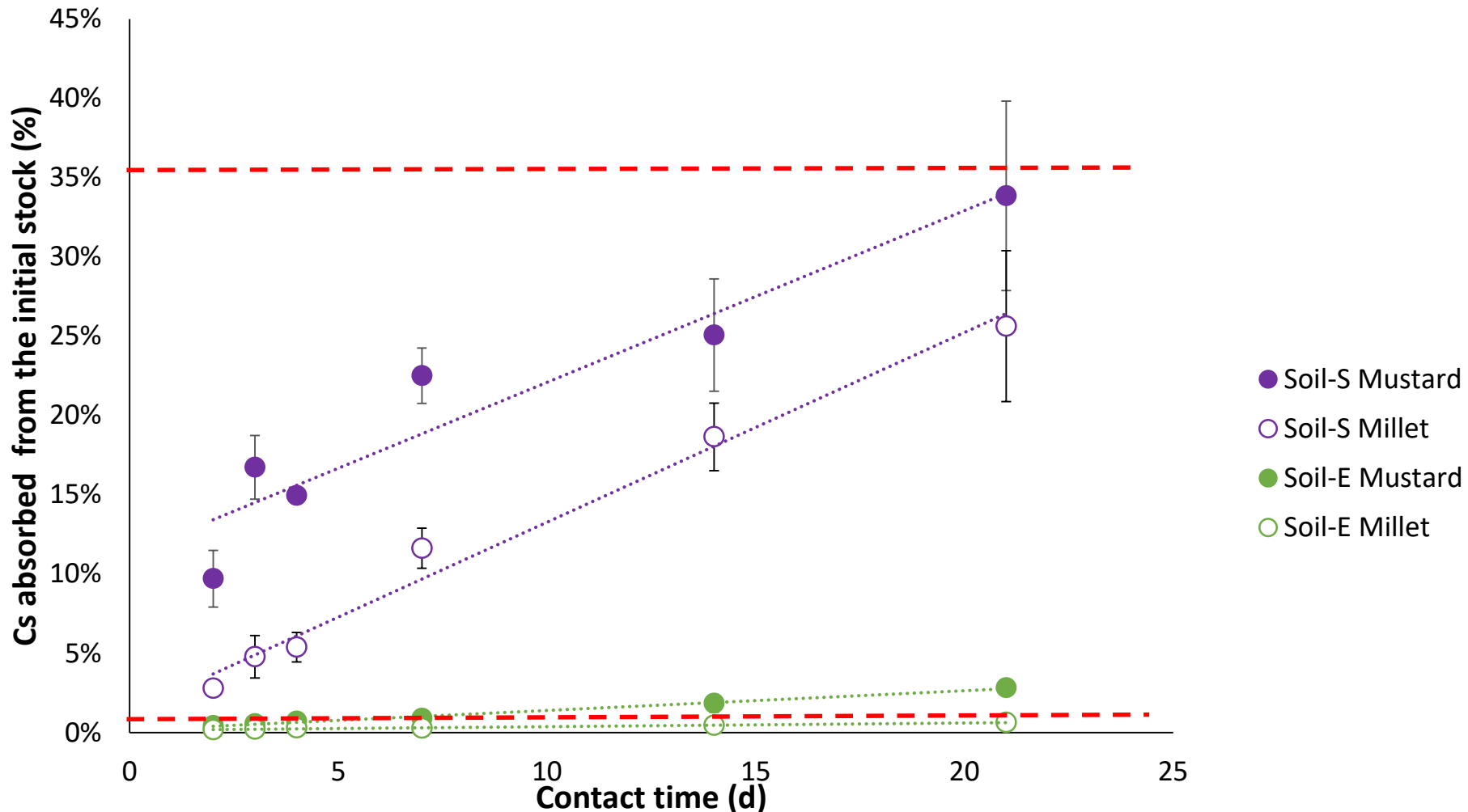
14d

21d

Soil Solution Plant Continuum



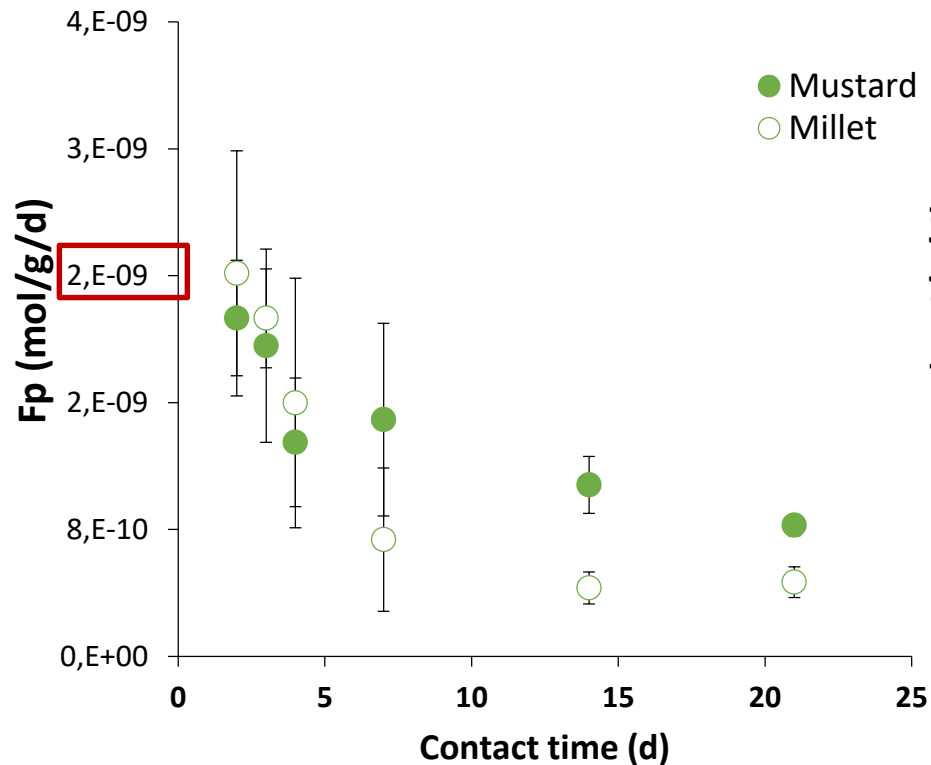
Plant Compartment



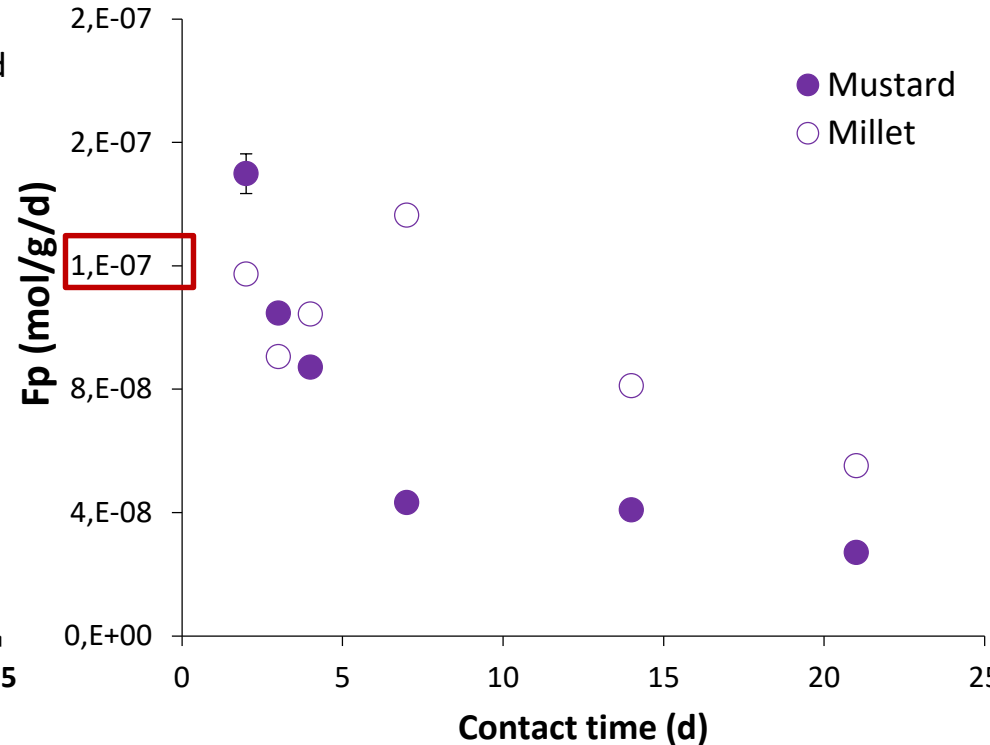
Linear adsorption, no plateau:

- Available Cs stock have not been depleted
- Plant maximal absorption capacity have not been reached

Soil-E



Soil-S



○ Same flux (Fp) for each plant on the same soil

○ $F_p(\text{Soil-S}) = 100 \times F_p(\text{Soil-E})$

↳ ^{137}Cs soil retention capacity is different for the two soils

↳ A good modeling of the soil-solution continuum is needed

■ Sol / Solution Modeling (PHREEQC)

○ Physico-chemical parameters

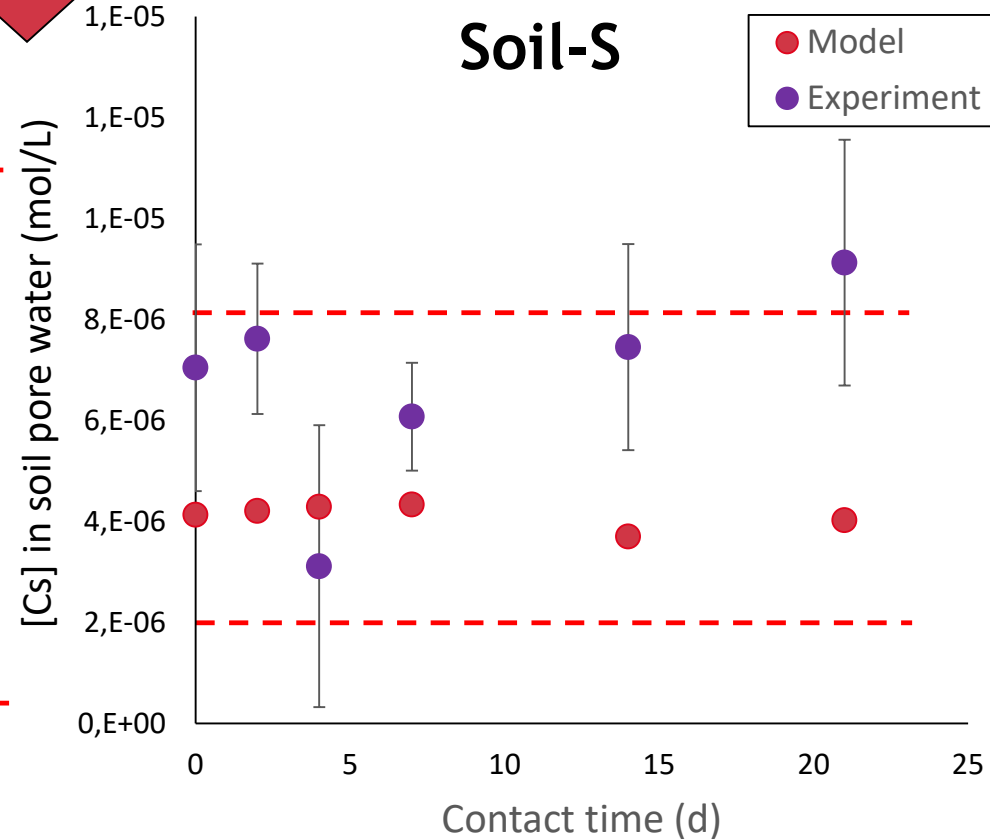
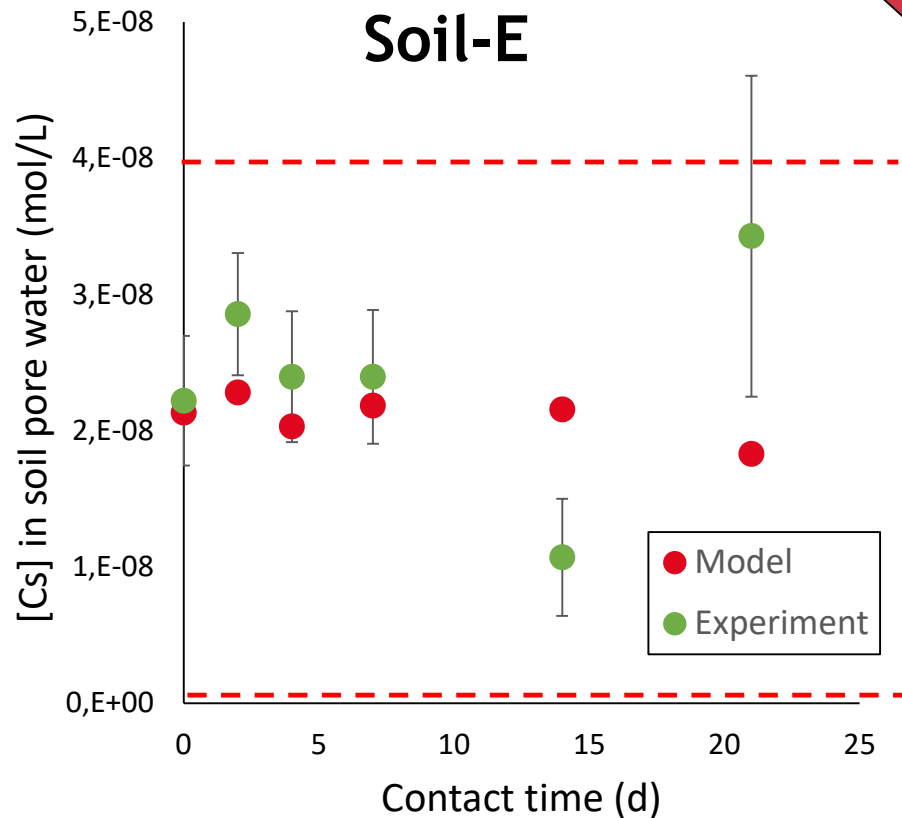
↪ Mineralogical clay contents

↪ M/V ratio into the RHIZOtest

↪ Solution composition ([mol/L], pH)

○ Hydrodynamic parameters

↪ Evaporation (pore water renewal rate)



- Sol / Solution / Plant / Modeling (PHREEQC)

Conclusion & Perspective

- Contrasted experimental data
 - ^{137}Cs availability
 - Soils have stronger impact than plants on ^{137}Cs mobility in soil-solution-plant continuum
 - ↳ A good modeling of soil-solution ^{137}Cs distribution over time is needed

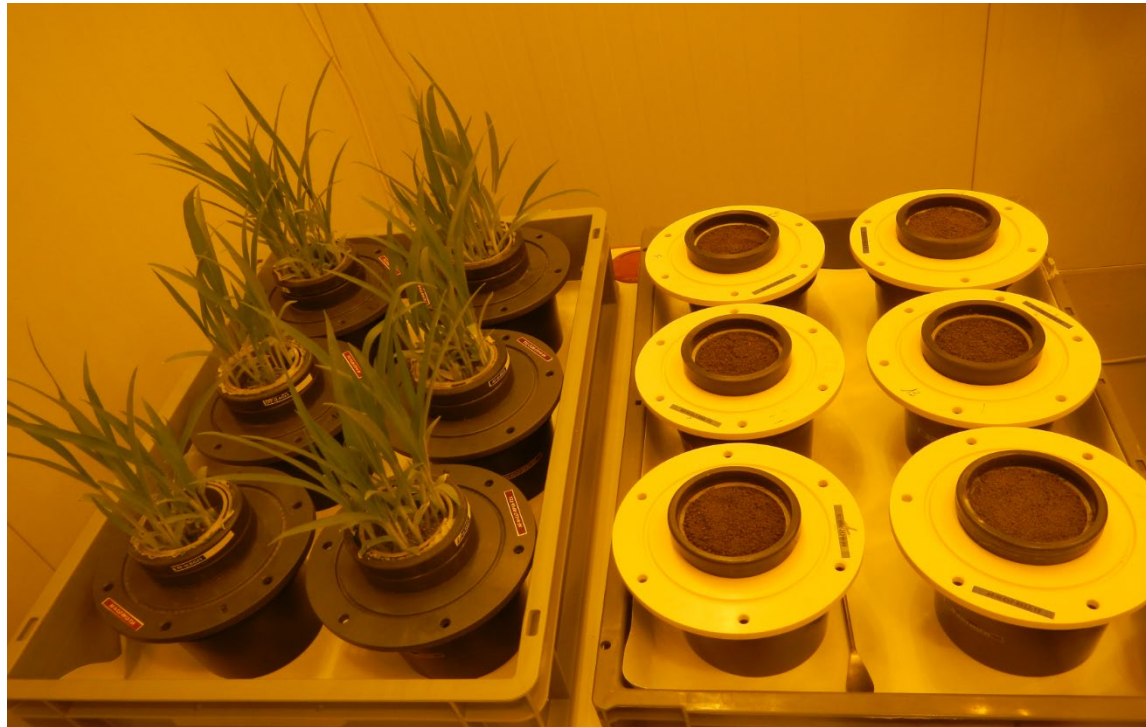
- Complementary data :
 - K and other major elements have been measured in soil, solution and plant

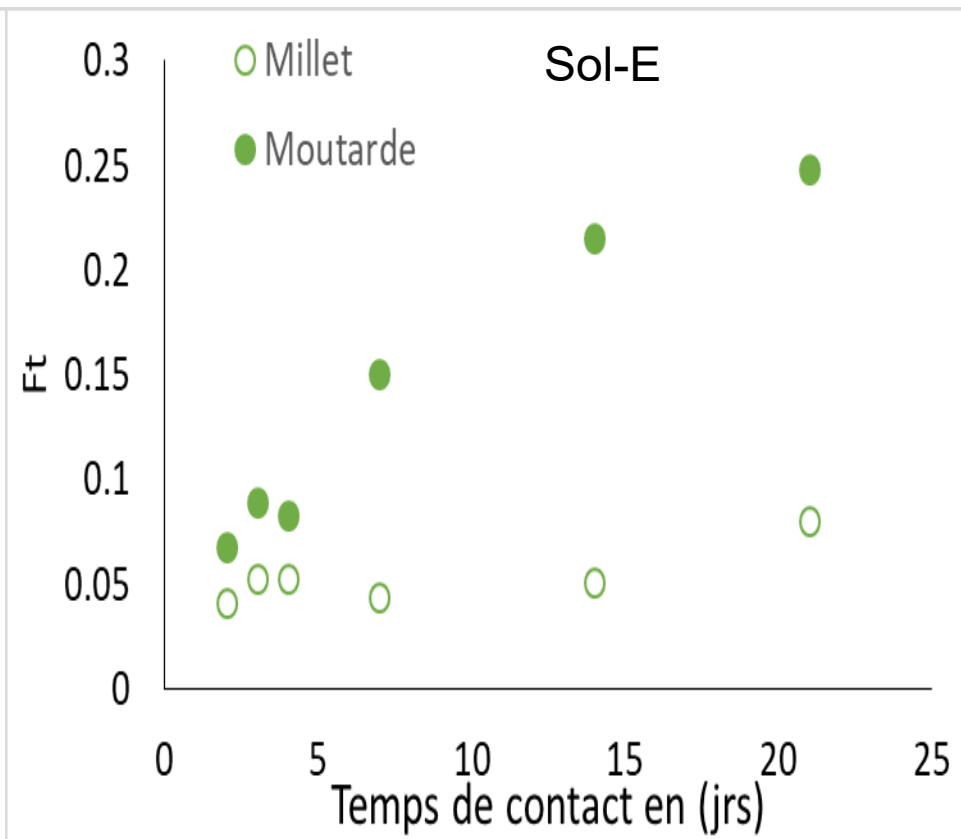
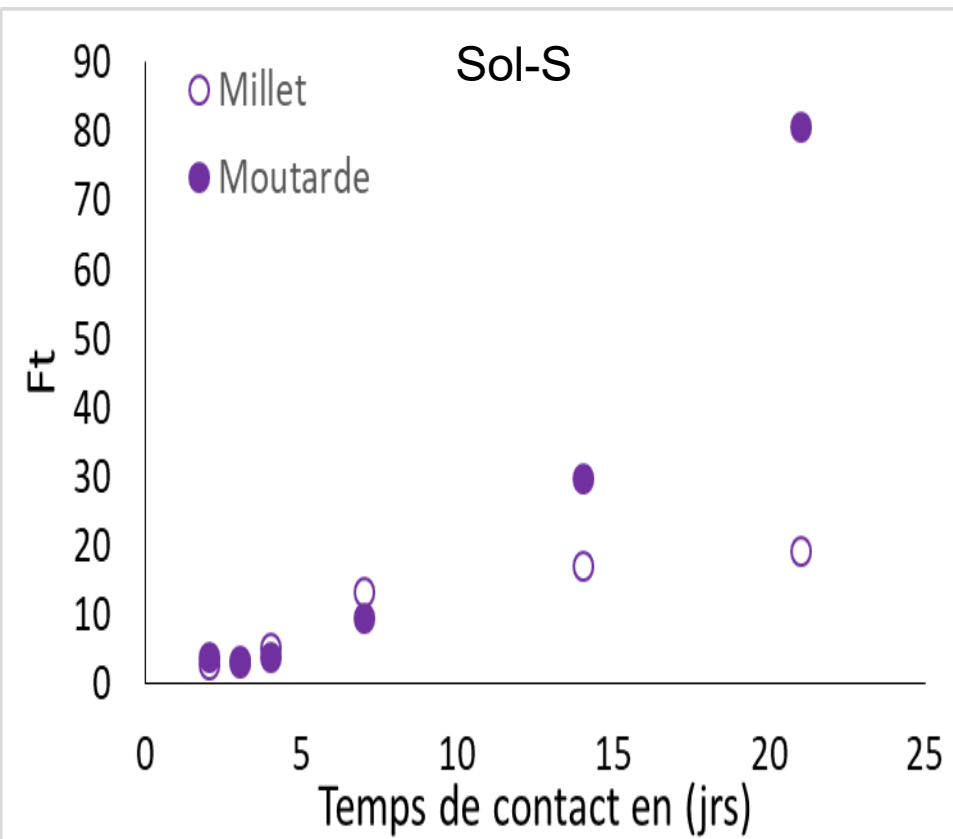
- Soil-solution modeling → Ok
- Soil-solution-plant modeling : ongoing
 - ^{137}Cs translocation
- Model comparison (E-K model vs surface complexation model)

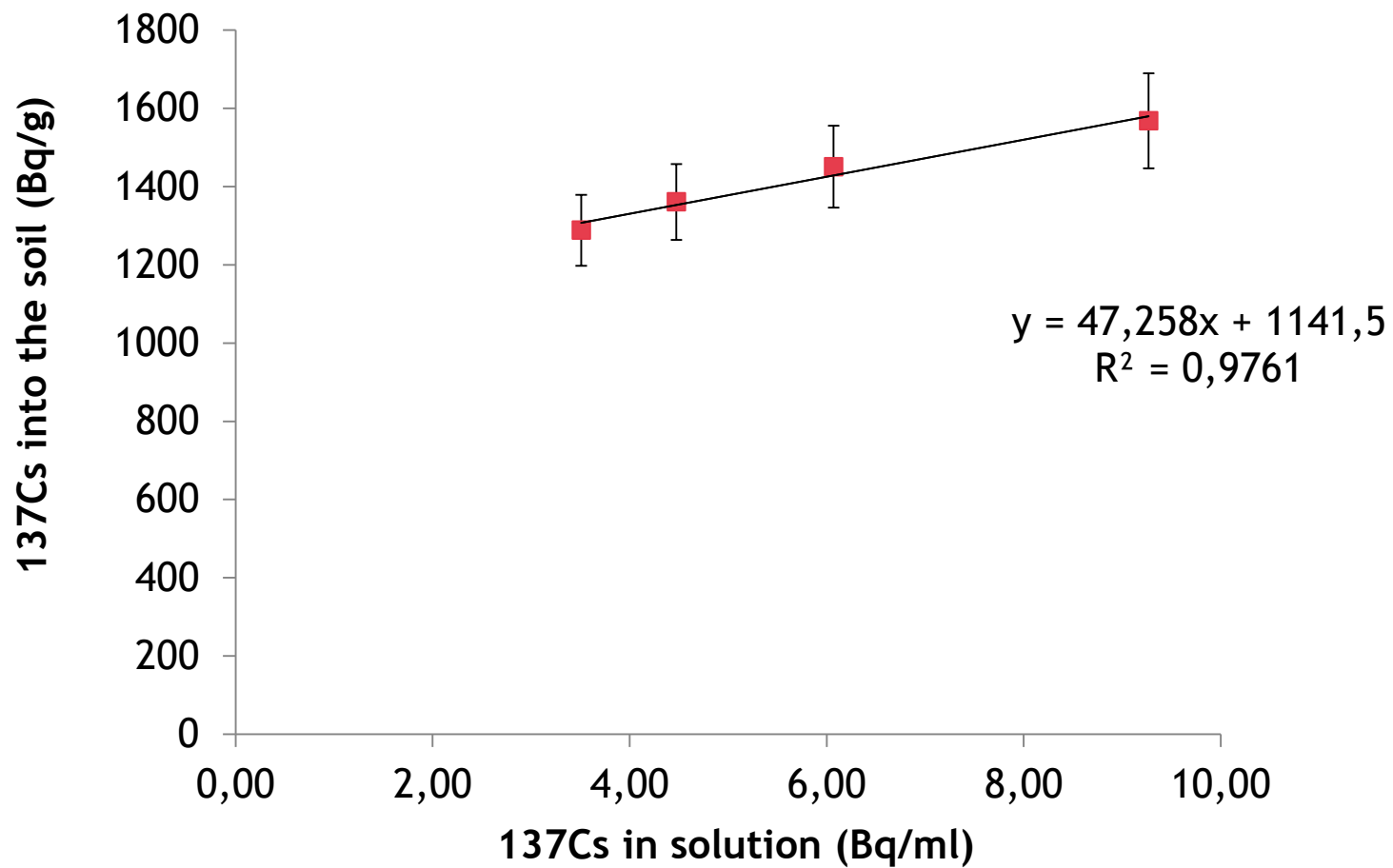
Thank you

Paper

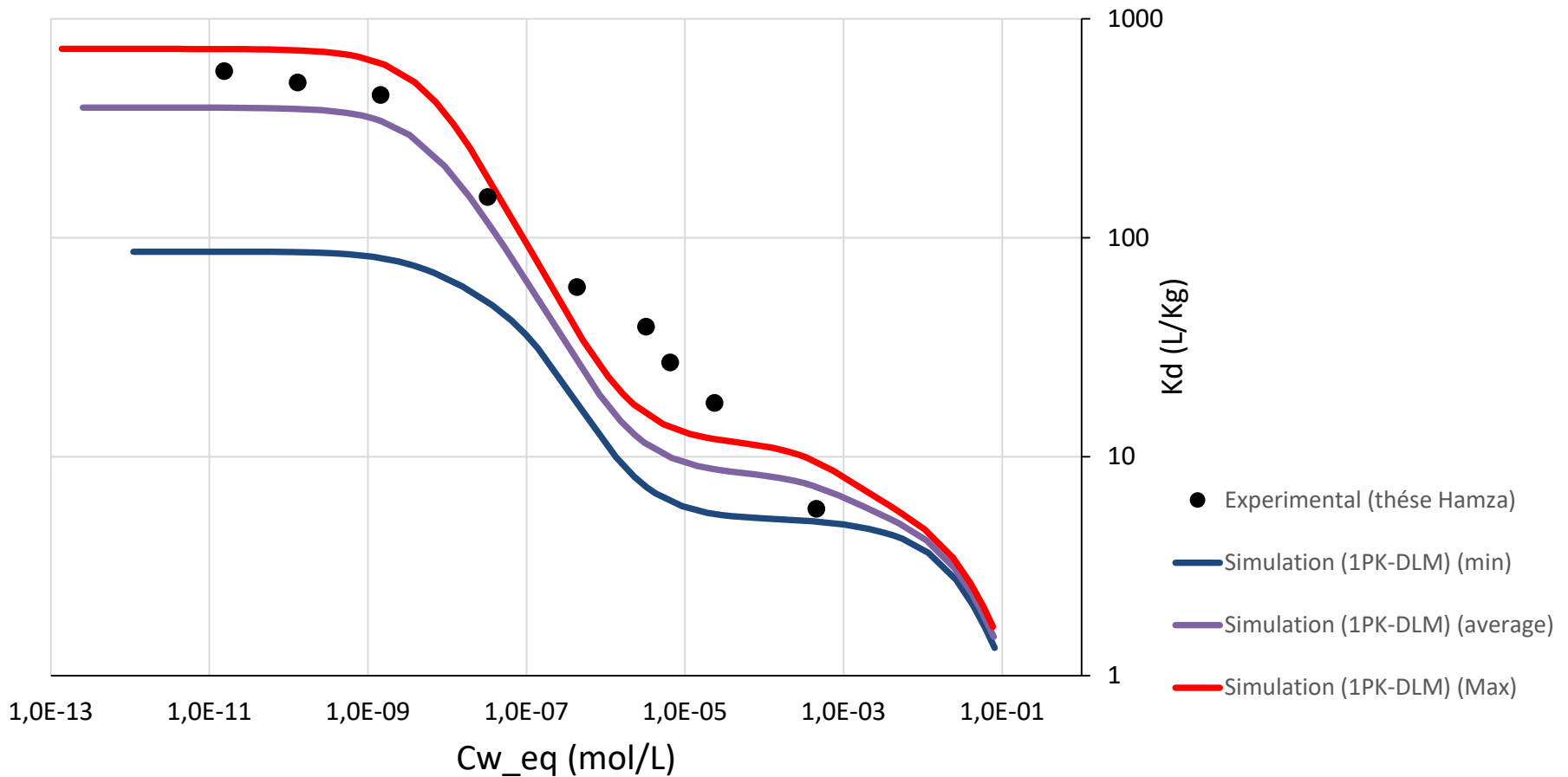
- Flouret A. et al., « Effect of soil and plant characteristics on ^{137}Cs transfer in contrasted RHIZOtest experiments », in prep

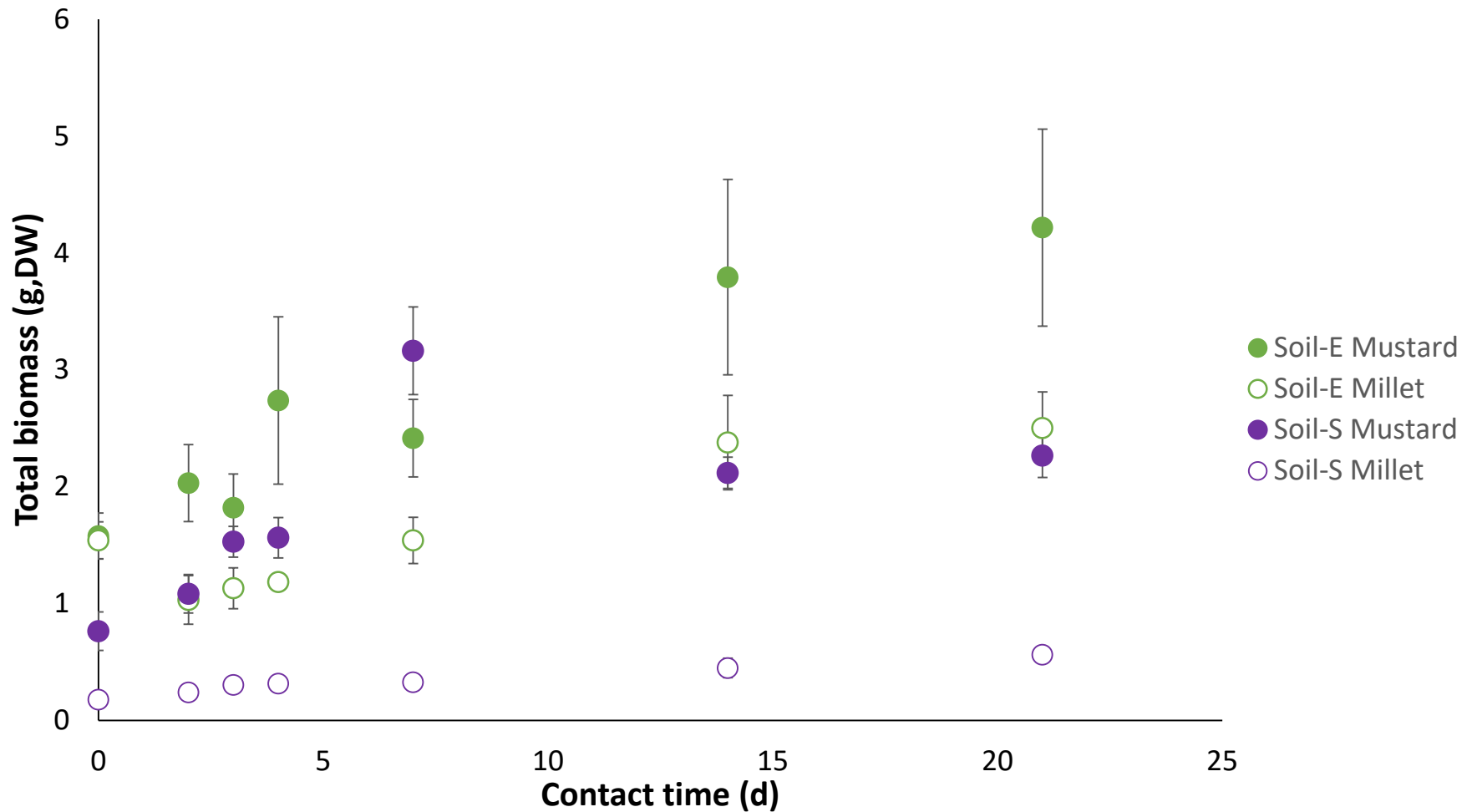




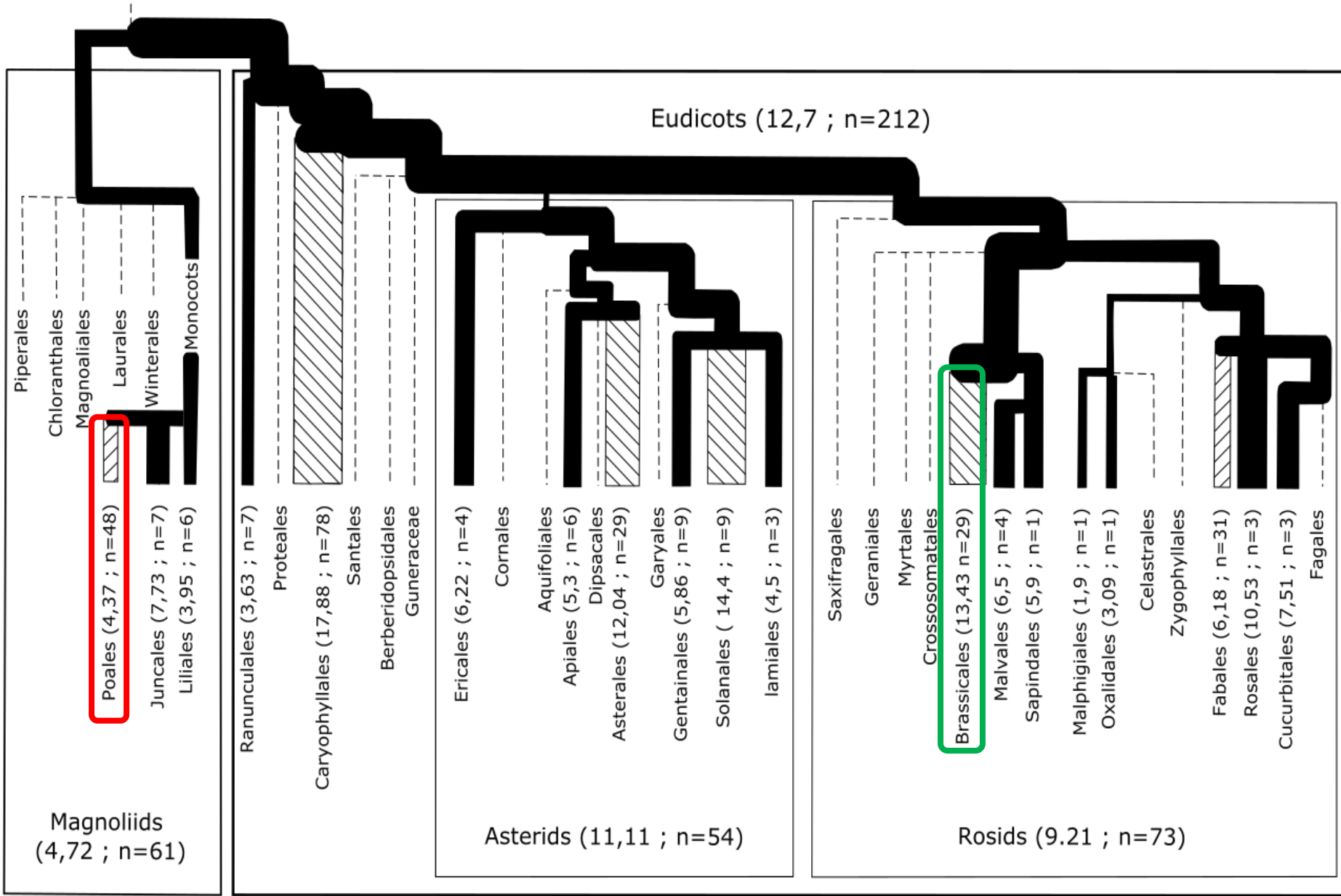


	Illite (%)		Montmorillonite (%)		Kaolinite (%)	
	0.01	2	23	27	4	9
Min (%)	0.01		23		4	
Average (%)	1.005		25		6.5	
Max (%)	2		27		9	

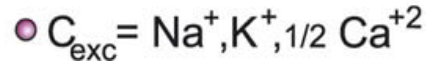




- Biomass are different for each type of plants
- Biomass are different for each type of soils for the same plant



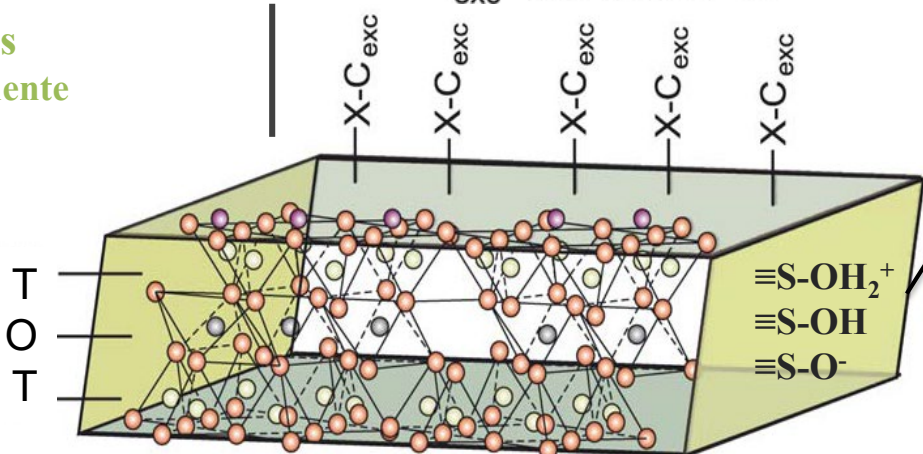
Illite et Smectites (Montmorillonite, bentonite)



Sites non spécifiques
à charge négative permanente



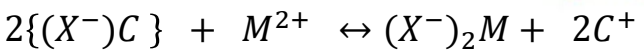
Modèle d'échange
d'ions



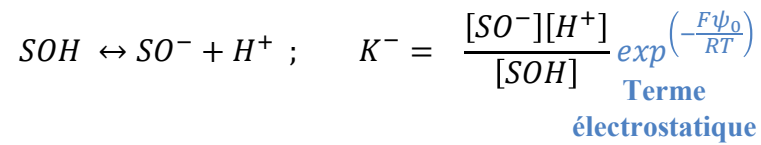
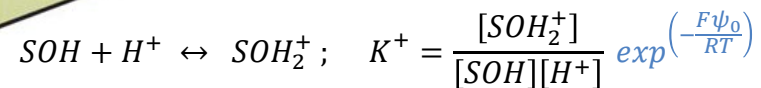
Sites spécifiques
à charge permanente

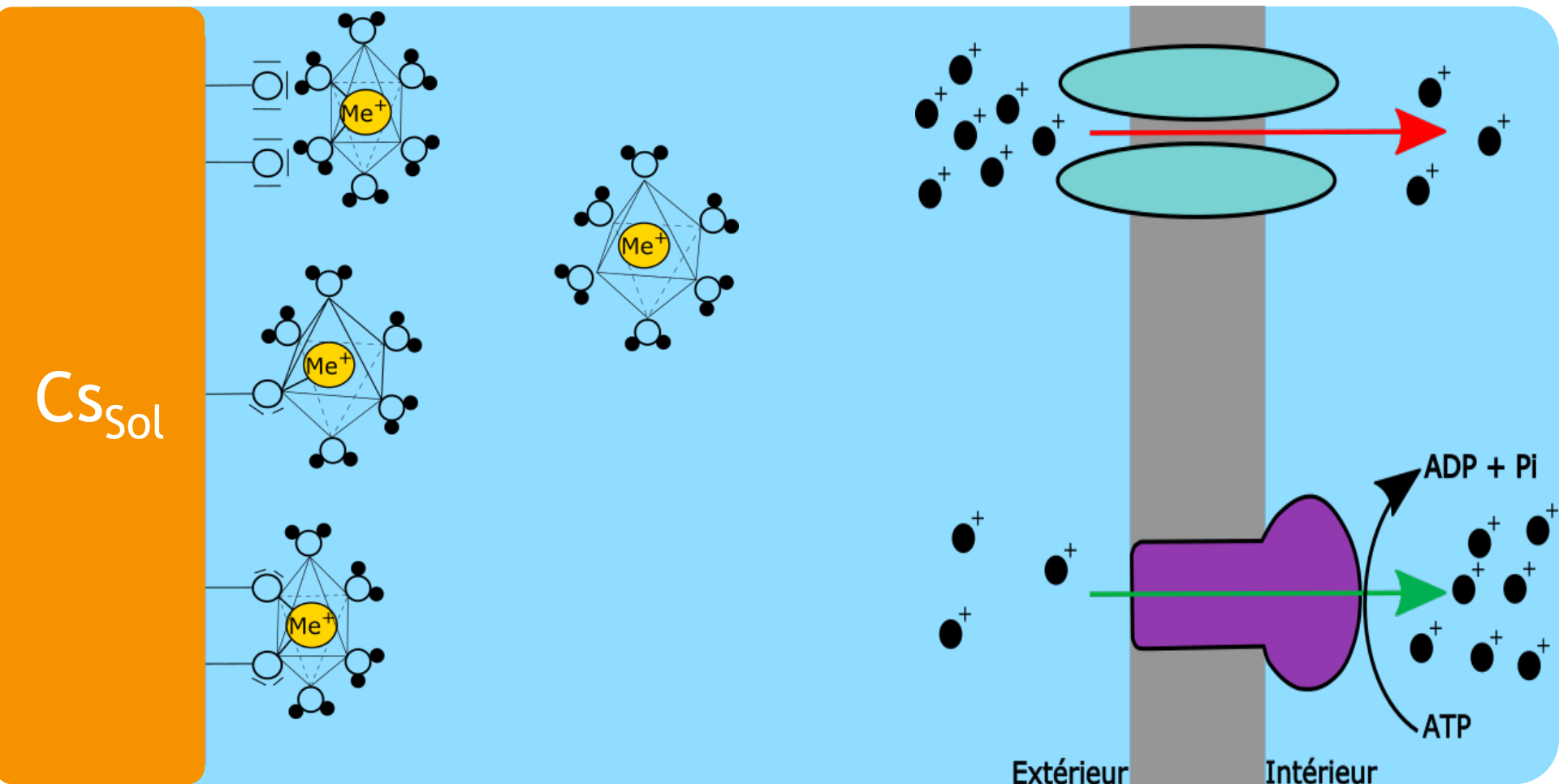


Modèles de complexation
de surface



$$K_c = \frac{[(X^-)_2M][C^+]^2}{[(X^-)C]^2[M^{2+}]}$$





Phase solide

Phase liquide

Racine