



ISIDRO ELVIRA, JULIA

Researcher

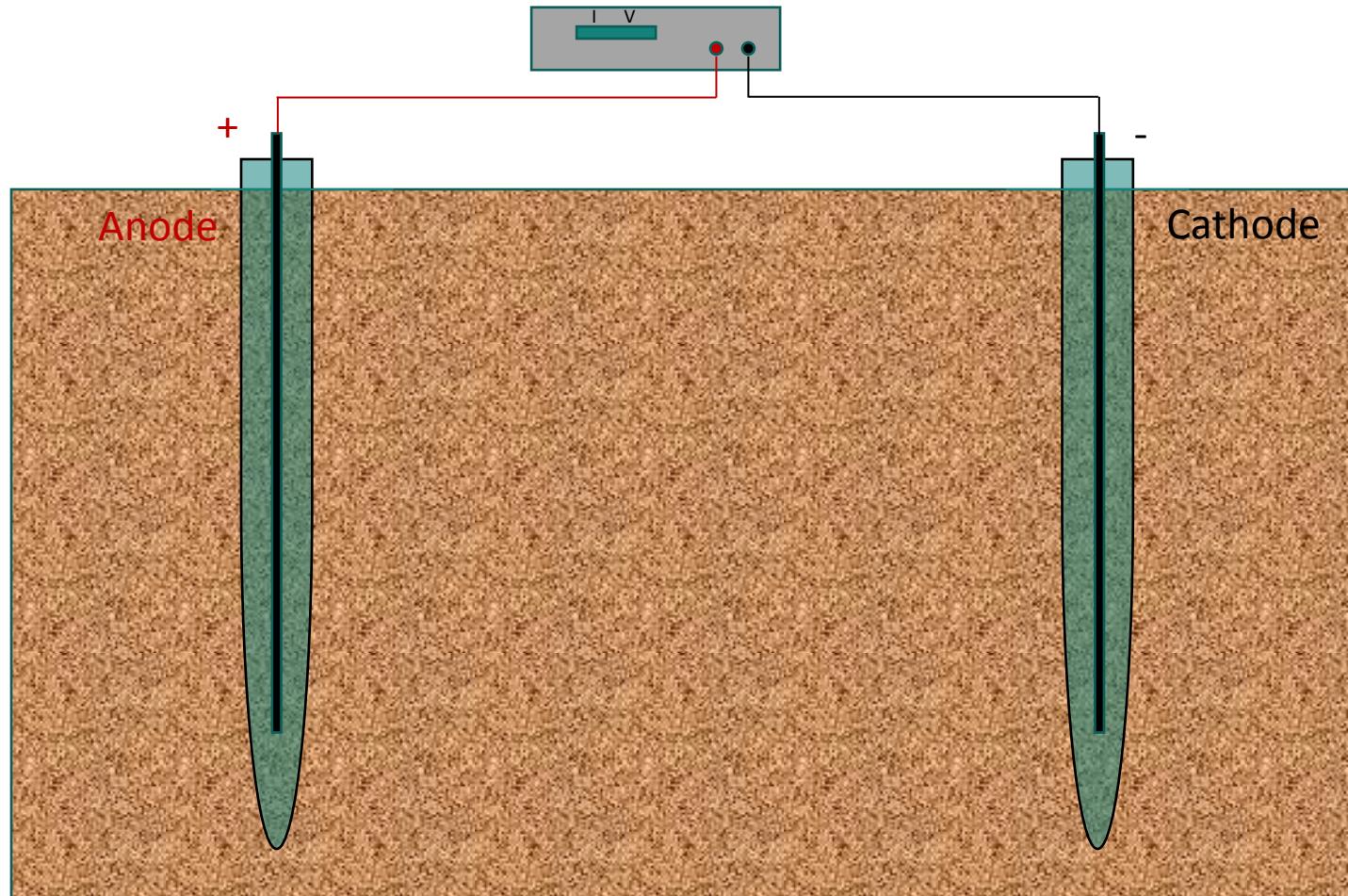


# DESIGN AND VALIDATION OF ELECTROKINETIC TECHNIQUES FOR THE REMEDIATION OF THE ALLUVIAL SILT OF THE SARDAS LANDFILL (SABIÑANIGO) CONTAMINATED WITH HCHS

**Isidro, J., Fernández-Cascán, J., Guadaño, J., Sáez, C., Rodrigo, M.A.**

## ***Soil Electrochemical Remediation***

Application of a low current ***electric field*** between pairs of electrodes positioned on the ***polluted soil***.



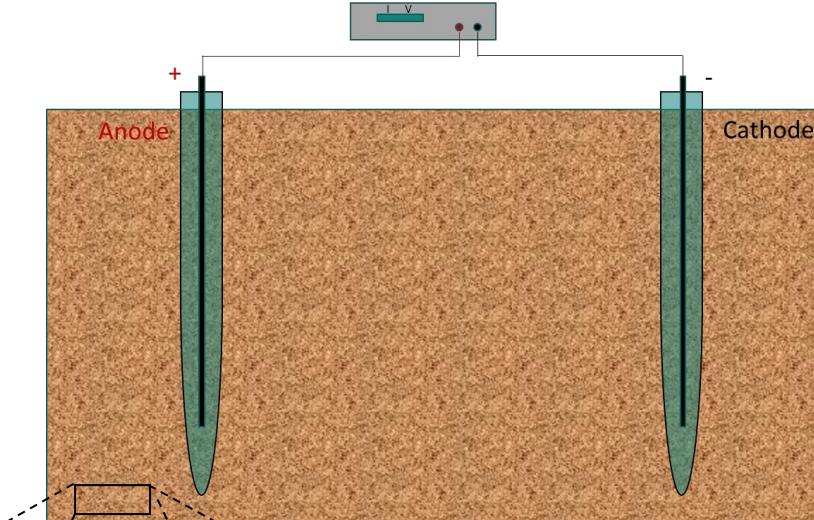
## **ELECTROKINETIC PROCESSES**

Includes ***different processes*** that take part in a soil as a result of the application of an electric field.

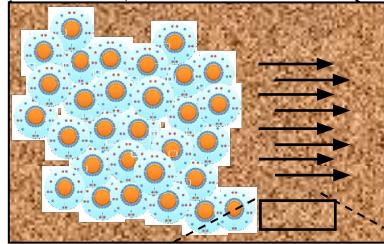
## **Soil Electrochemical Remediation**

Electric field

Application of a low current **electric field** between pairs of electrodes positioned on the **polluted soil**.



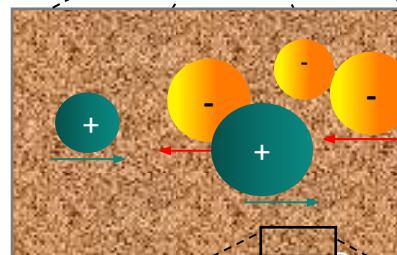
Macroscopic level



### **Electroosmosis**

Mobilization of **water** contained in the soil

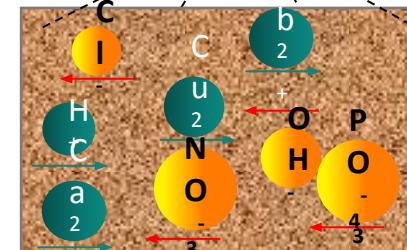
Microscopic level



### **Electrophoresis**

High size **charged species** movement  
(colloids, charged micelles, etc.)

Molecular level



### **Electromigration**

Ions transport through the soil

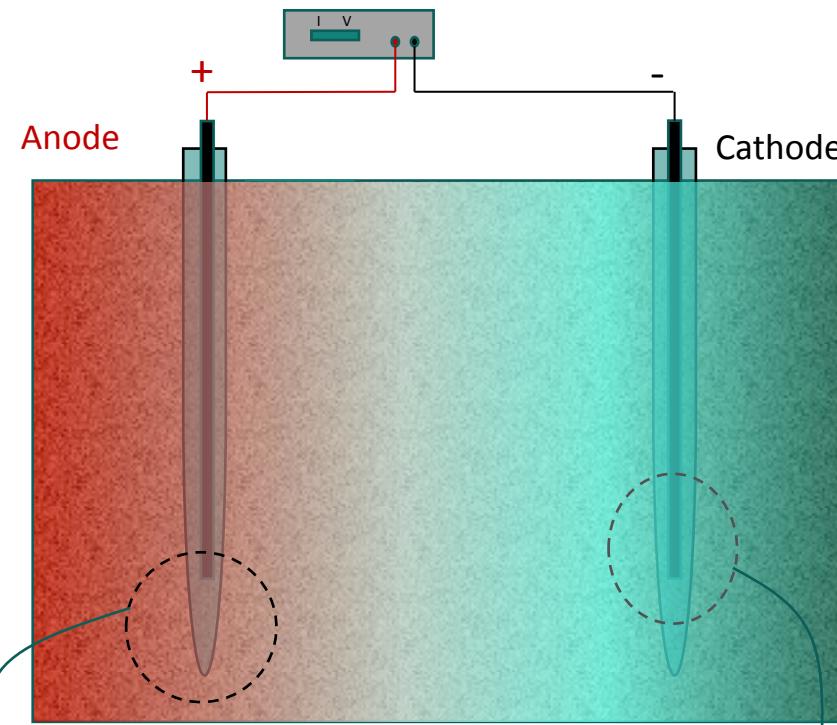
## **ELECTROKINETIC PROCESSES**

Includes **different processes** that take part in a soil as a result of the application of an electric field.

## Electrolysis

Water oxidation on the anodic surface

Water reduction on the cathodic surface

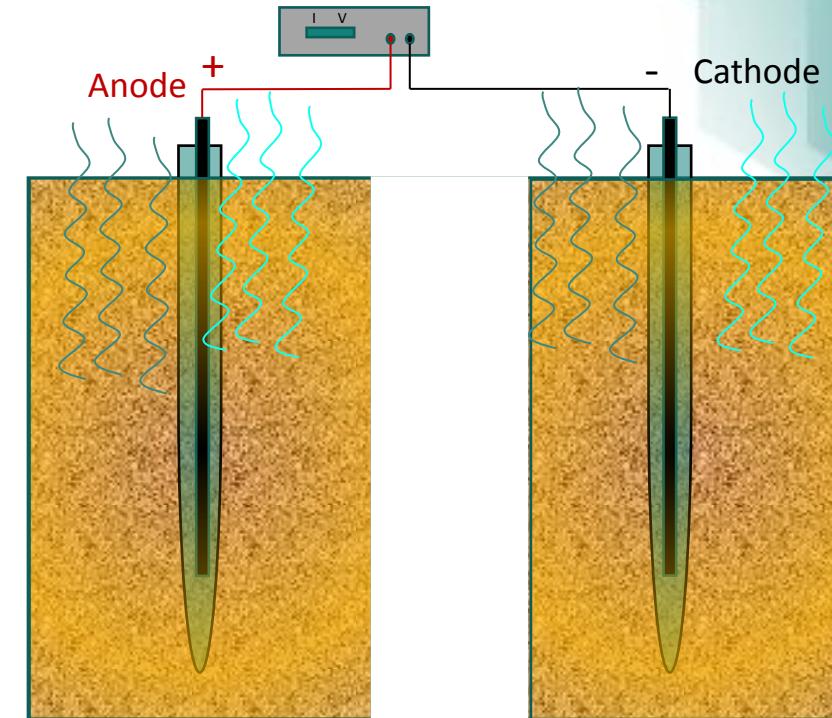


Influences:

- Different species precipitation / redisolution
- Fixation or liberation of species by ionic exchange
- Microbial viability

## Soil electrical heating

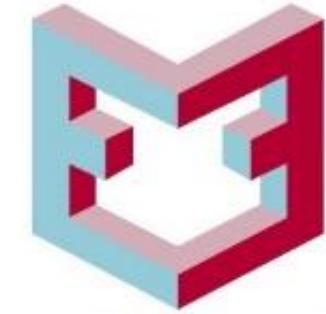
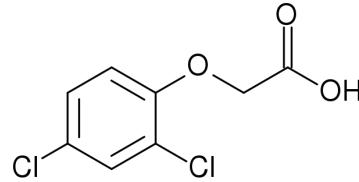
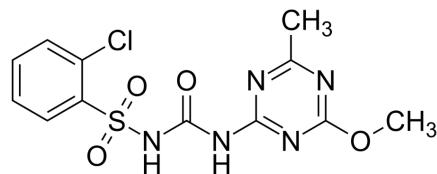
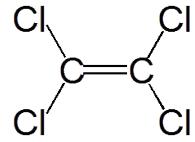
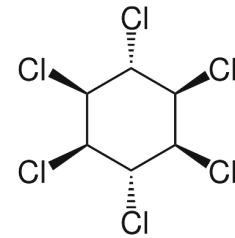
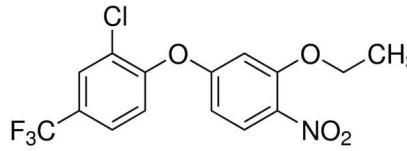
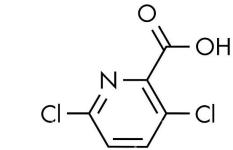
Temperature increase that occurs in the soil due to the ohmic drop generated by the **high electrical resistance** of the soil.



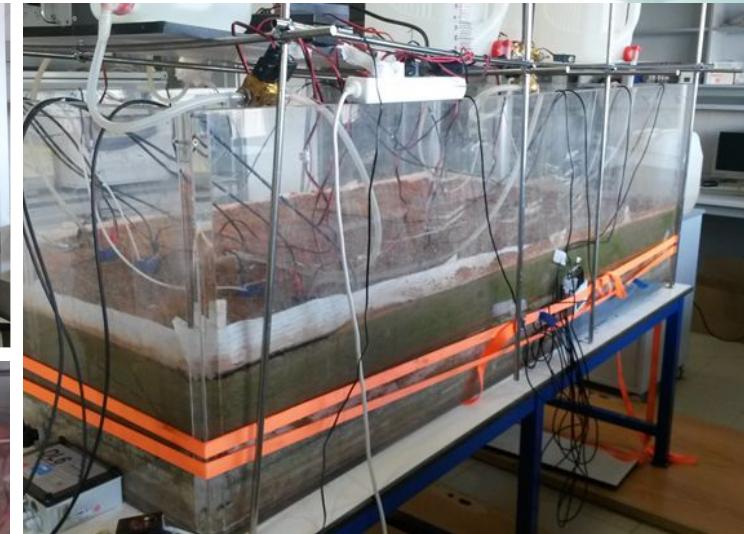
Influences on:

- Viscosity changes in liquids contained in the soil
- Pollutants volatilization
- Water evaporation
- Microbial populations

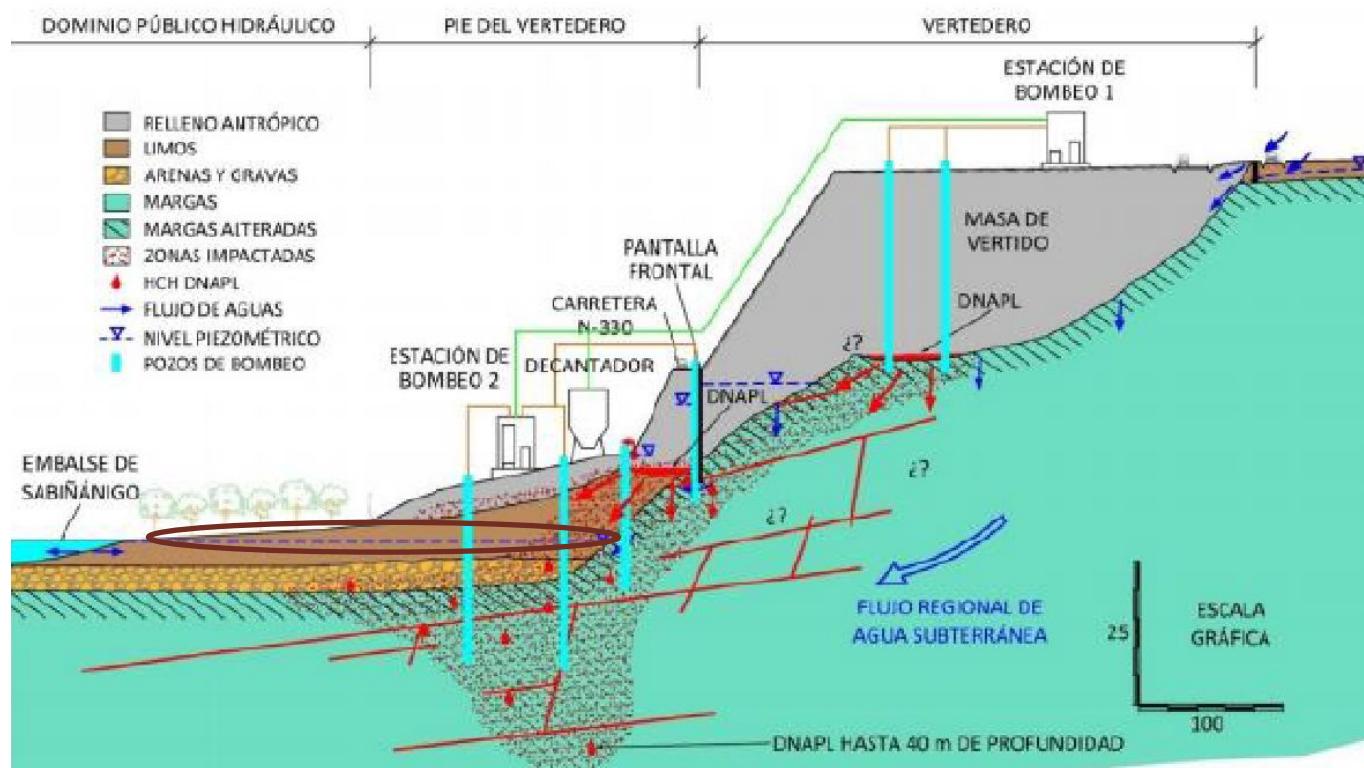
# Soil remediation: from lab to prototype scale set-ups



Electrochemical & Environmental Engineering Lab  
TEGUMA Research Group, Department of Chemical Engineering  
UCL



# Sardas landfill scheme



Modelo conceptual de la hidrogeología del vertedero de Sardas (Fernández et al., 2013).





**Goal:**

**Design and validation of electrikinetic techniques for the remediation of the alluvial silt of the Sardas landfill (Sabiñanigo) contaminated with HCHs**

## Levels of performance

TRL 4  
1D mock-ups (560 cm<sup>3</sup>)



To evaluate the mobility of pollutants under controlled conditions.

- Transport of pollutants
- Gas phase transfer.

TRL 5  
Unaltered samples



To evaluate how interact the different processes that are induced when electric fields are applied to aged silt from the Sardas landfill (Sabiñánigo, Huesca).

- Soil characterization
- Mobilization of contaminants.

TRL 6  
In situ pilot test



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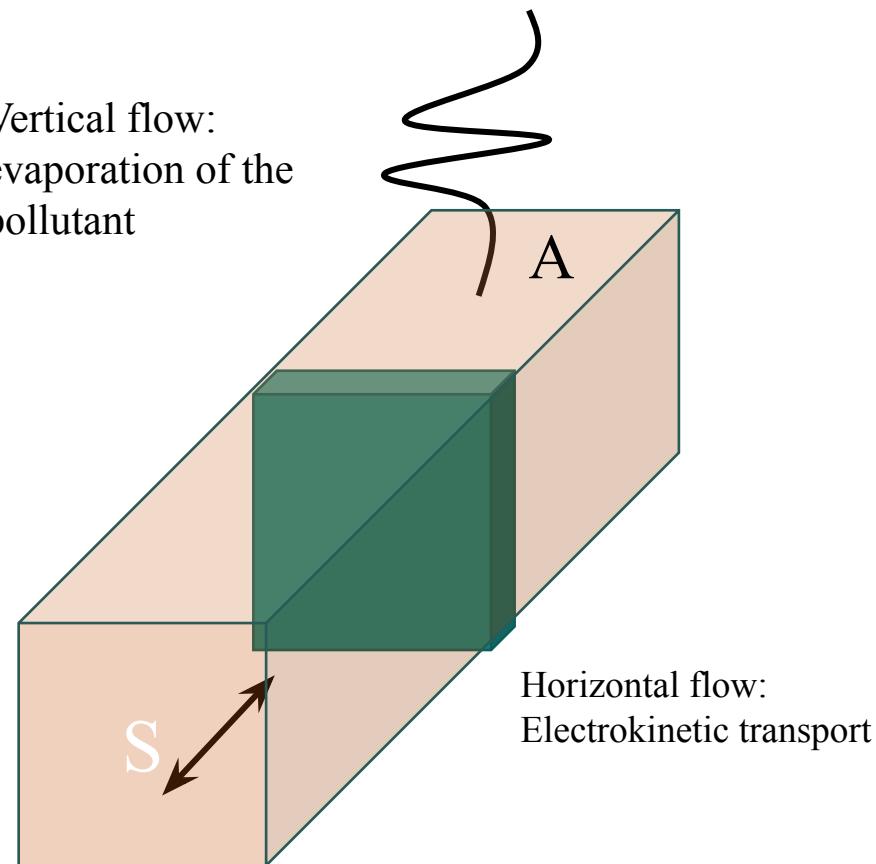
- Soil characterization
- Mobilization of contaminants.

TRL 6  
In situ pilot test



To evaluate how the influence of electrokinetic process when it is working in a real scale.

## 2 D-MODEL



$$\frac{\partial C_i(x,t)}{\partial t} = D_{eff} \frac{\partial^2 C_i(x,t)}{\partial x^2} - u_{eff} \frac{\partial C_i(x,t)}{\partial x} - \lambda A C_i(x,t)$$

### Parameters:

C: mmol m<sup>3</sup>

m<sub>cont</sub>: mmol

x: m

t: d

A: área de contacto con atmósfera (m<sup>2</sup>)

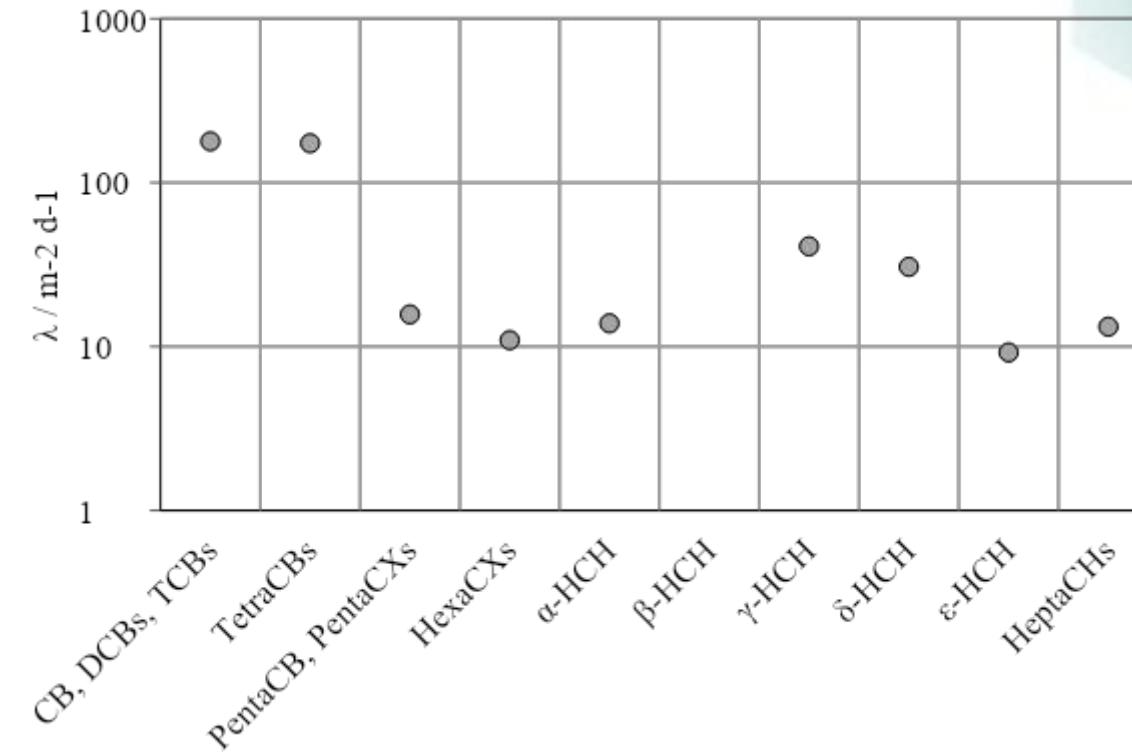
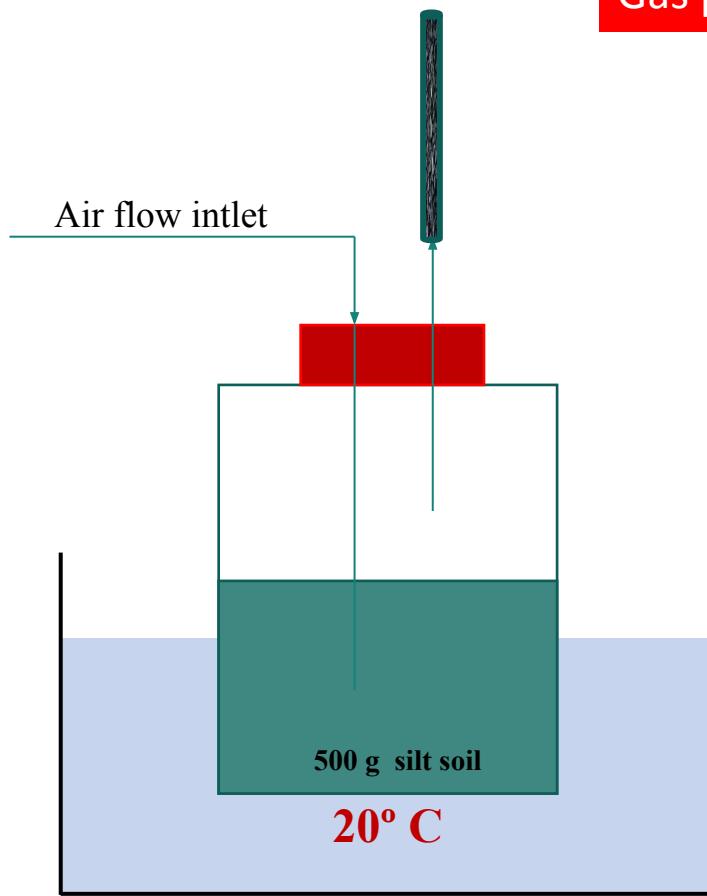
S: sección de paso (m<sup>2</sup>)

**v<sub>eff</sub>: m d<sup>-1</sup> (dragging rate)**

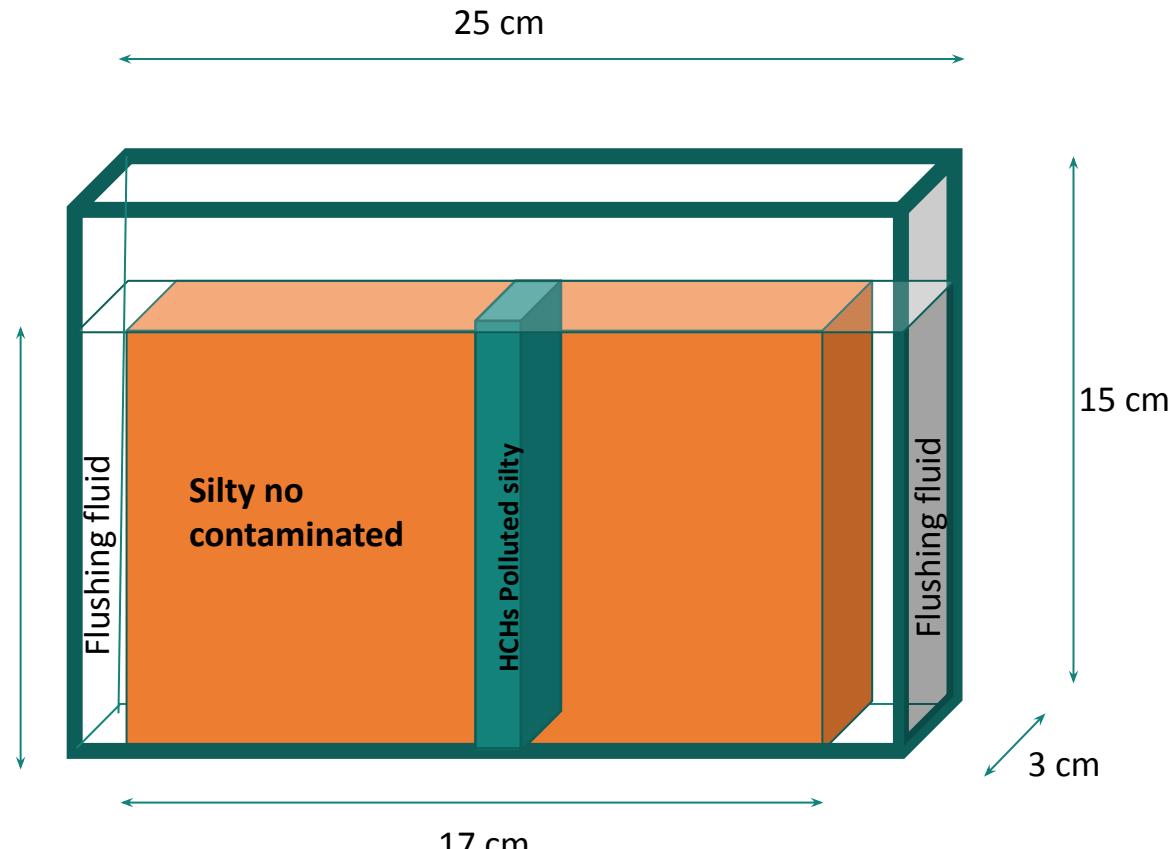
**D<sub>eff</sub>: m<sup>2</sup> d<sup>-1</sup> (diffusion coefficient)**

**λ: m<sup>-2</sup> d<sup>-1</sup> first order kinetic constant  
(volatilization)**

$$C_i(x, t) = \frac{m_0 e^{-\lambda At}}{\theta S \sqrt{4\pi D_{eff} t}} e^{-\frac{(x-u_{eff}t)^2}{4D_{eff}t}}$$



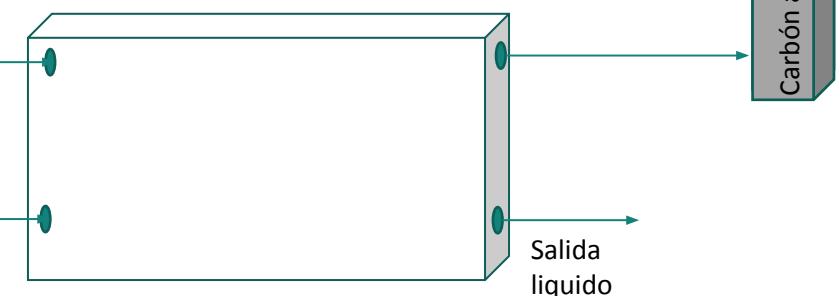
## Mobilization of pollutants in soil



Room T  
High T (50 °C)

Entrada aire mediante  
compresor de pecera  
(1 o dos veces /día)

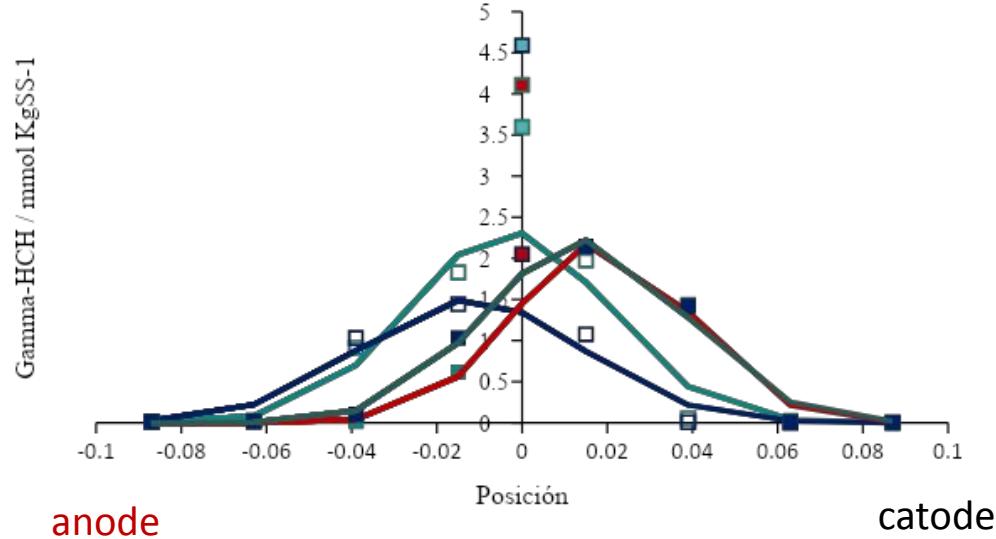
Entrada fluido (1 o  
dos veces días con  
jeringa a demanda)



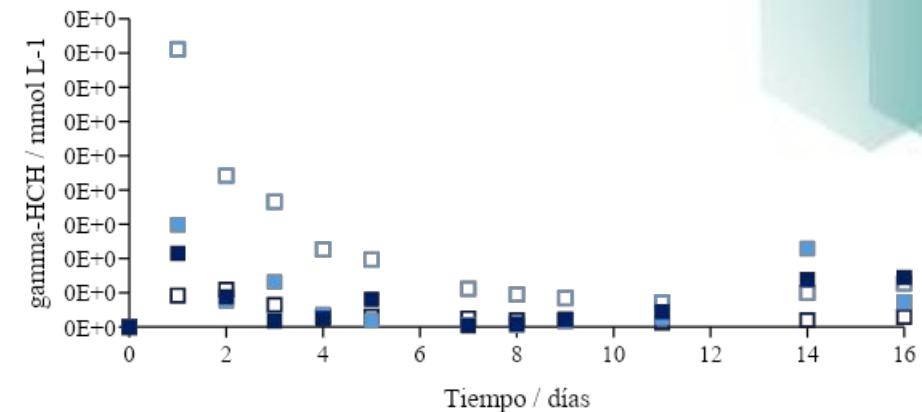
## Mobilization of pollutants in soil

### Gamma-HCH

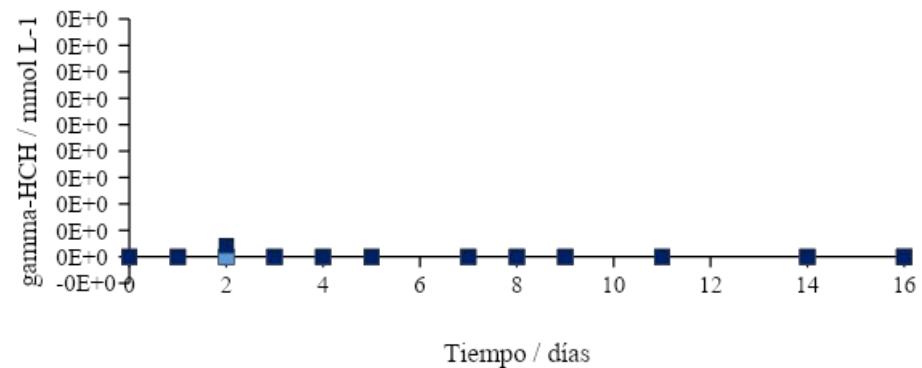
soil



### Anodic well

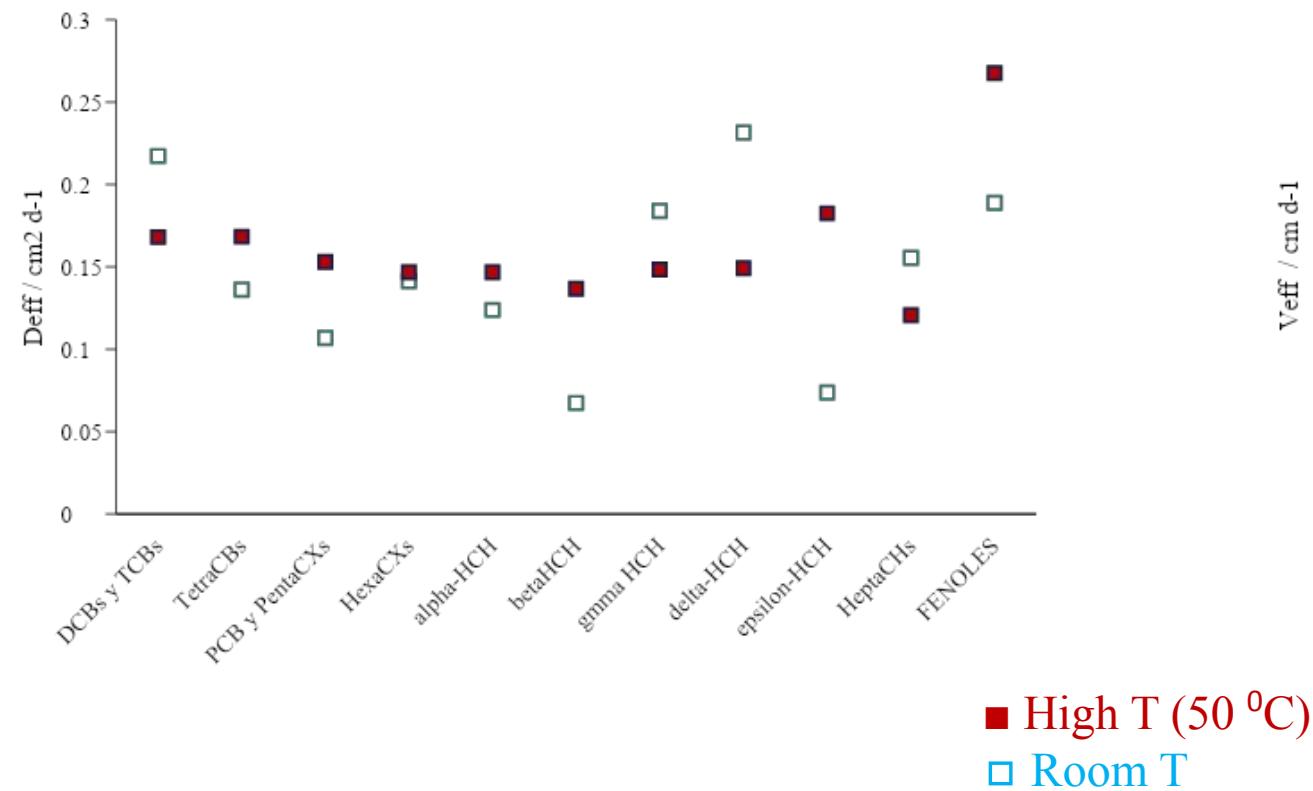


### Catodic well

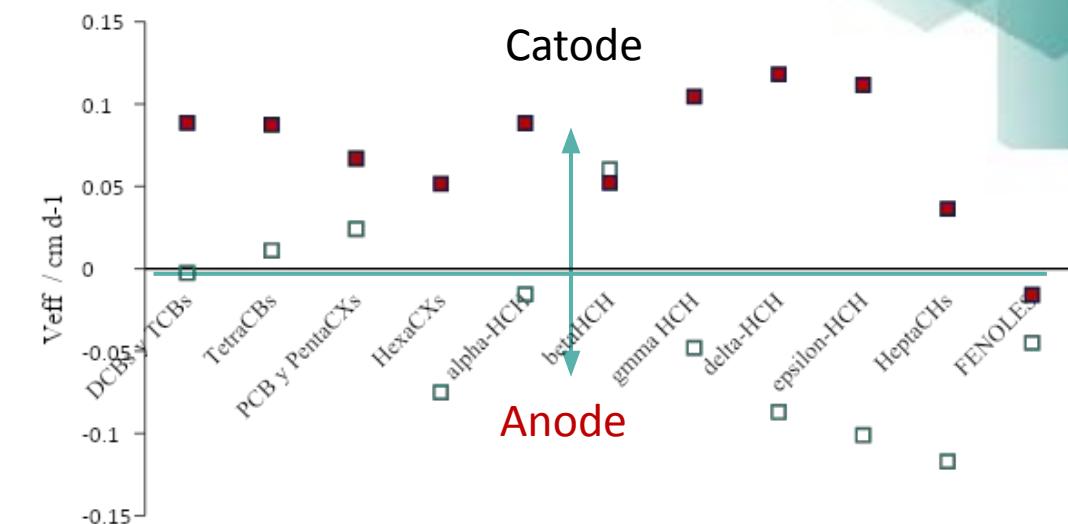


	Tamb 1	Tamb 2	T 50 °C 1	T 50 °C 2
Deff / m <sup>2</sup> d <sup>-1</sup>	0.17	0.21	0.13	0.17
v / m d <sup>-1</sup>	-0.02	-0.076	0.12	0.092
r <sup>2</sup>	0.94	0.94	0.99	0.98

Average Effective Diffusivity by type of high and low temperature mock-ups



Average dragging speed by type of high and low temperature mock-ups



- Important volatilization at ambient temperature that have been promoted by ohmic loses.
- Dragging highly dependence on temperature and type of species transport.

## Levels of performance

TRL 4  
1D mock-ups ( $560\text{ cm}^3$ )



To evaluate the mobility of pollutants under controlled conditions.

- Transport of pollutants
- Gas phase transfer.

TRL 5  
Unaltered samples



To evaluate the viability of electrokinetic remediation for the treatment of aged silt from the Sardas landfill (Sabiñánigo, Huesca).

- Soil characterization
- Mobilization of contaminants.

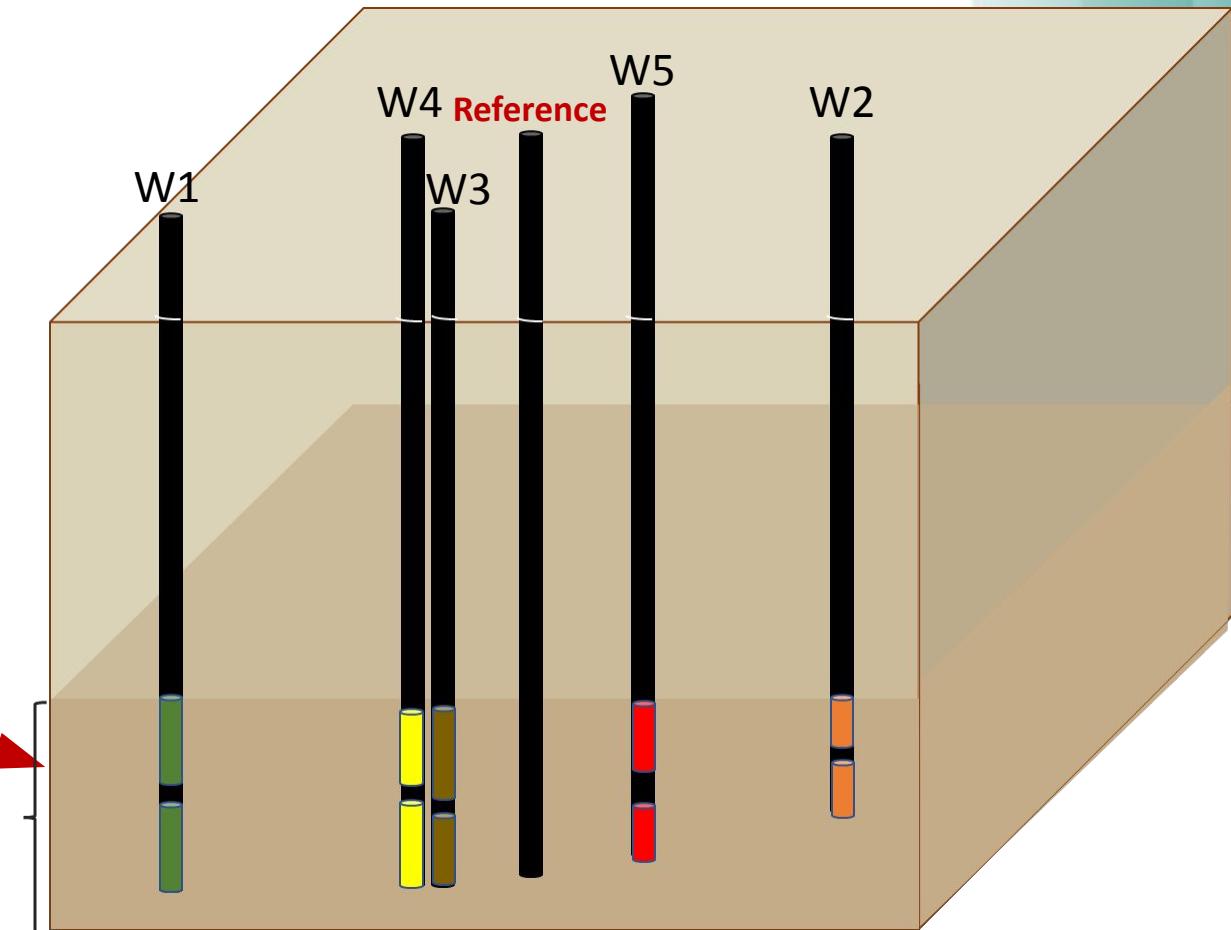
TRL 6  
In situ pilot test



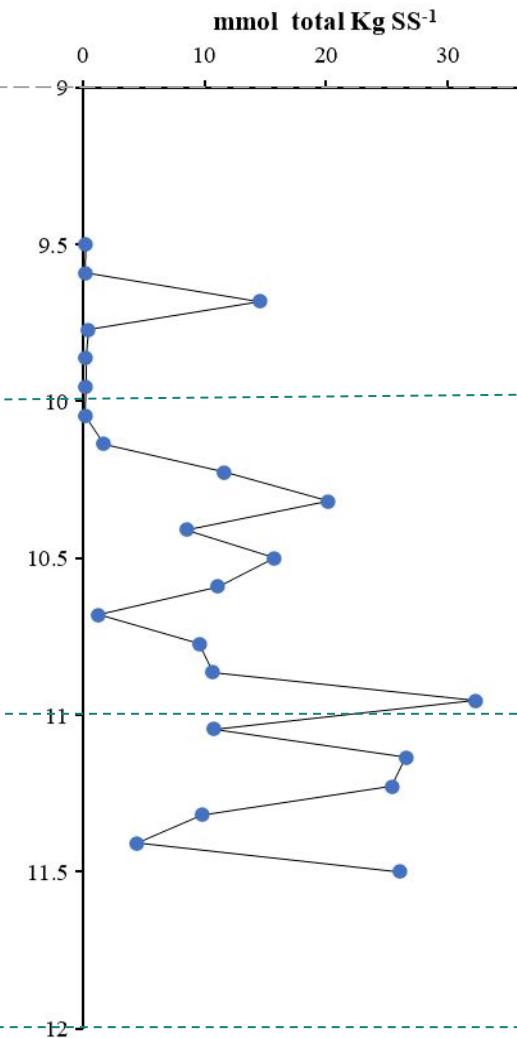
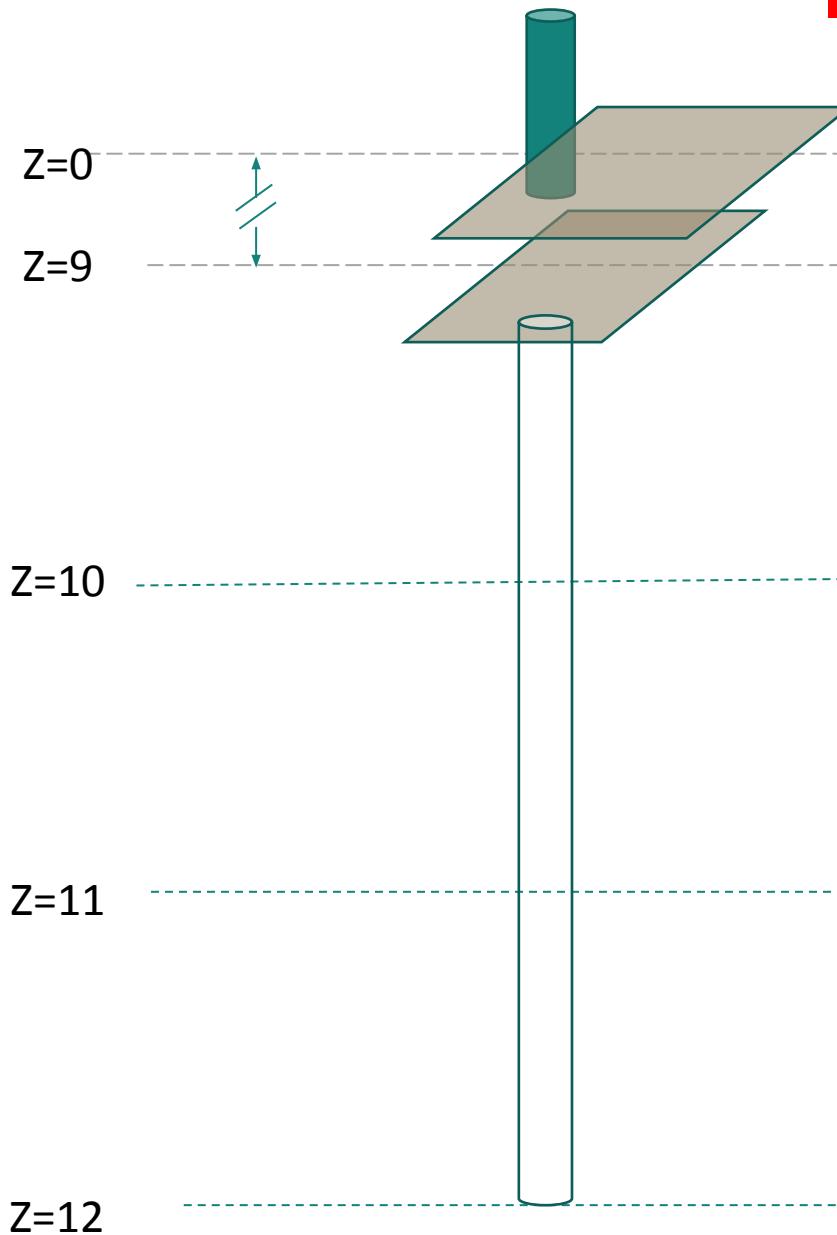
10 unaltered soil samples

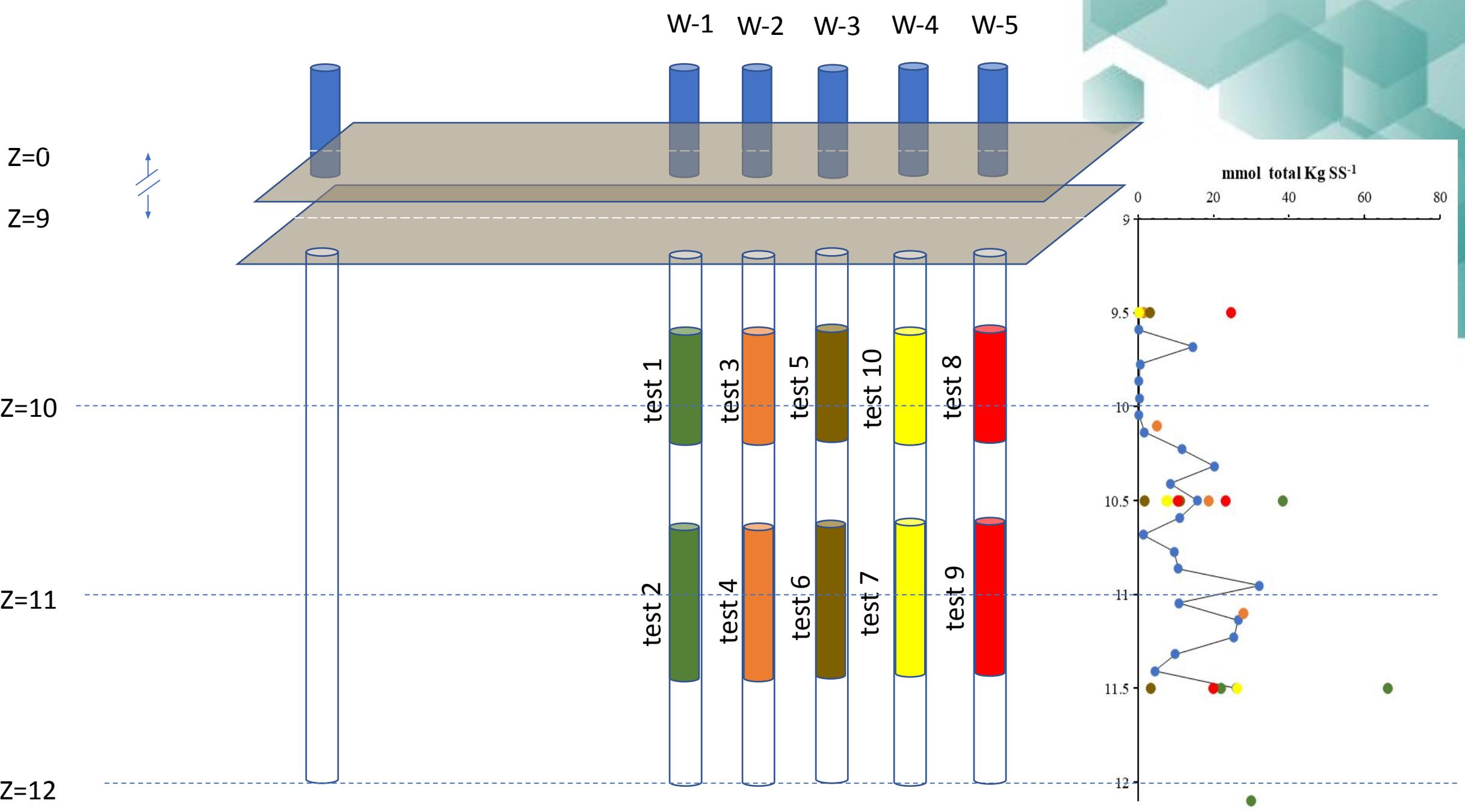


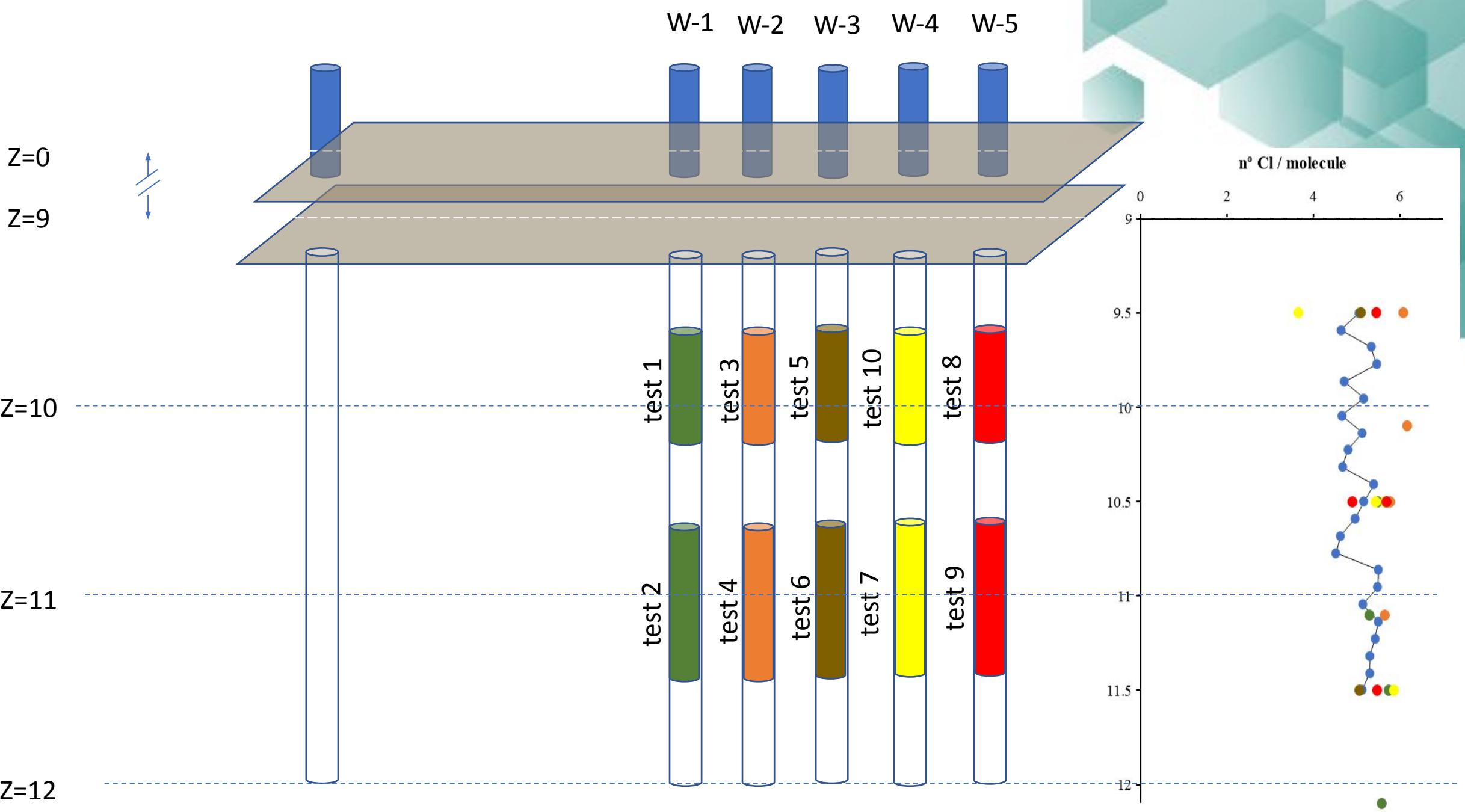
9.5-12 m



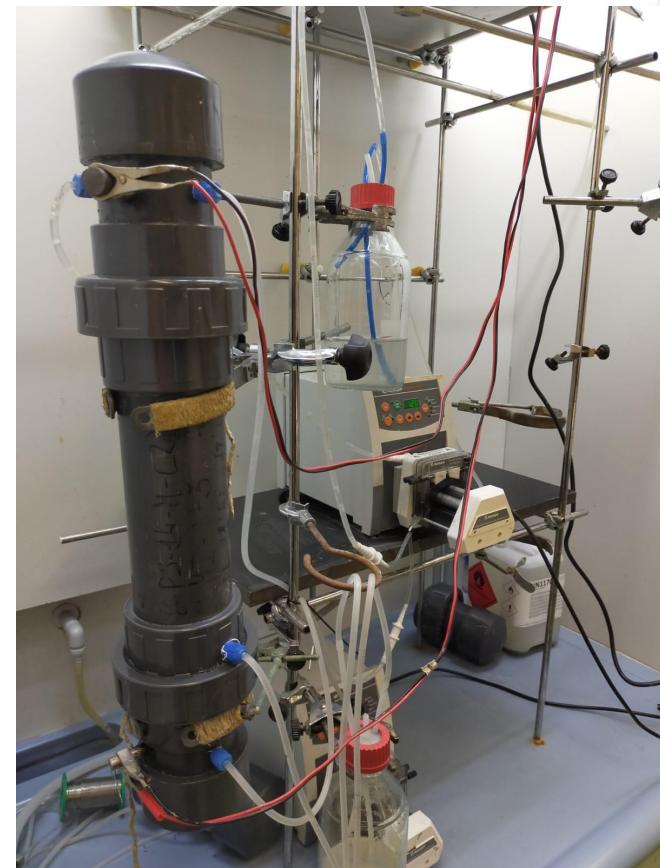
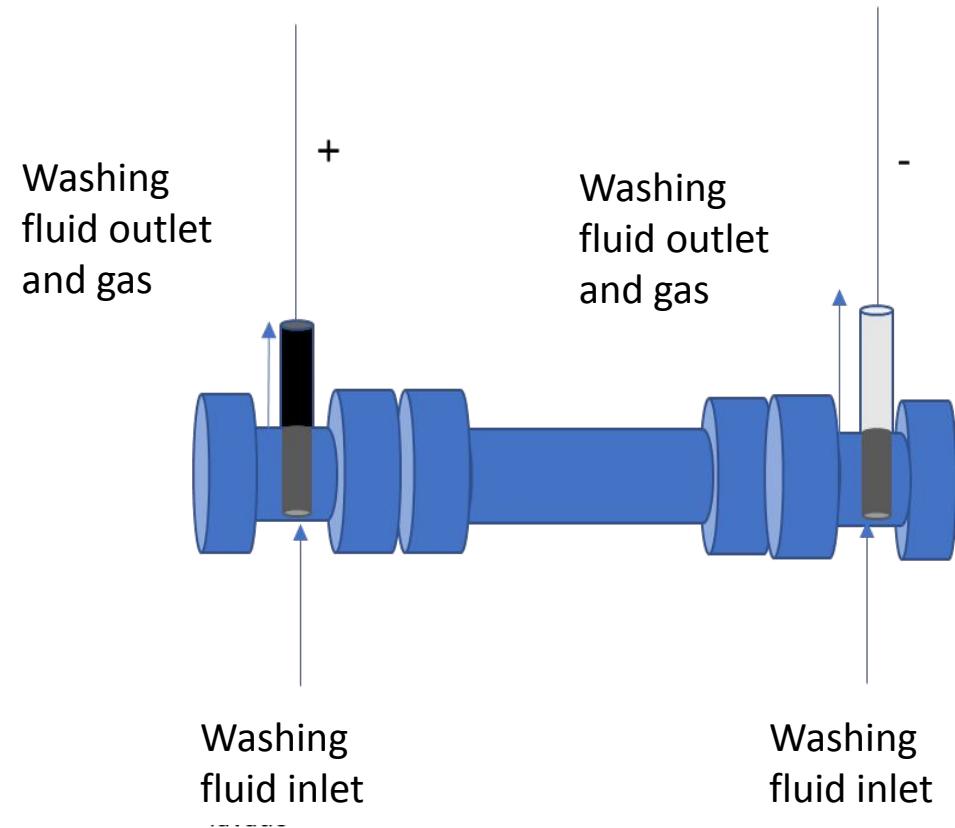
## Reference borehole







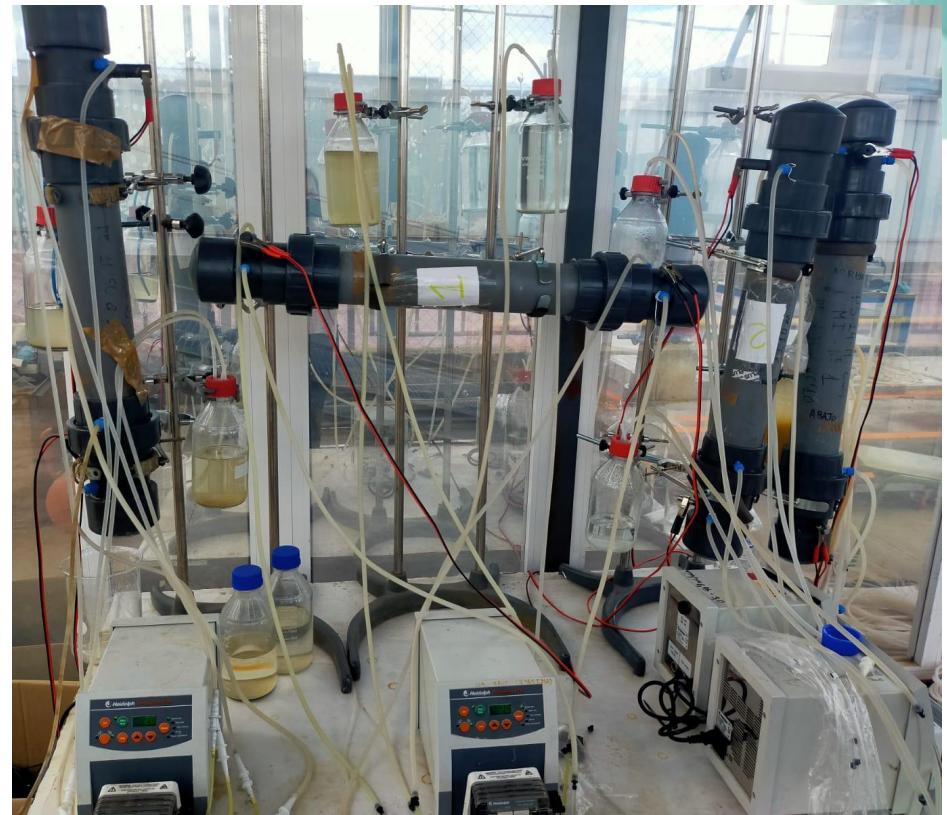
## Experimental set-up



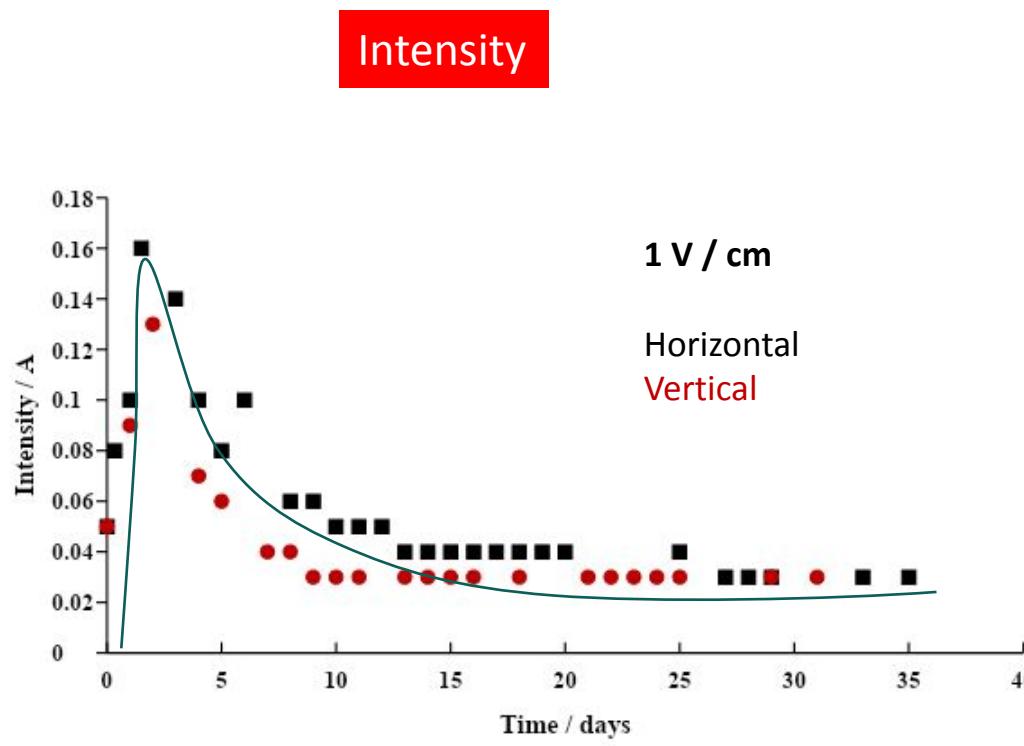
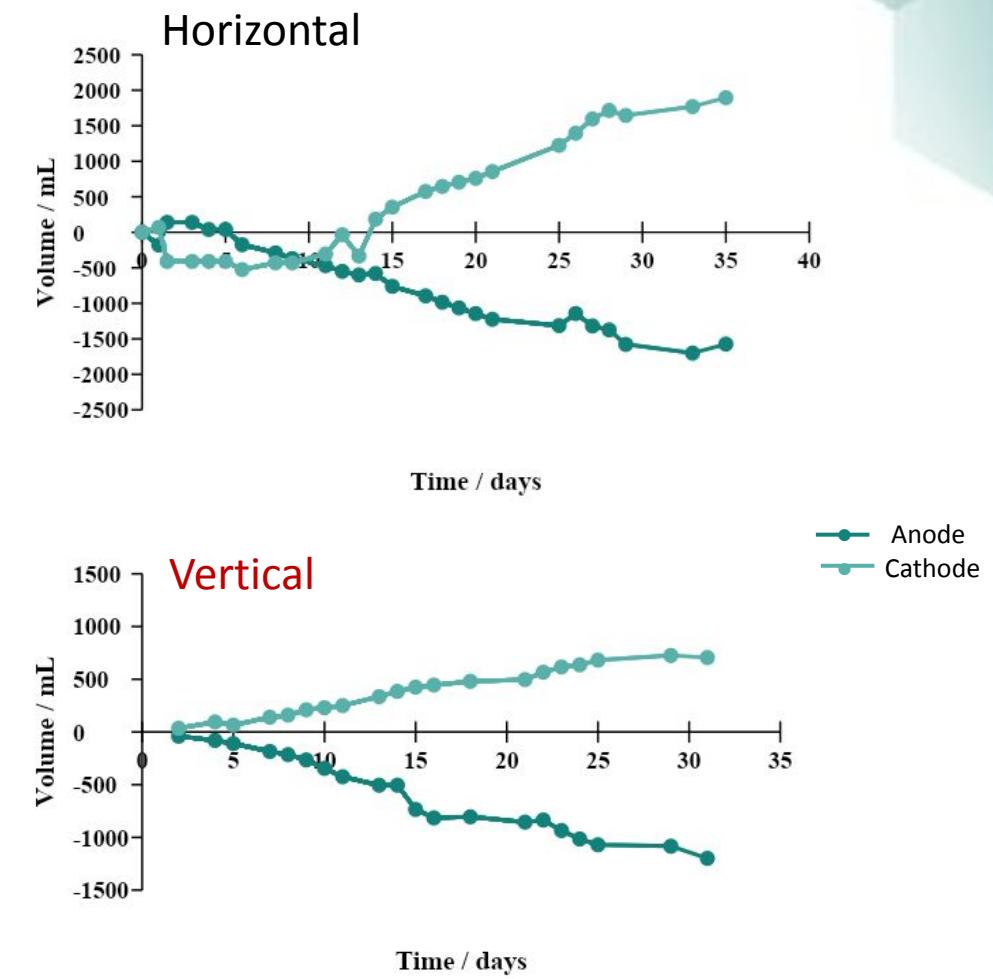
## 10 test to

**Objective:** The aim is to understand, at a higher level of detail, how interact the different processes that are induced when electric fields are applied to the silt of the site, for which there are parameters that take on greater relevance than when the processes try to be isolated:

- 1) **electrode arrangement:** horizontal or vertical.
- 2) **treatment time**
- 3) **addition of improvement fluid:** washing water (the water contained in the reservoir itself so as not to modify its characteristics), surfactants to encourage the removal of organic pollutants contained in the silt.
- 4) **reversal electric field**
- 5) **electric field induced** (1.0-4.0 V/cm)



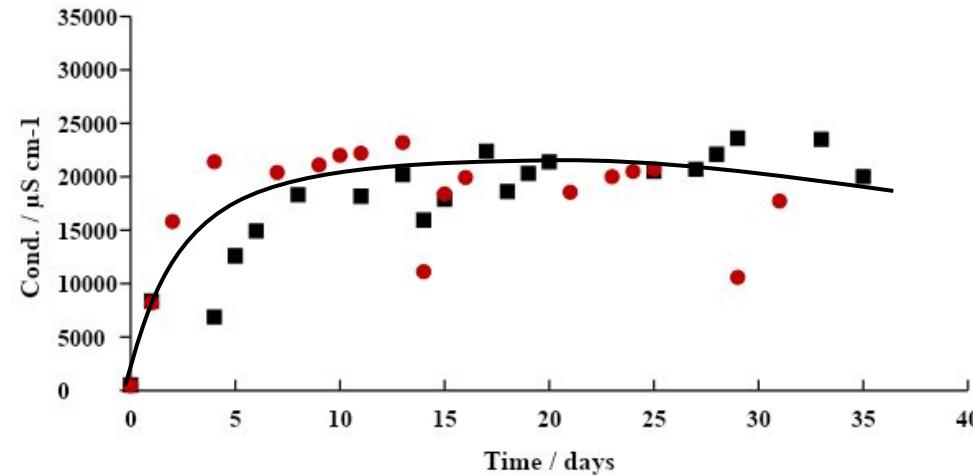
## Volume electrolyte compartment



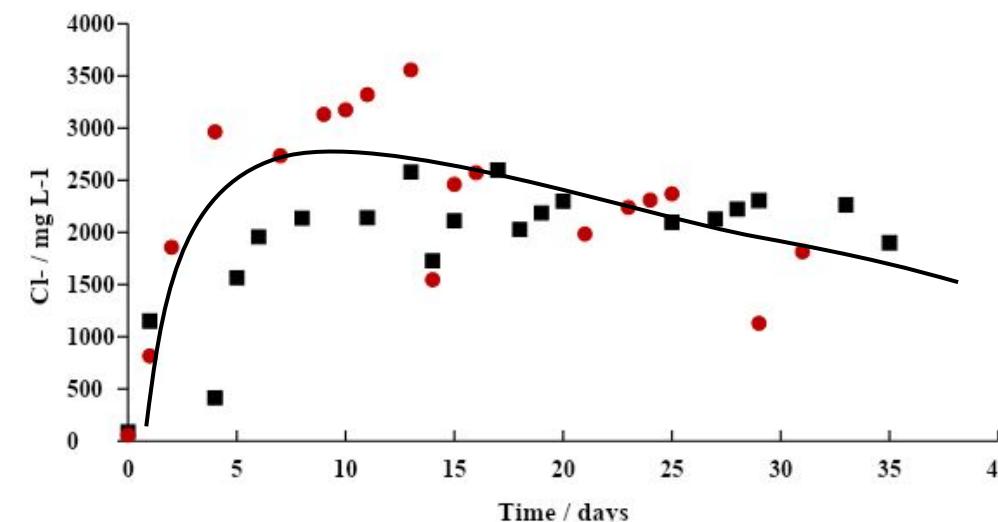
Electroosmotic flux / cm day <sup>-1</sup>	
T1 (horizontal)	0.8
T2(vertical)	0.7

## Ions mobility

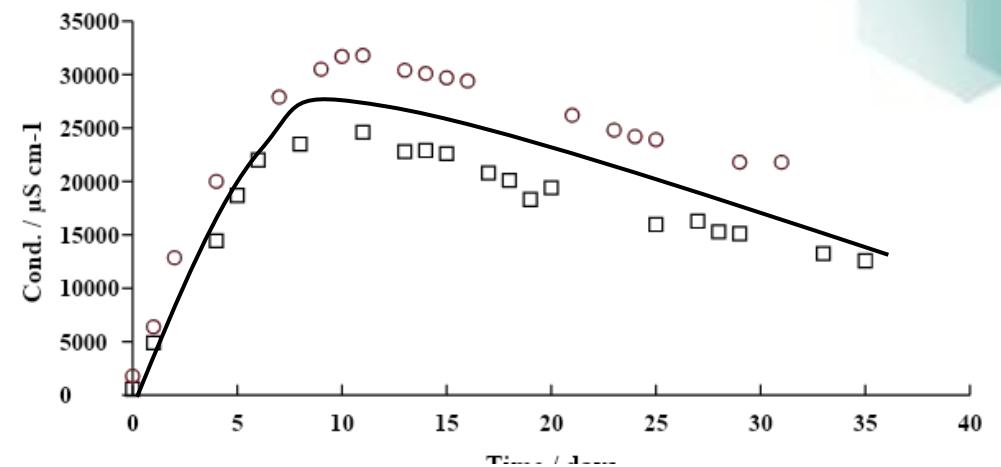
Anodic well



Migration

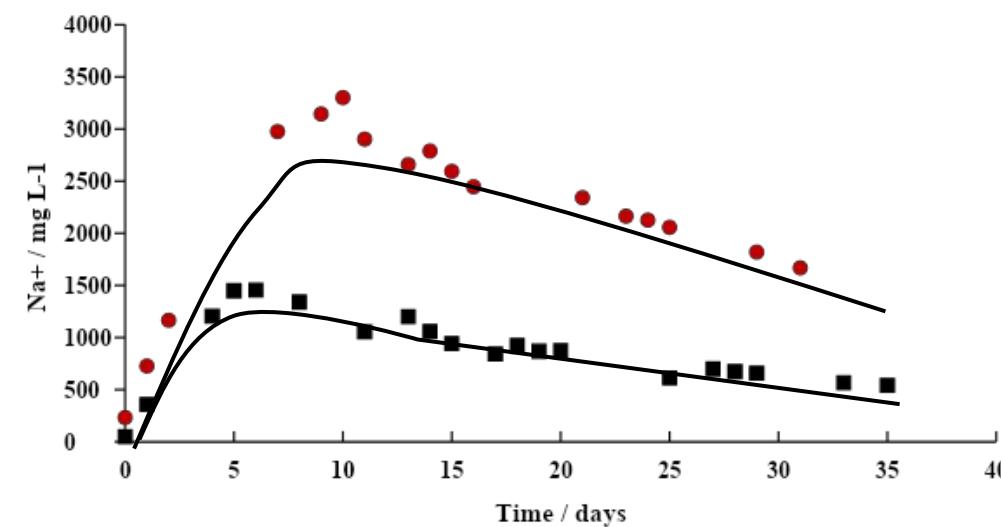


Cathodic well

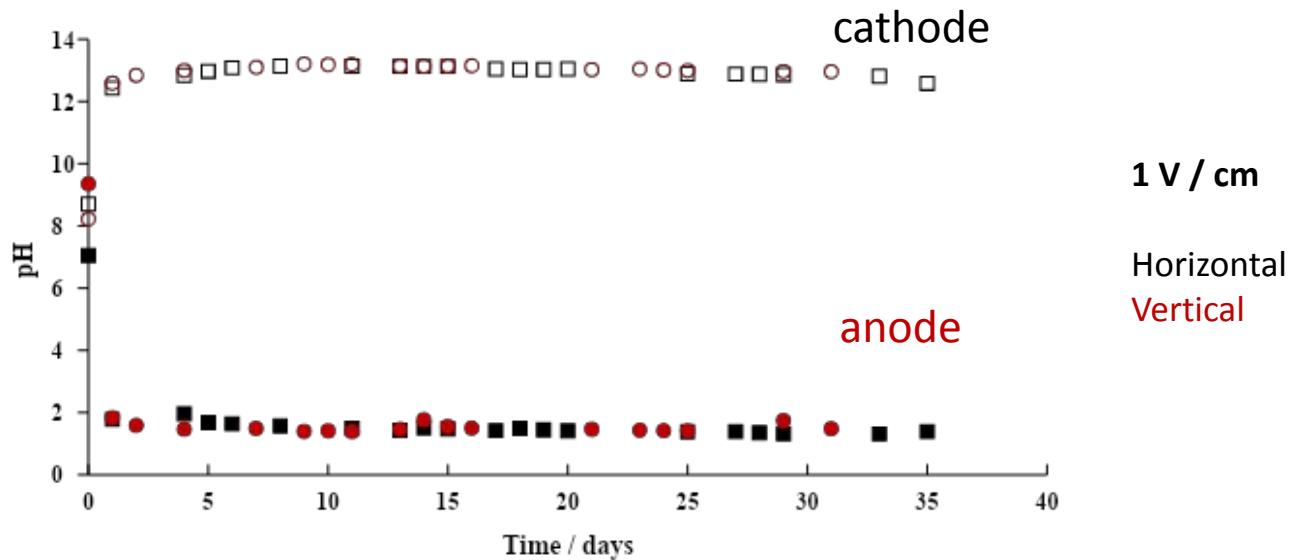


1 V / cm

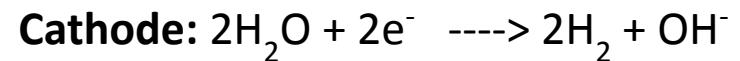
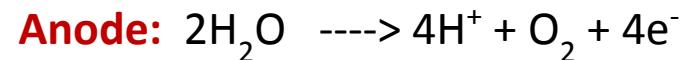
Horizontal  
Vertical



pH



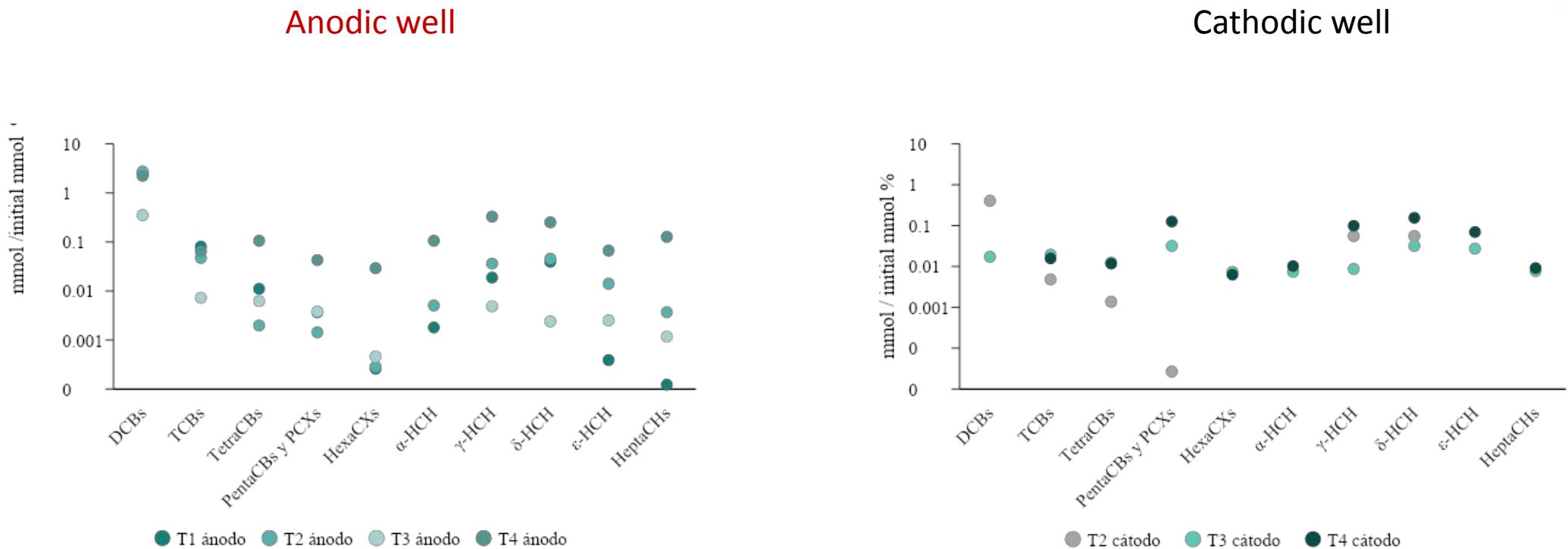
Water electrolysis:



$\text{H}^+$  acid front / Anode -> Cathode

$\text{OH}^-$  basic front / Cathode-> Anode

## HCHs in electrolyte wells

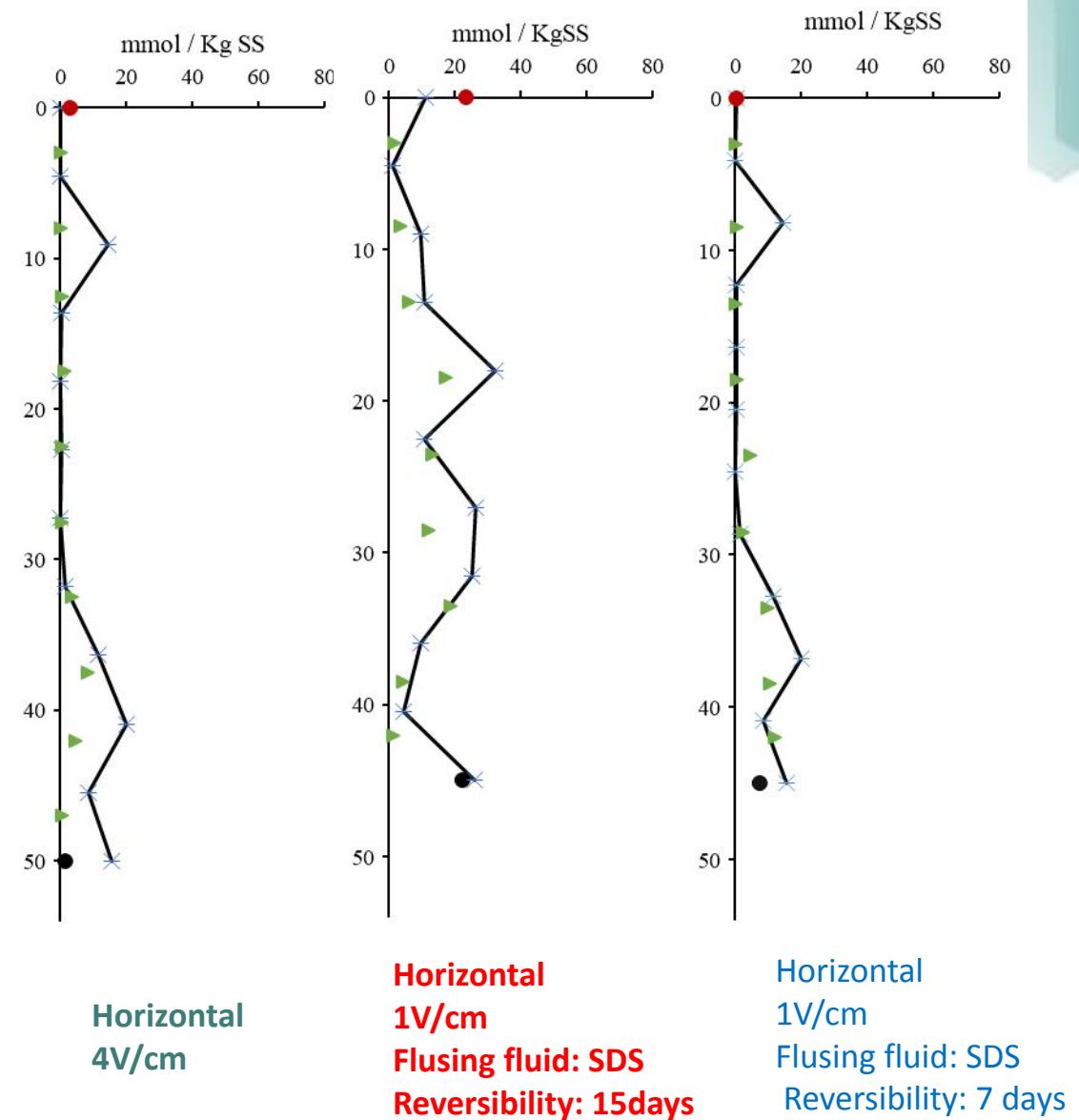
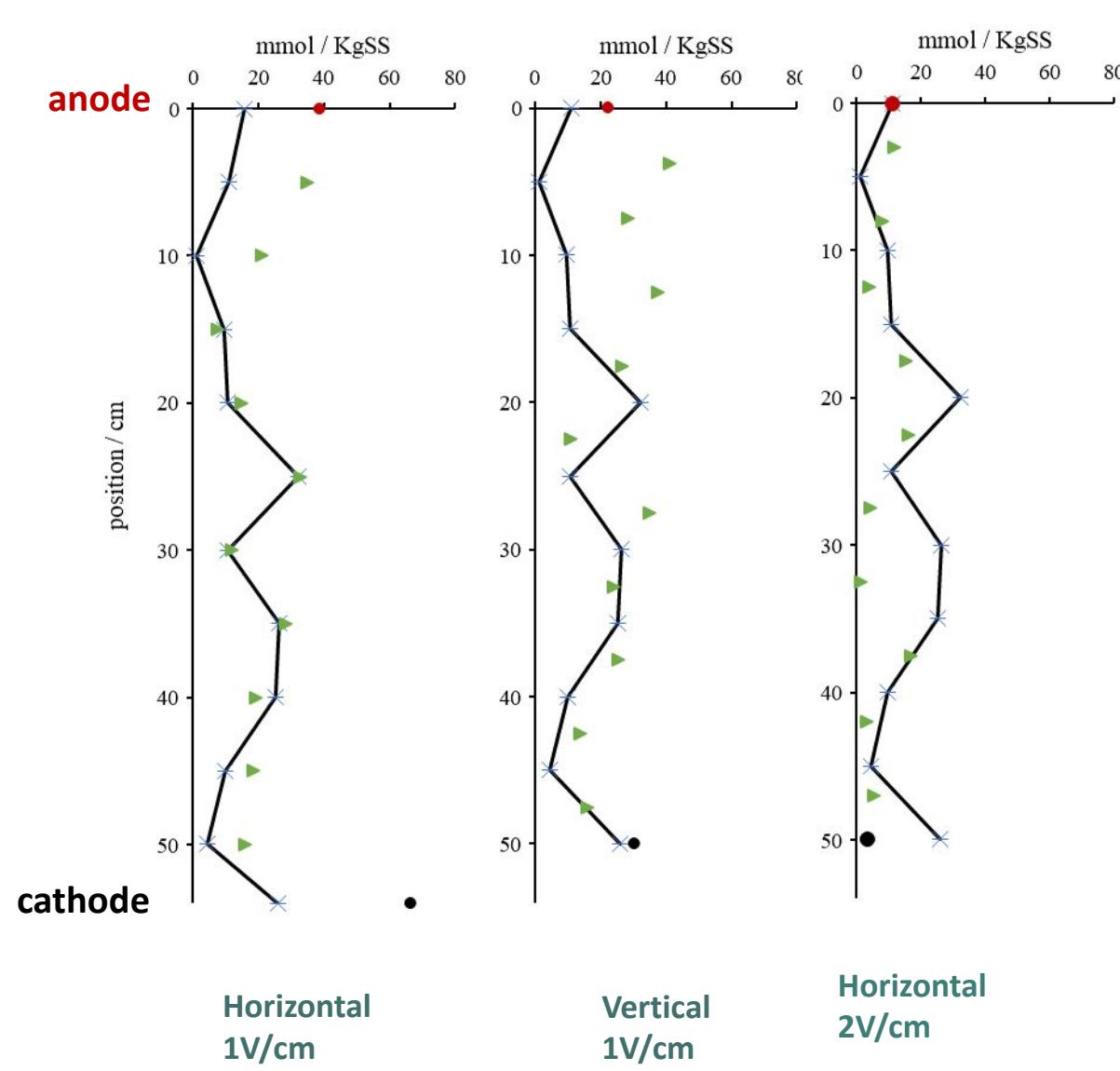


## Post-mortem analysis



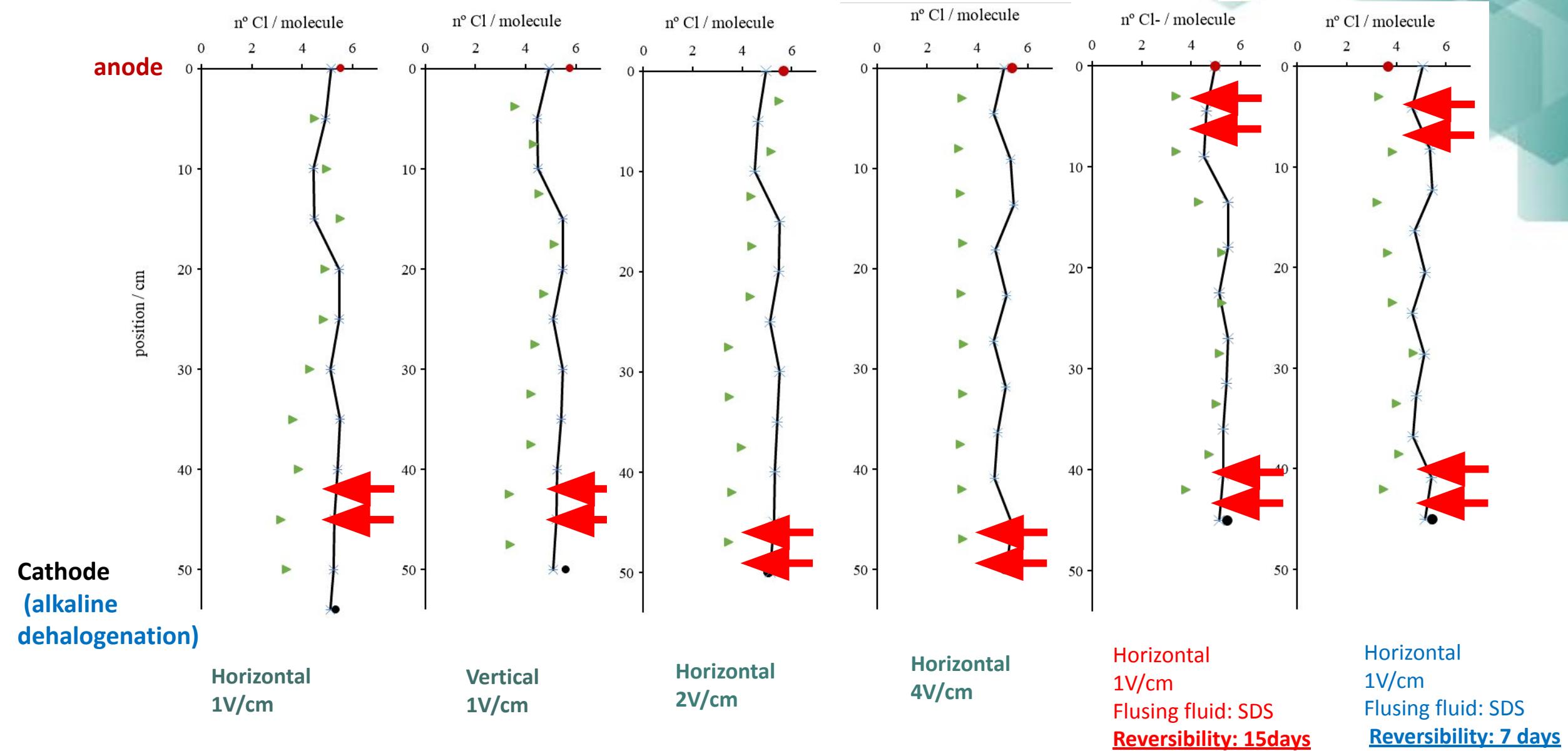
## HCHs in soil

- ▲ Post-mortem
- Anode end
- Cathode end
- \* Reference well

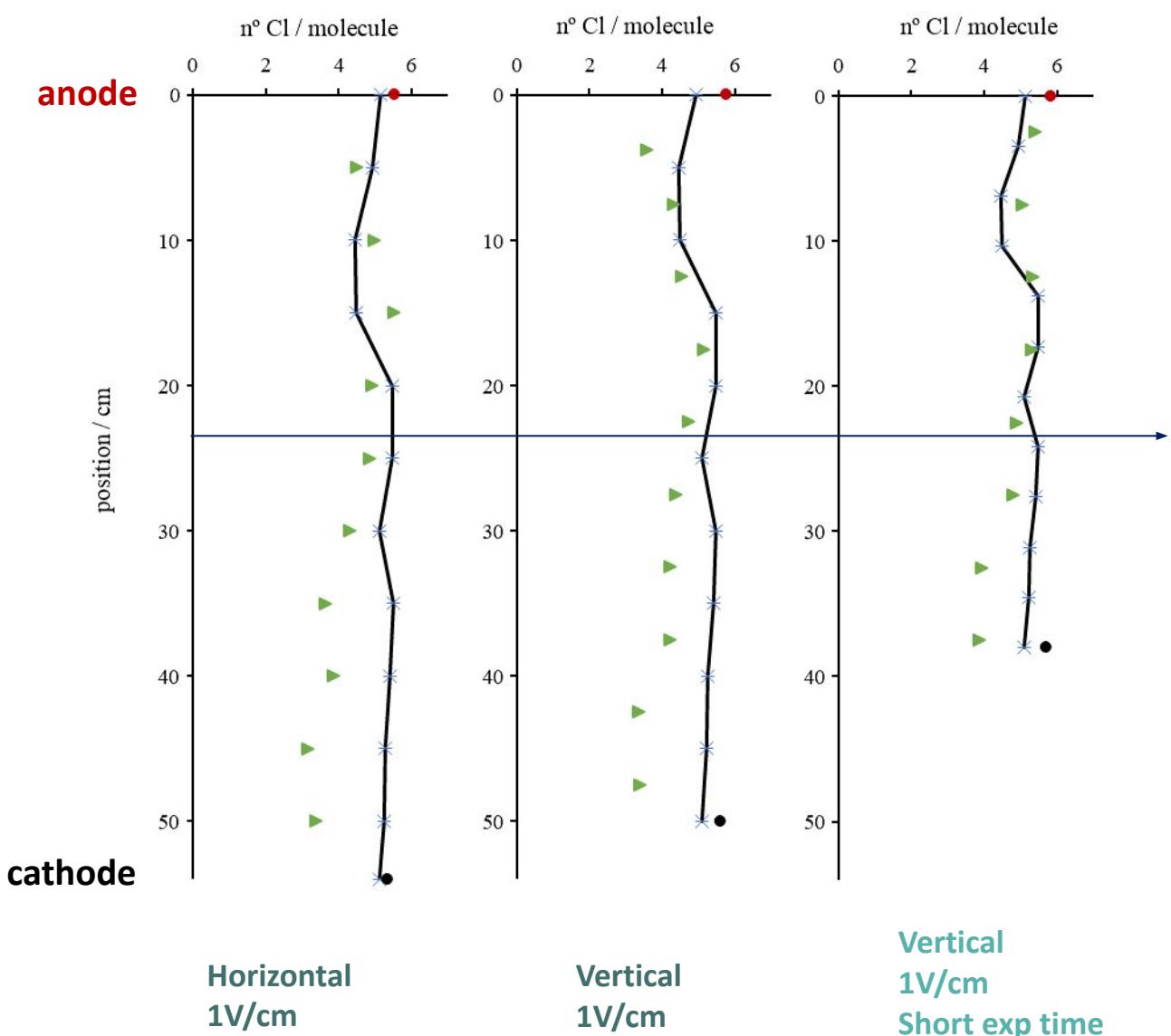


## HCHs in soil

Post-mortem  
Anode end  
Cathode end  
Reference well



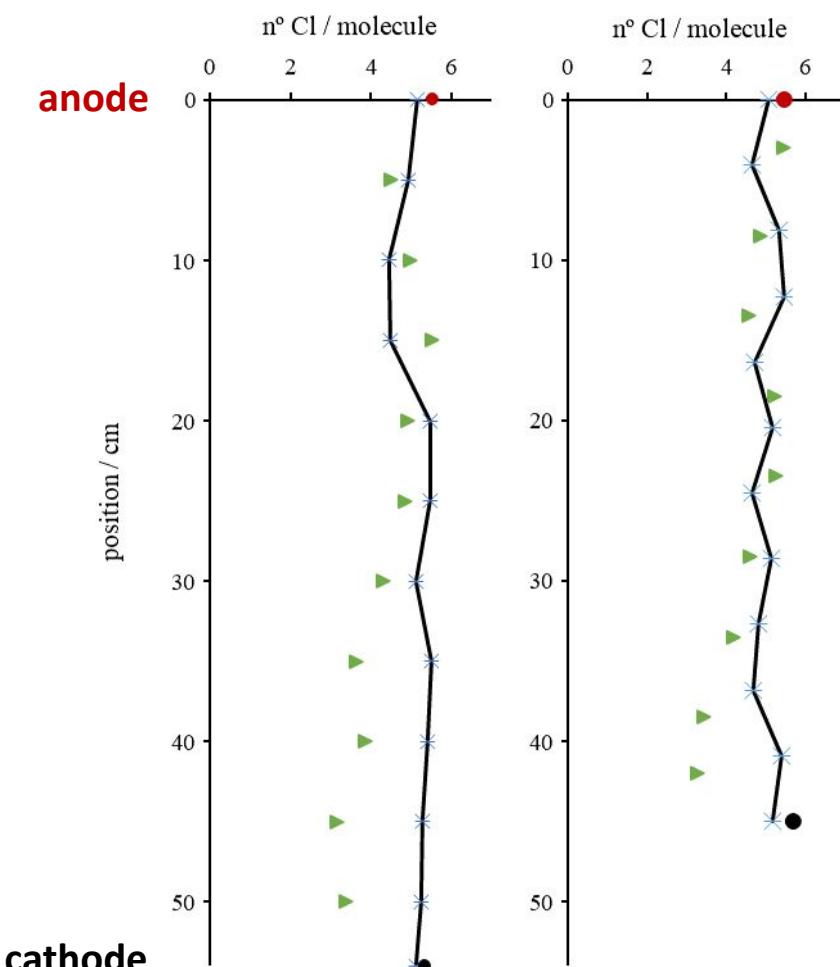
## HCHs in soil



▲ Post-mortem  
 ● Anode end  
 ● Cathode end  
 \* Reference well

**electrode arrangement**

## HCHs in soil

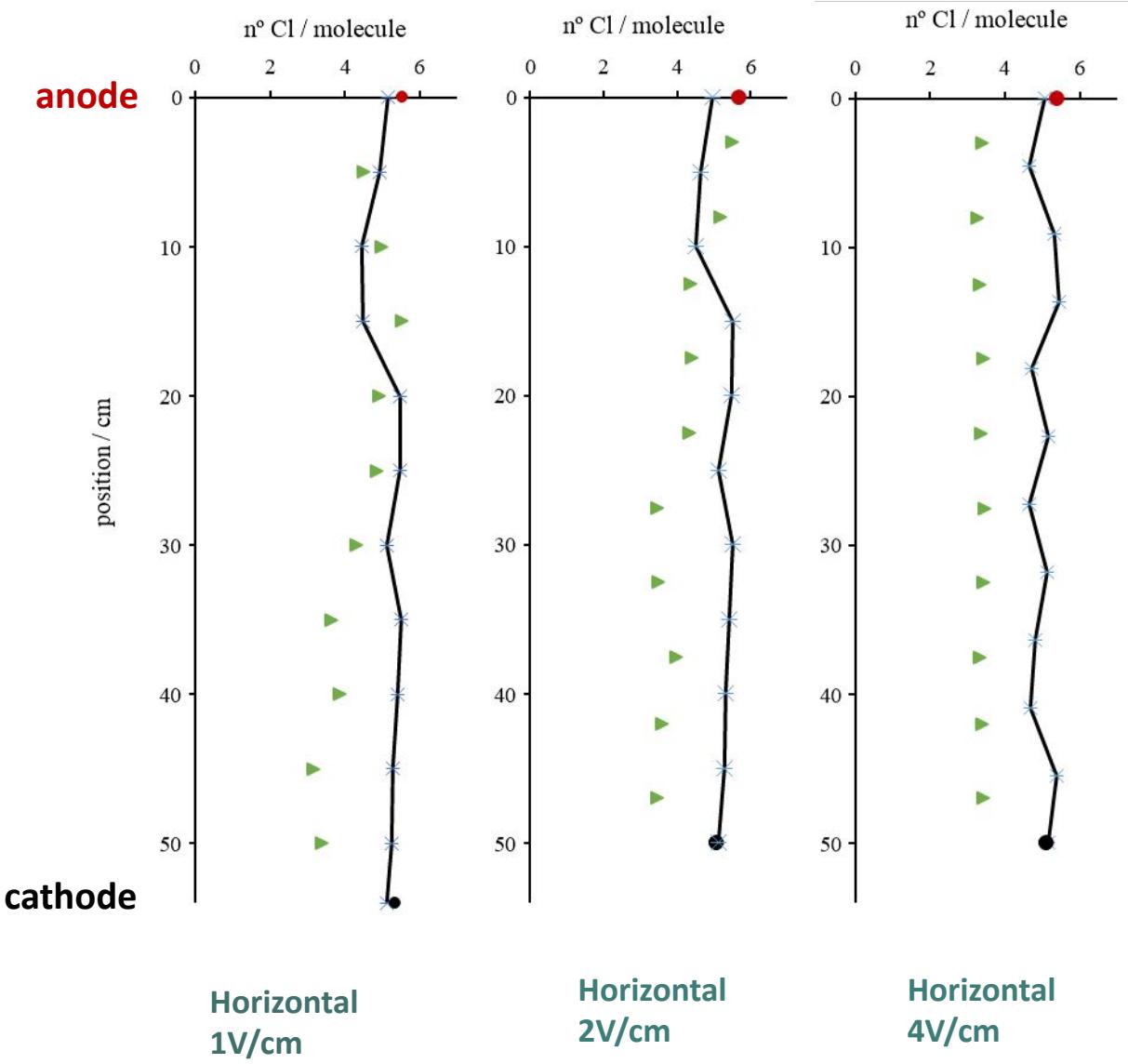


- ▲ Post-mortem
- Anode end
- Cathode end
- Reference well



Type of flushing fluid

## HCHs in soil



1V/cm □ 2V/cm □ 4 V/cm

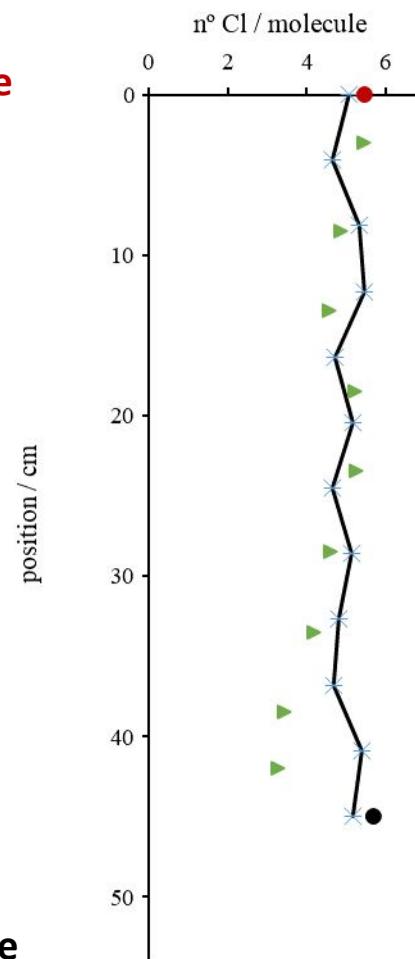
↑↑↑ Dechlorination

Electric field applied

Post-mortem  
Anode end  
Cathode end  
Reference well

## HCHs in soil

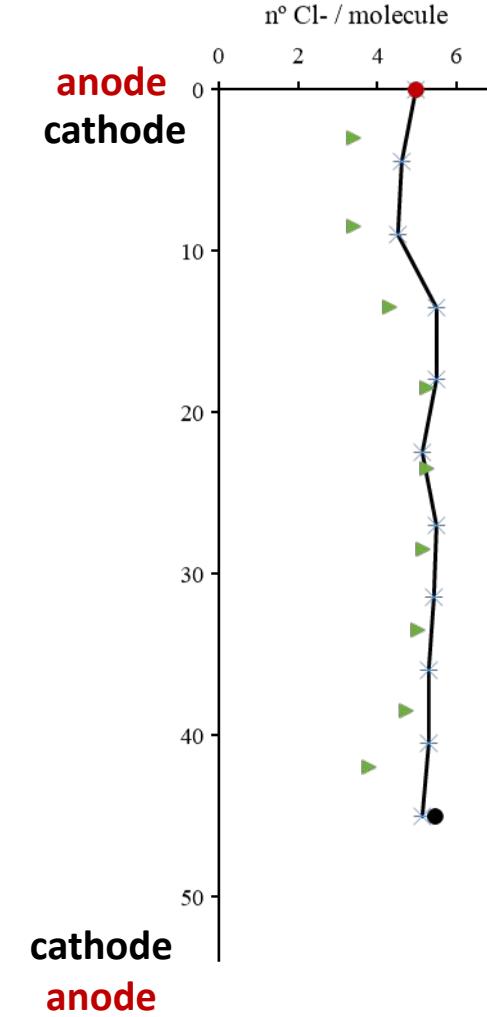
**anode**



**cathode**

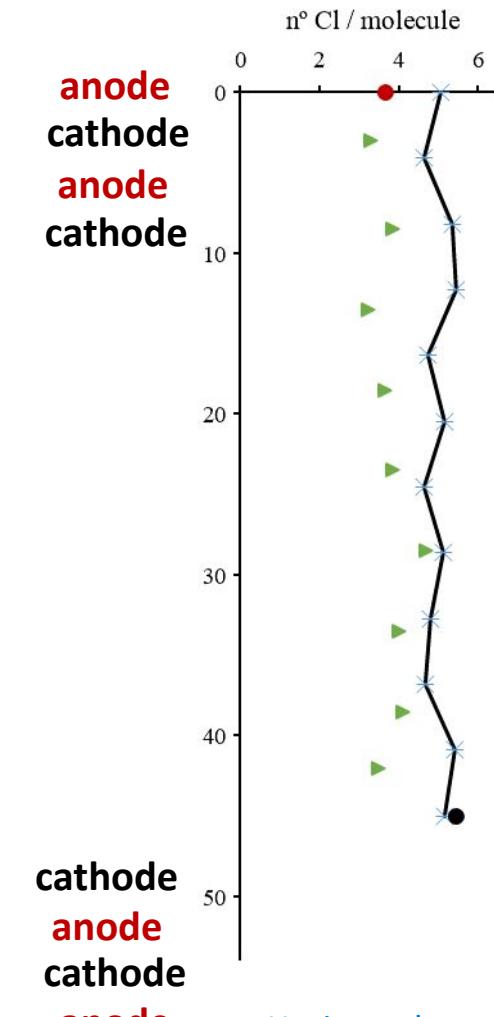
Horizontal  
1V/cm  
Flusing fluid: SDS  
No reversibility

**anode**  
**cathode**



Horizontal  
1V/cm  
Flusing fluid: SDS  
Reversibility: 15days

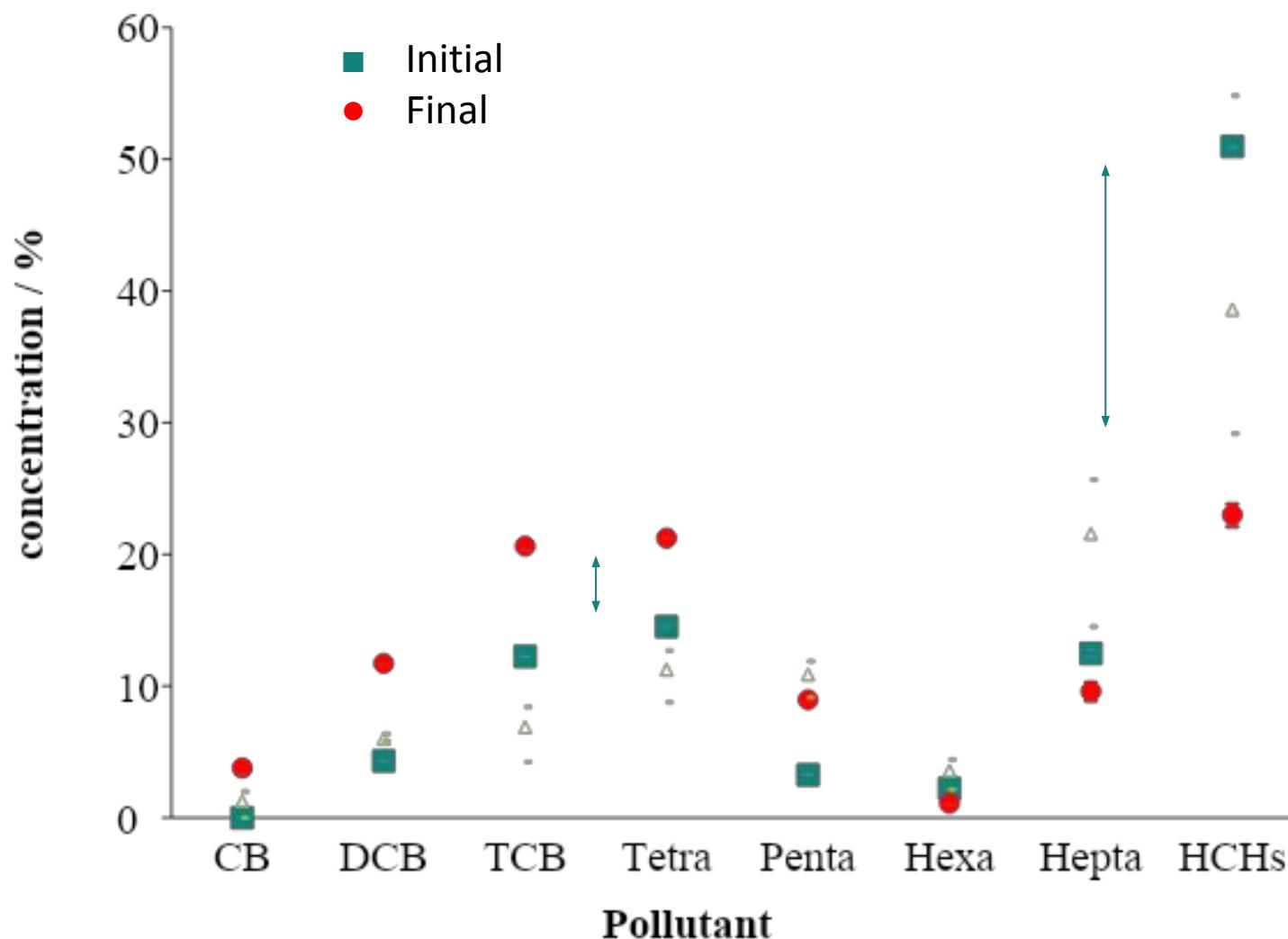
**anode**  
**cathode**  
**anode**  
**cathode**

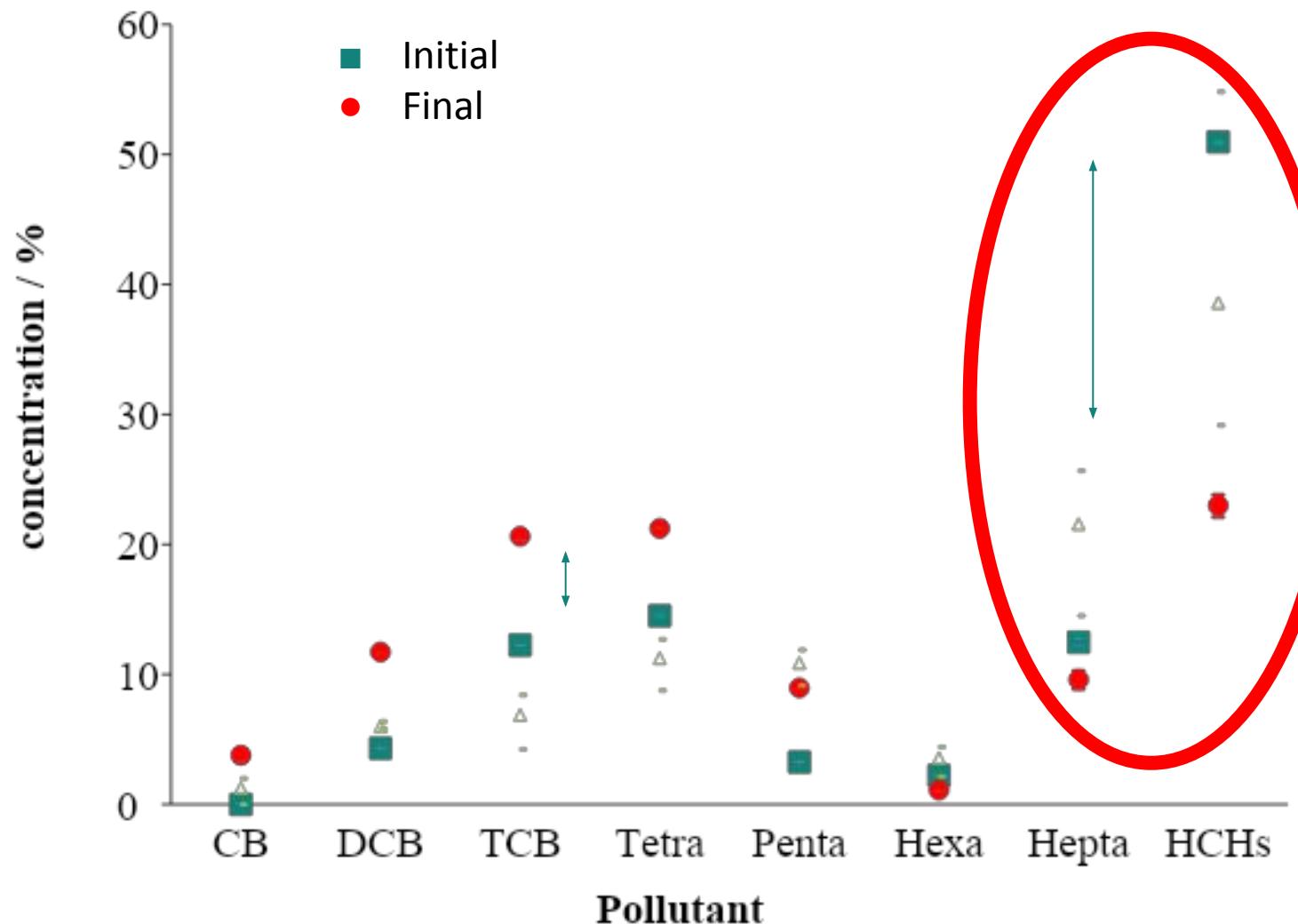


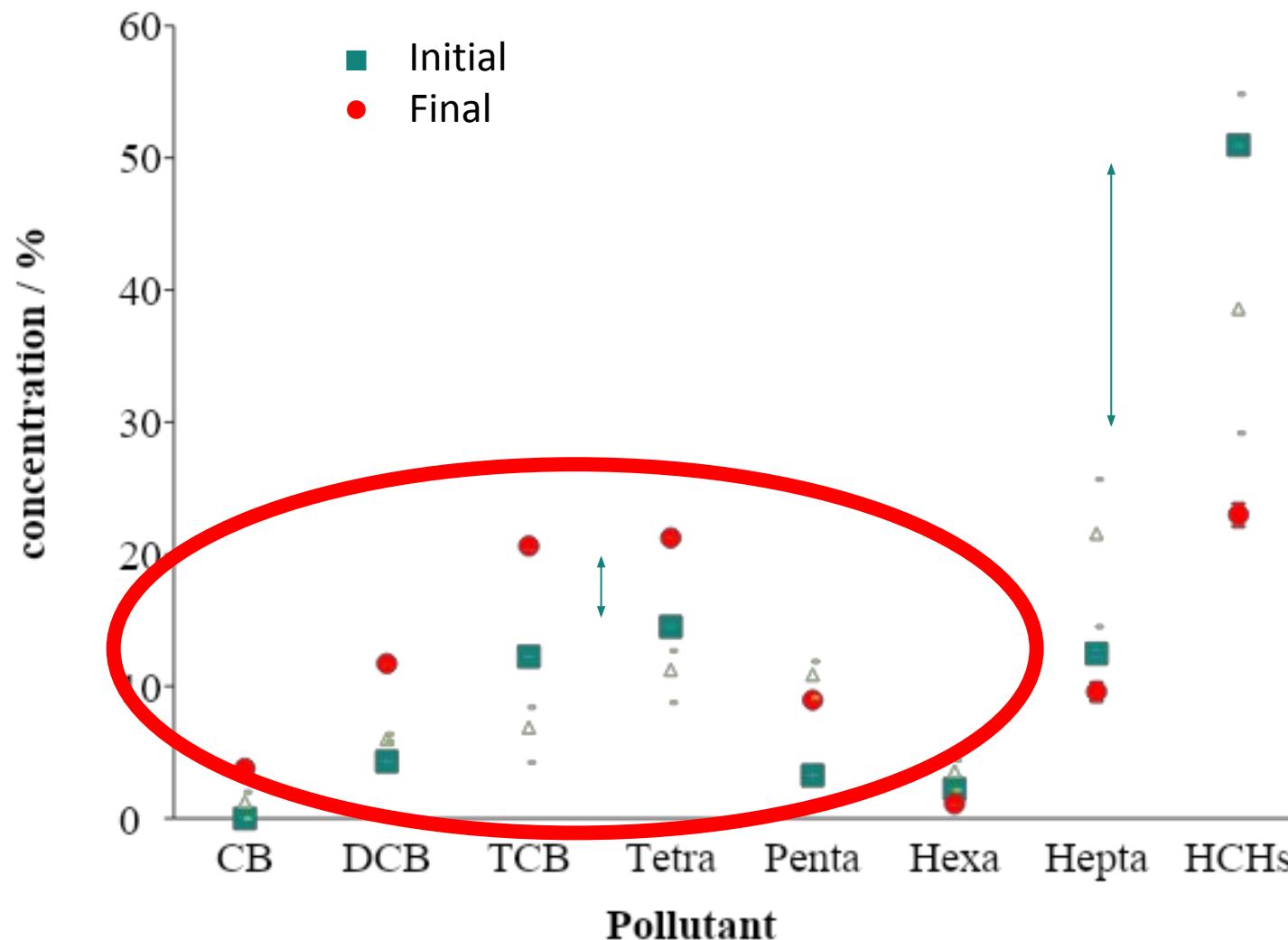
Horizontal  
1V/cm  
Flusing fluid: SDS  
Reversibility: 7 days

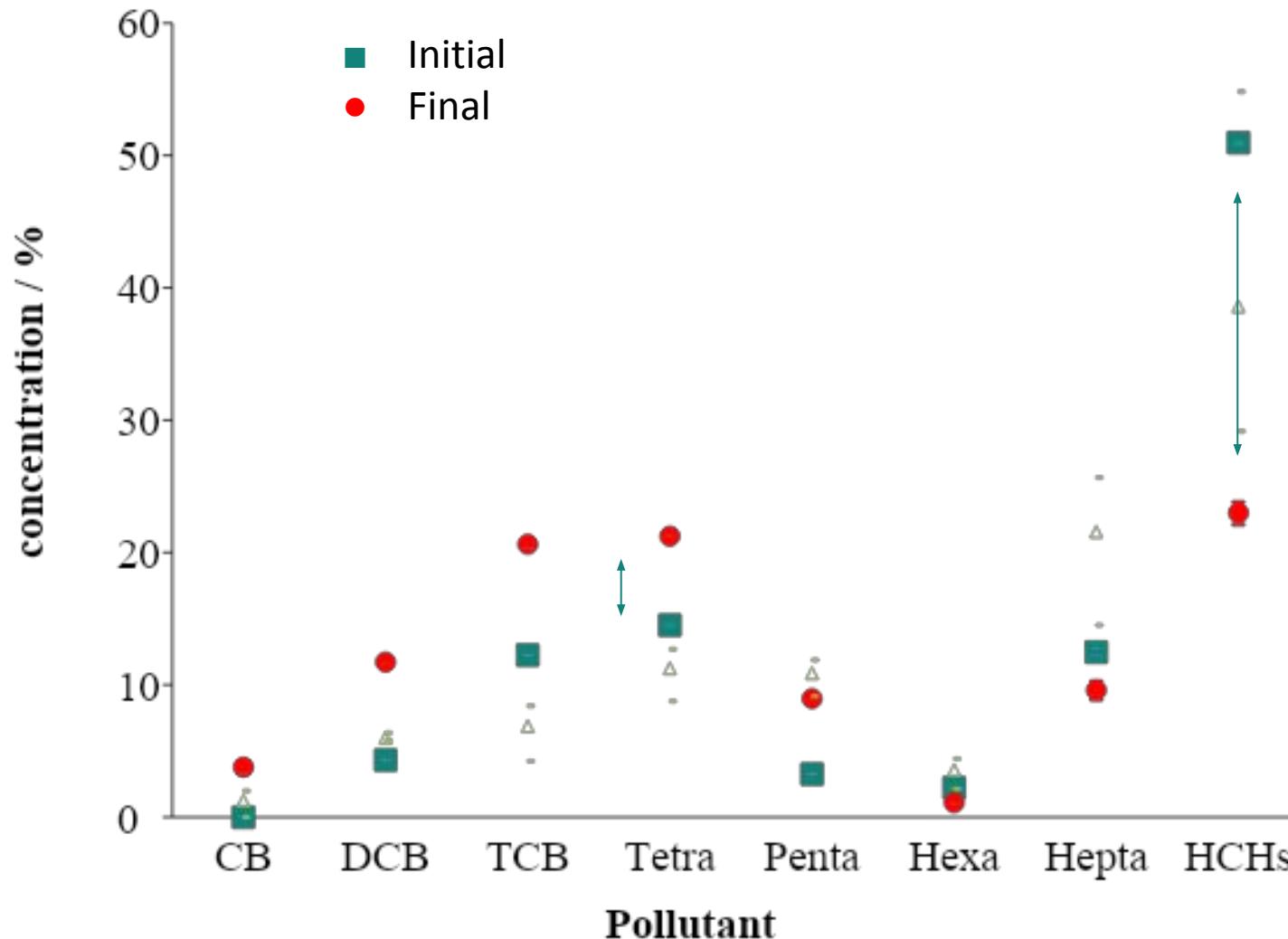
**Reversal electric field**

▲ Post-mortem  
● Anode end  
● Cathode end  
\* Reference well









Low mobility !!!!!  
High dehalogenation!!!!

Next

## In-situ Pilot test in Sardas landfill (Sabiñanigo)





**Validación y diseño de técnicas electrocinéticas para la remediación de los limos del aluvial al pie del vertedero de Sardas (Sabiñánigo, Huesca), contaminados con HCH y otros compuestos organoclorados.**

**Eliminación de HCH y otros compuestos organoclorados en limos del vertedero de Sardas (Sabiñanigo, Huesca) por procedimientos electrocinéticos.**



Departamento de Ingeniería Química



Electrachemical & Environmental Engineering Lab  
E3Lab Research Group, Department of Chemical Engineering  
UCLM





# THANK YOU FOR YOUR ATTENTION

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