



LORENZO, DAVID

Universidad Complutense de Madrid



FACULTAD DE
CIENCIAS QUÍMICAS



INPROQUIMA



PILOT TEST SEAR APPLICATION IN SARDAS LANDFILL REMEDIATION

**Aurora Santos, David Lorenzo, Carmen M. Domínguez, Salvador Cotillas, Raul García Cervilla,
Jesús Fernández, Joaquín Guadaño, Jorge Gómez**

CONTENTS

Introduction



Experimental:



Results:



Conclusions:

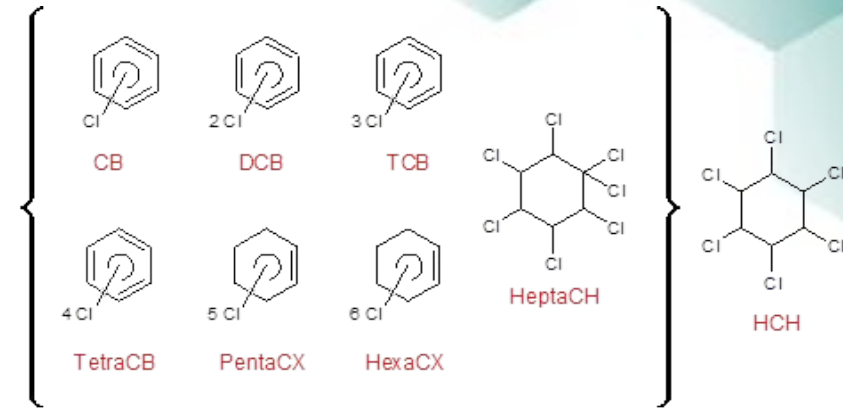


INTRODUCCTION

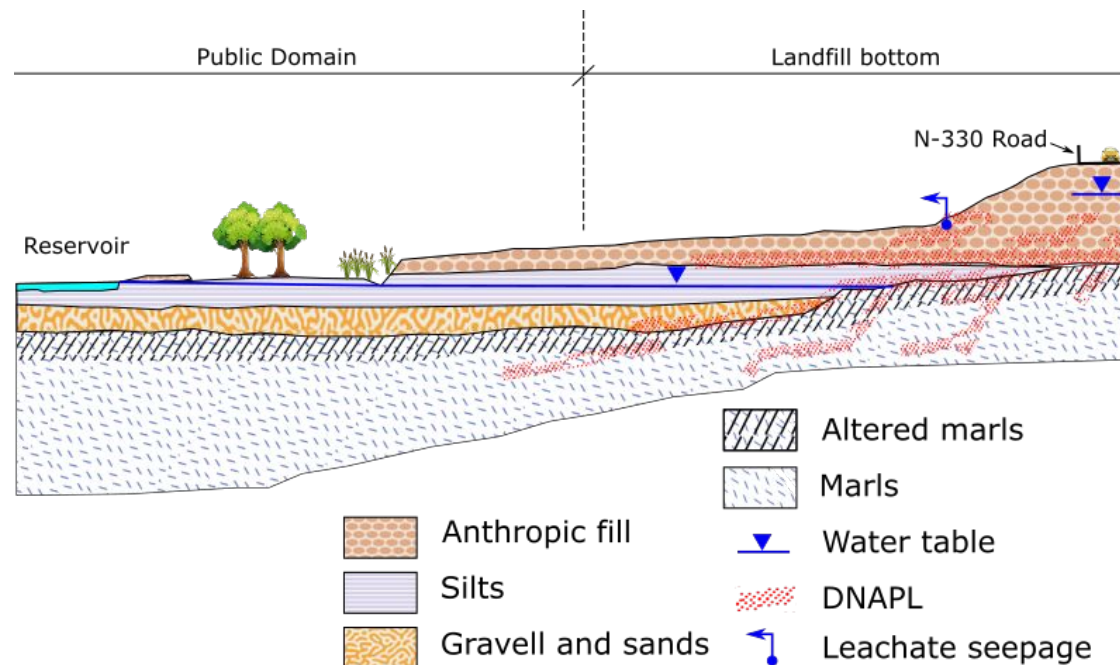
INQUINOSA

Lindane production
(1975-1989)

28 Chlorinated Organic
Compounds
(COCs)



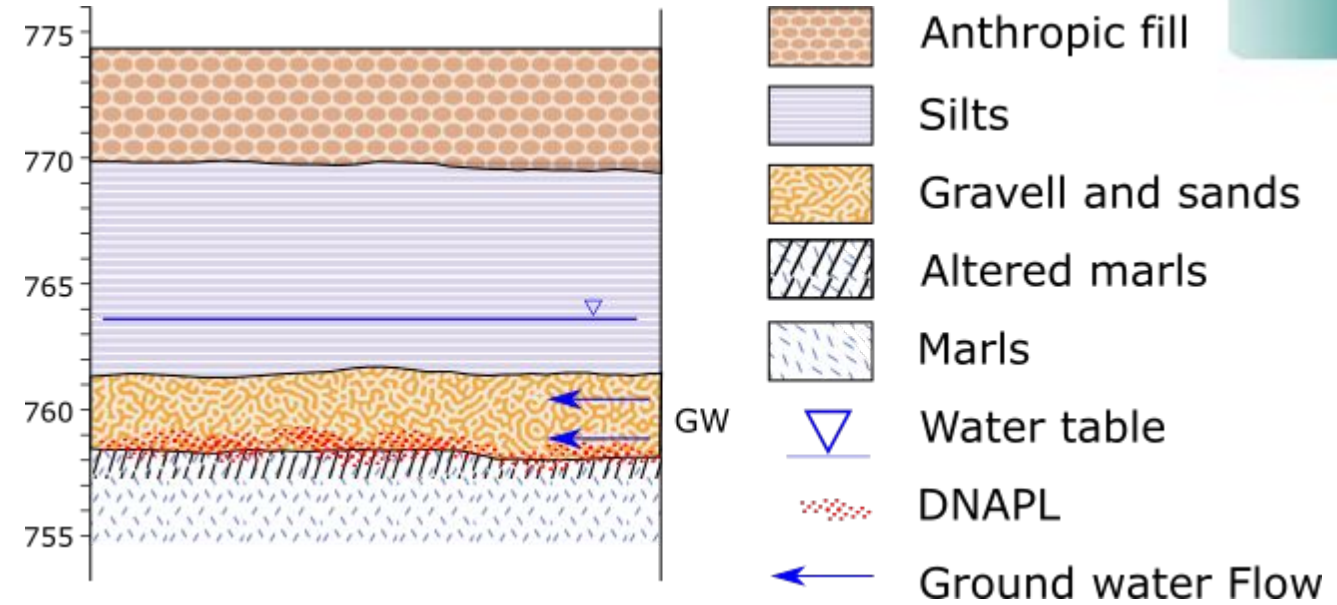
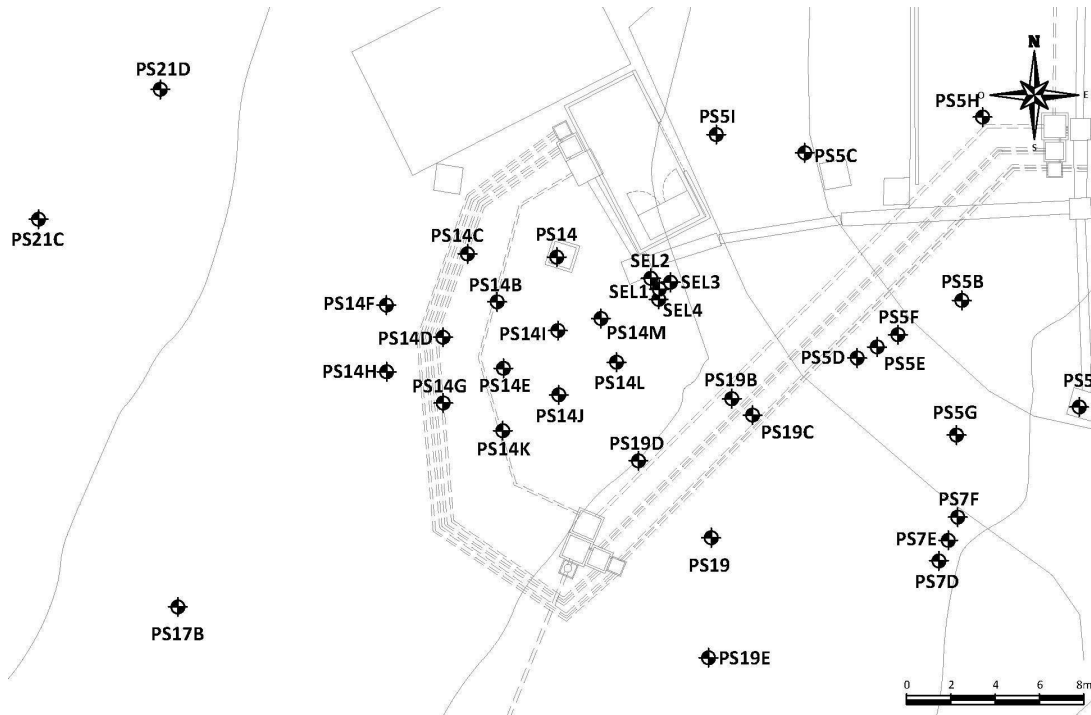
Dumping of untreated waste
at **Sardas Landfills**





CONCEPTUAL MODEL

TEST CELL 81 m²

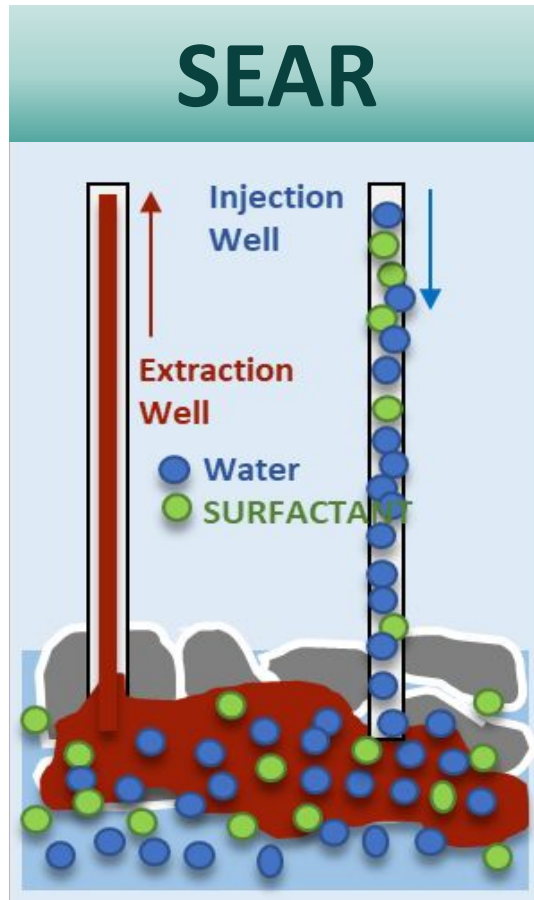


Alluvial depth = 3 m
Porosity = 0.12
Pore Volume = 30 m³.

INTRODUCCTION



SEAR: Surfactant-enhanced aquifer remediation Surfactant selected **Emulse®3**



Surfactant Injection

Solubilisation and mobilisation of DNAPL

Extraction of DNAPL and polluted emulsion

INTRODUCCTION



SEAR ACTIONS IN SARDAS LANDFILL

July 2018

1st action

E-Mulse3® (13 g/L) +130 mg/L bromide
Injection: 5.8 m³ PS14B at 0.6 m³/h.
Monitoring: PS14D, PS14C PS14.
Extraction: 16 h after the injection

Nov 2020

2nd action

E-Mulse3® (20 g/L) +250 mg/L bromide
Injection: 9m³ PS14B,PS14D,PS14E at 0.3 m³/h.
Monitoring: 13 surrounding wells
Extraction: 48 h after the injection

Apr – Oct 2021

3rd action

A new strategy was planned in 2021 to improve the recovery of DNAPL

EXPERIMENTAL: INJECTION EVENTS

7 Injection Events (A-G): April and October 2021

Injection points

The solution was injected using a flexible 1-inch PVC hose and an electric transfer pump.

Alluvial (0.5 m above the contact with marls) or in the alluvial-marls contact.

Injection strategies

Event A: three wells PS14B, PS14E and PS14I

Events B, C, D, E and G, one well (PS5D, PS14E, PS14E, PS14I and PS14D, respectively).

Event F: injection in wells PS14B, PS14J, and PS14M with simultaneous extraction in well PS14I (triangle disposition).

A conservative tracer added during injection events A and B

Variables Tested

$$C_{surf} = 5.4 - 53 \text{ g/L}$$

$$V_{inj} = 0.2 - 7.20 \text{ m}^3$$

$$Q_{inj} = 0.08 - 0.85 \text{ m}^3/h$$

Time elapsed between injection and extraction events = 18 – 391 h

Monitoring

The conductivity profile with the alluvial height was determined during the injection event F.

COC Analysis : Groundwater monitoring during injection.

Surfactant concentration.



EXPERIMENTAL: EXTRACTION EVENTS



Extraction points

The solution was extracted using a flexible 1-inch PVC hose and an electric transfer pump.

Alluvial (0.5 m above the contact with marls) or in the bottom of piezometer.

Extraction strategies

The fluid extracted was sent to sedimentation tanks (2 m³). After 72 h a supernatant sample was analyzed:

COCs concentrations < 200 mg/L to the water treatment plant.

COCs concentrations > 200 mg/L NaOH is added to reach a concentration of 4 g/L in the aqueous phase.



Variables Tested

$$V_{ext} = 6.52 - 38.4 \text{ m}^3$$

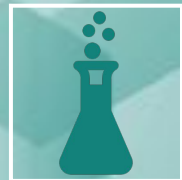
$$Q_{ext} = 0.3 - 5 \text{ m}^3/\text{h}$$

Monitoring

COCs concentrations

Surfactant Concentration

DNAPL recovery



COCs

SURFACTANT

CONDUCTIVITY

TRACER

Dilution 1:10 (MeOH)
GC-FID/ECD

Limonene

Model 914 pH Metrohm

Metrohm 761
Compact IC



GC-FID/ECD

GC-FID

Conductometer

IC

RESULTS: DNAPL CHARACTERIZATION



PS14D September 2021

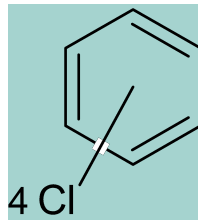
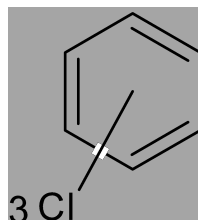
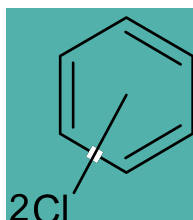
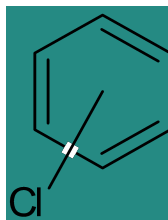


CB

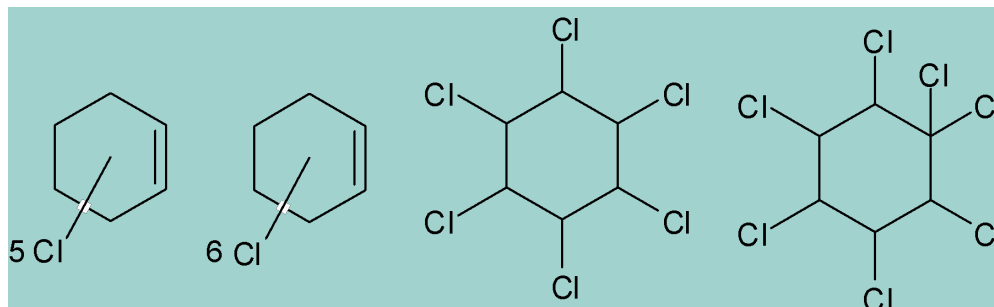
DCB

TCB

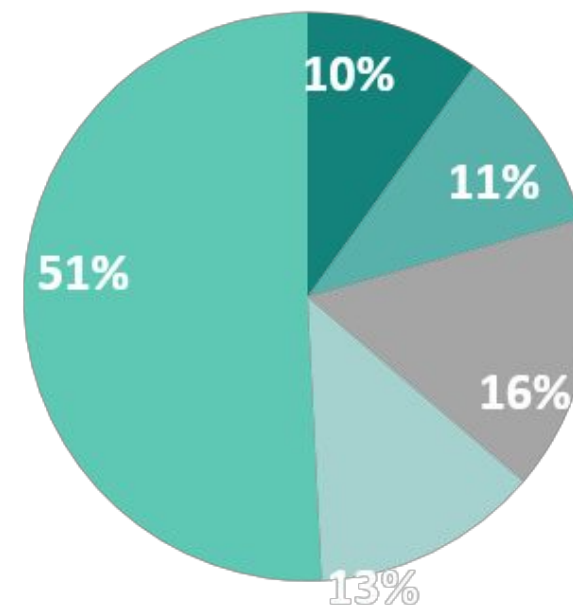
TeCB



NACS

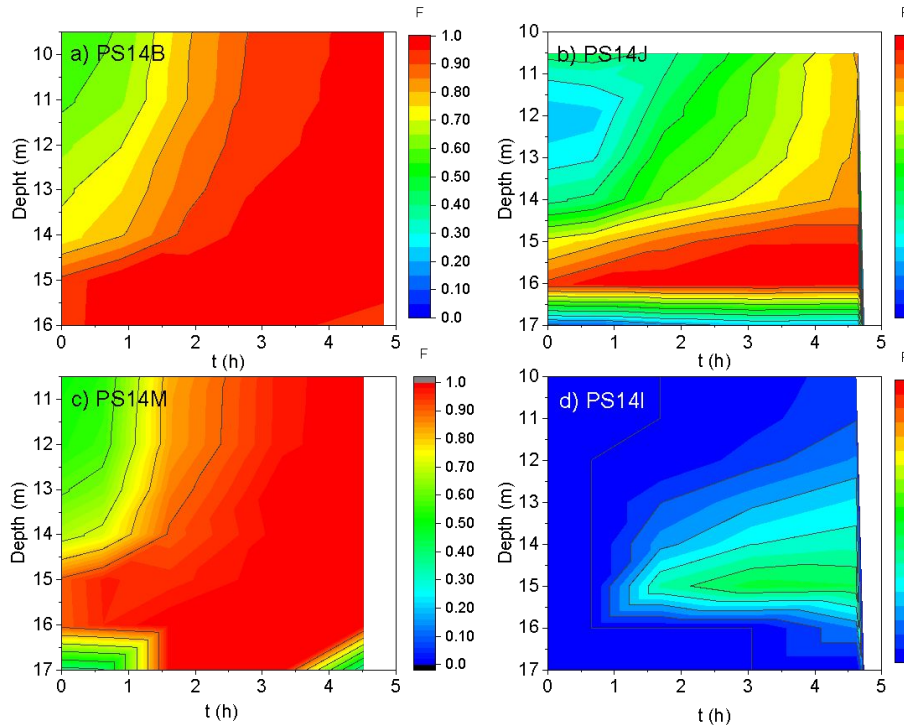


Mass composition

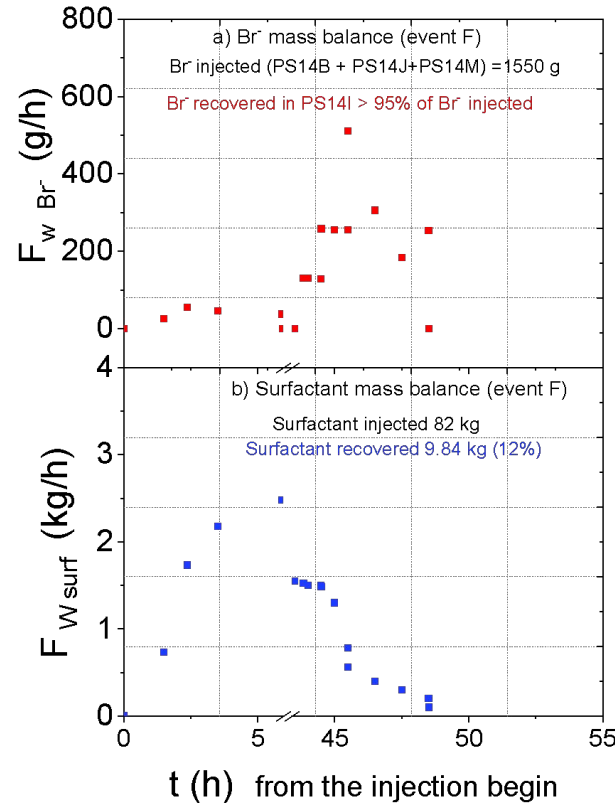


RESULTS: Tracer and conductivity analysis

EVENT F



Dimensionless conductivity profiles (F_K , Eq (3)) with time and depth (m.s.n.s) in wells a) PS14B, b) PS14J, c) PS14M and d) PS14I.



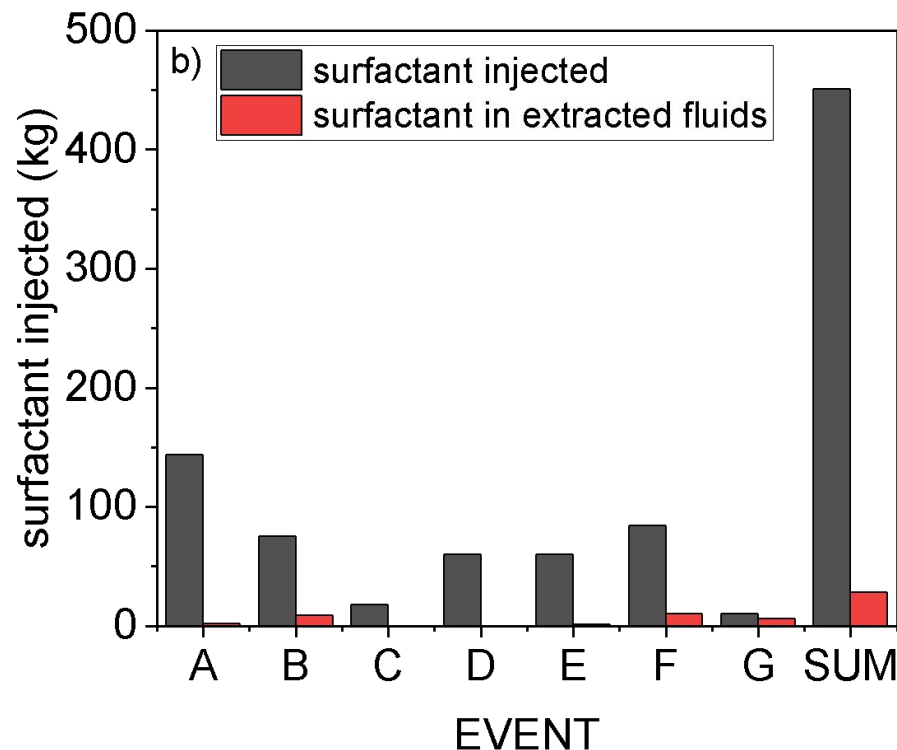
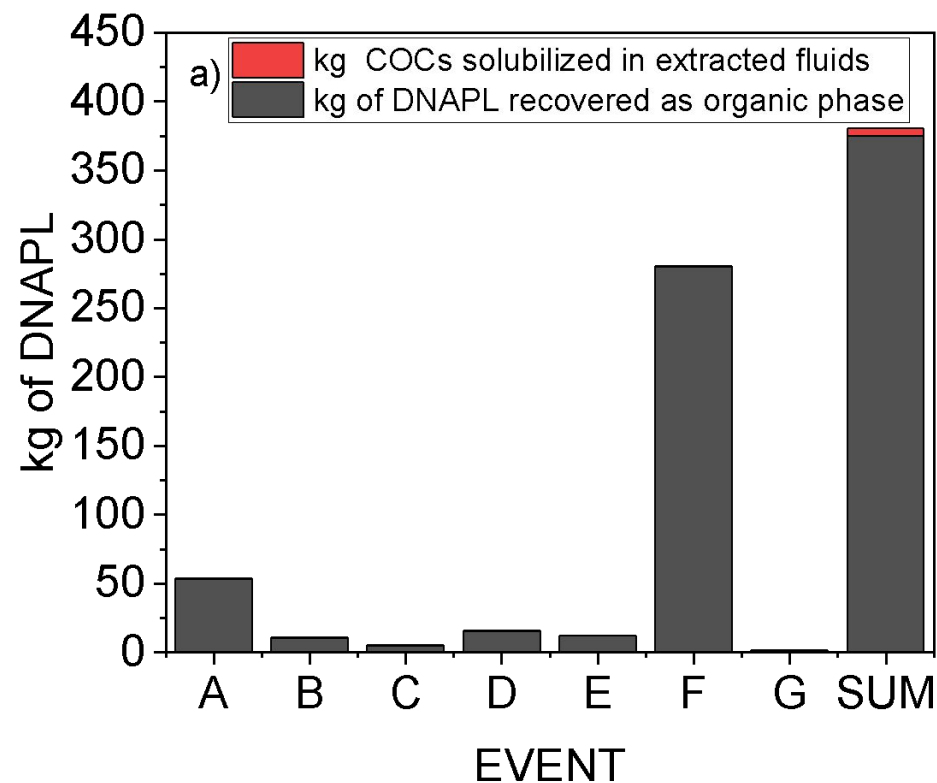
Mass flow rate of a) bromide and b) surfactant with time in the extraction well PS14I in the injection event F. (Area corresponds to the bromide or surfactant recovery mass in well PS14I).

The fluid injected showed a **high radial dispersion.**

$$F_{surf} = \frac{C_{surf}}{C_{surf\ injected}} \quad F_{Br^-} = \frac{C_{Br^-}}{C_{Br^-\ injected}}$$

$F_{surf} < F_{Br^-}$ surfactant is **adsorbed** in the alluvial clays or absorbed in DNAPL

RESULTS: DNAPL RECOVERY



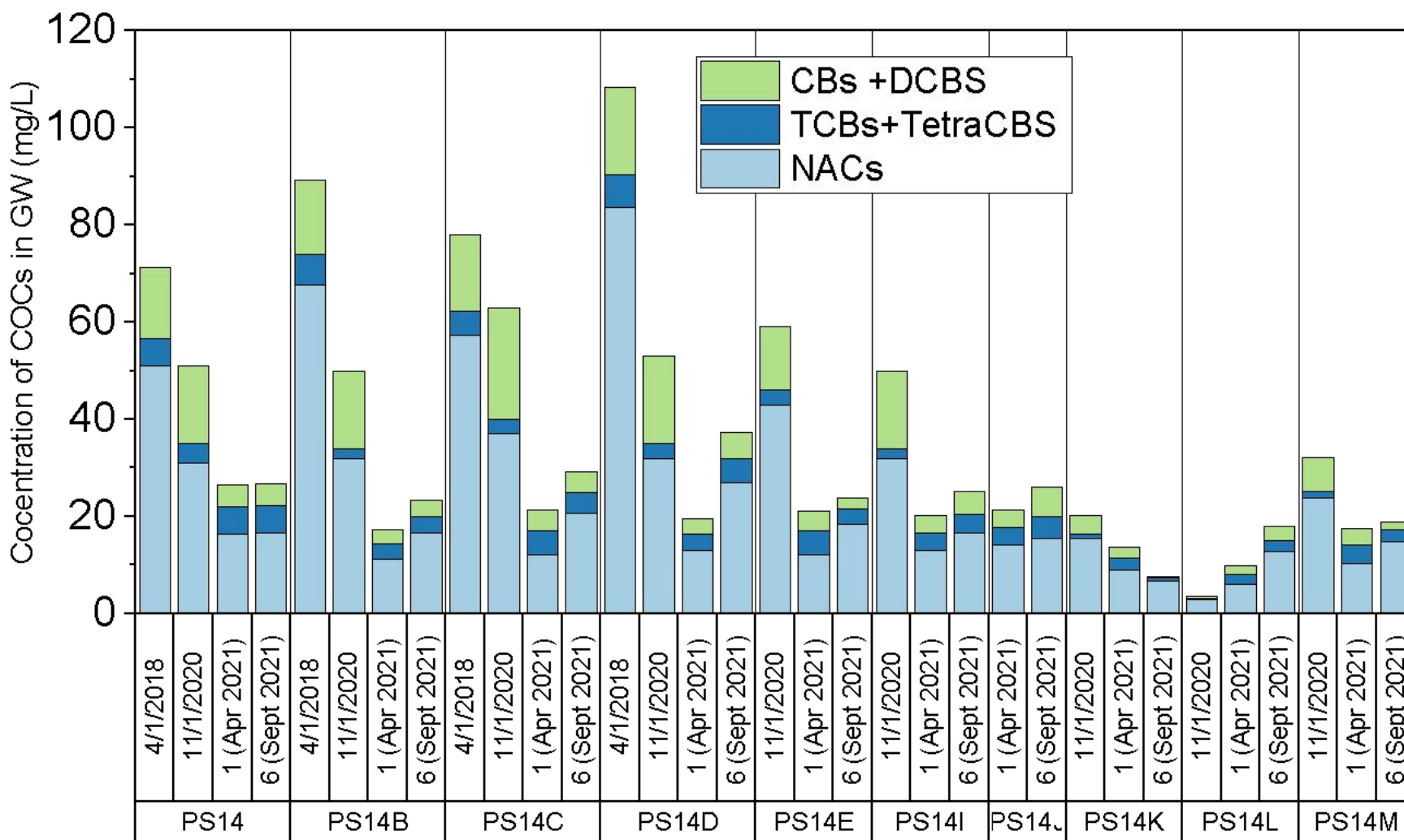
Events B, C, D, E and G. In these events, the extracted GW were analyzed. DNAPL recovered was mainly found as droplets that sediment with time.

Event F most productive.

Time elapsed between the injection and extraction stages have significantly influenced this recovery.

Higher DNAPL masses have been extracted by injecting low flow rates of the surfactant solution (less than 0.3 m³/h) and higher extraction flow rates of the injected fluid (> 3 m³/h).

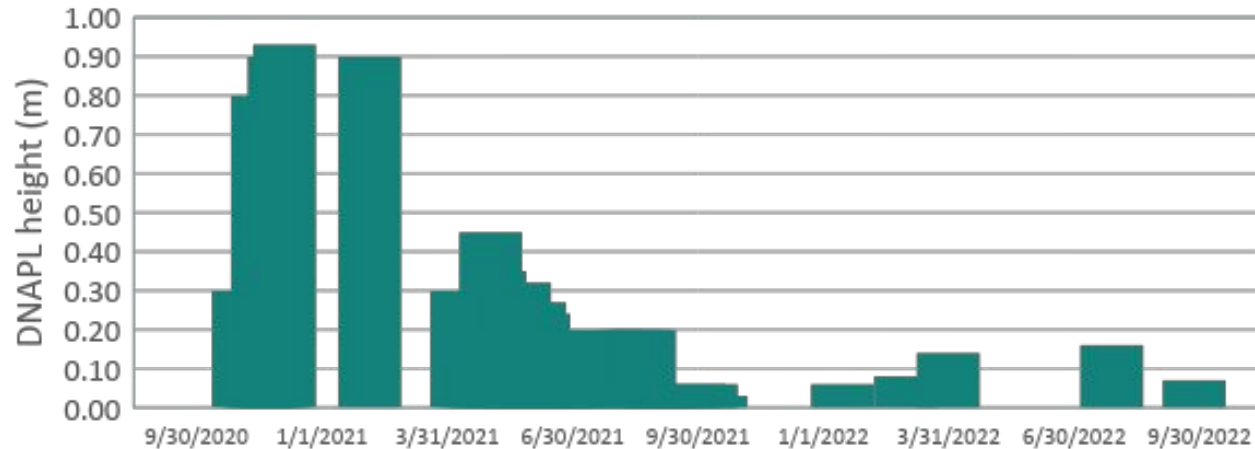
RESULTS: Groundwater monitoring in 2021



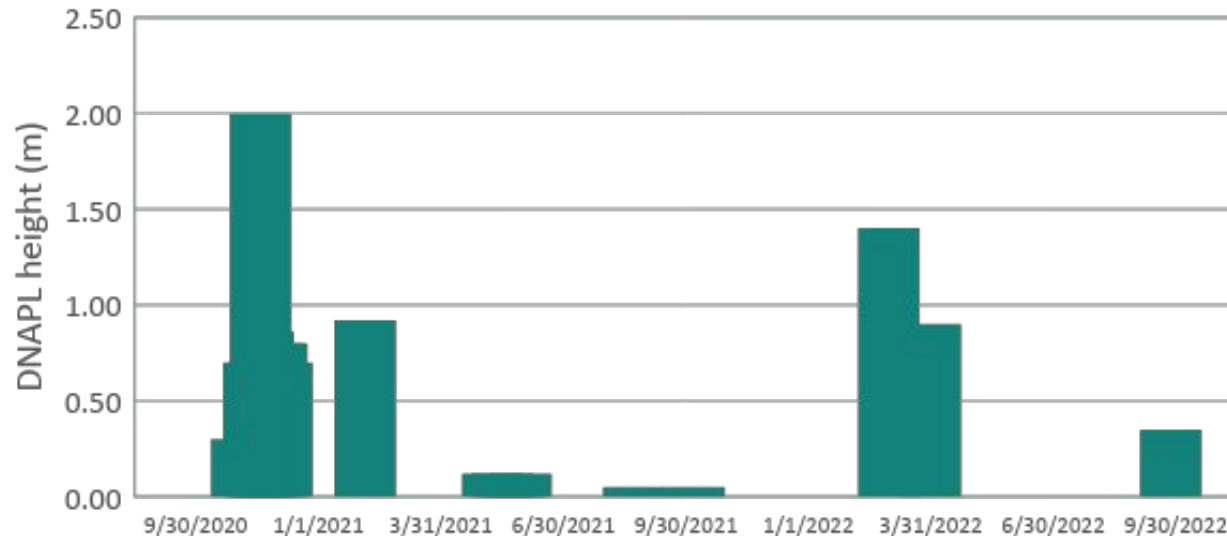
After the surfactant injection in 2020, a remarkable COCs decrease in GW was noticed in 2021.

In soil flushing carried out in 2018 and 2020 had a high impact in the COCs concentration in GW.

RESULTS: DNAPL accumulation in PS14x wells

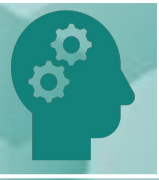


In well PS14E, DNAPL accumulation was always lower with time. **The DNAPL has been notably reduced in this area near PS14E by surfactant injections in 2020 and 2021.**

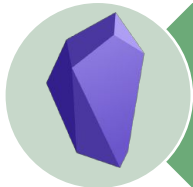


DNAPL accumulation is still significant in PS5D. In these wells, fewer SEAR events have been carried out (only event 2 in 2021), with low efficiency.

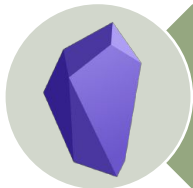
CONCLUSIONS



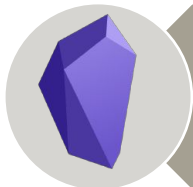
Since 2018, the surfactant injections to remediate a highly contaminated area of this alluvial have led to a **decrease in groundwater contamination** from 14 to 4 mg/L of HCHs.



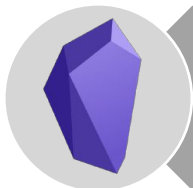
Solubilization of DNAPL adsorbed in the soil alluvium during the successive surfactant injections.



Recovery of the DNAPL by mobilization.



The flow rates of surfactant injection and injected fluid extraction and the time elapsed between the injection and extraction stages have significantly influenced this recovery



The **SEAR treatment is a better choice** until the residual contamination drops to a sufficient value and other methods, such as ISCO or bioremediation, could be applied.

ACKNOWLEDGEMENTS:

This work was supported by the project UCM-EMGRISA (ref 434-2020) “Aplicación de tratamientos fisicoquímicos en el vertedero de Sardas” under contract with Gobierno de Aragon (Exp. 1404-4422-2019/19).

THANK YOU FOR YOUR ATTENTION

dlorenzo@ucm.es

