Evaluation of plant effects on the mobility of heavy metals in an ancient mine phytoremediation action.

The case of « The Avinières » at St Laurent le Minier (F)

Photo : JC Cleyet-MAREL, LSTM

Navel A., Spadini L., Gaudet J.P., Schneider J.,

Vince E., Sebastianutti S. and J.M.F. Martins

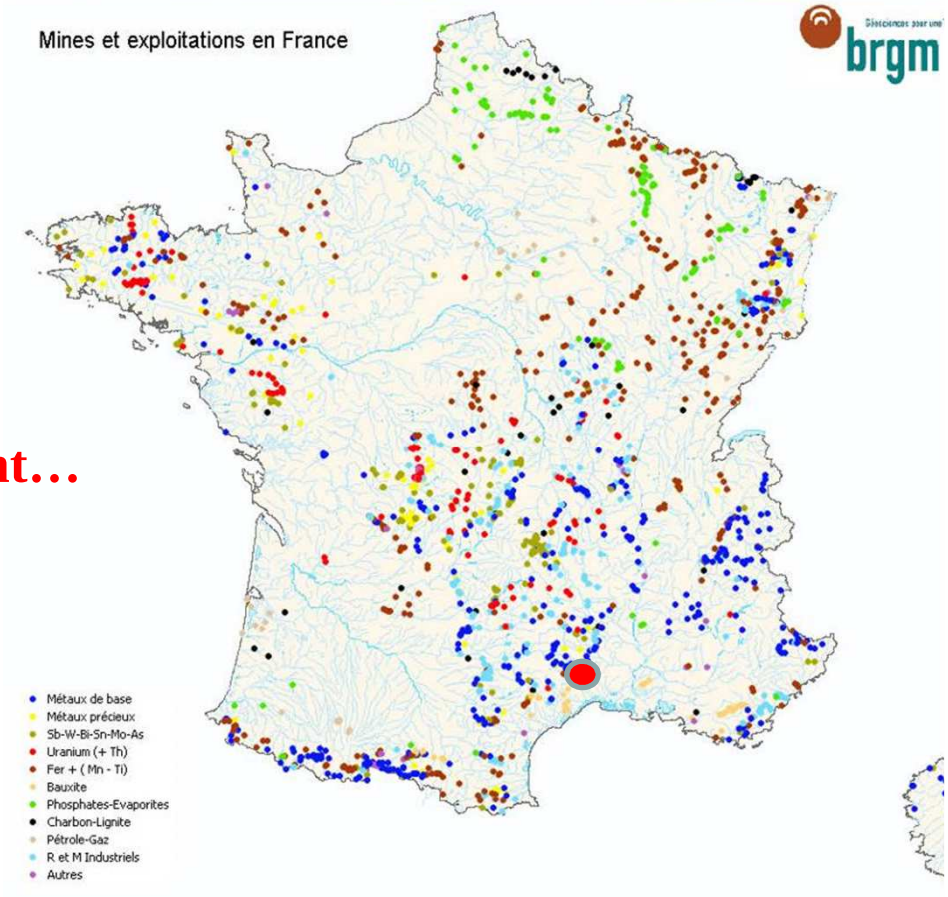
Univ. Grenoble France

Context : mining activity in France

Numerous active or abandoned mines

Orphan sites polluted with metals :

→ hot-spots of heavy metals (x100 to x1000 > norms)



These metals are toxic in the environment…

- Contamination of soils and the food chain.

… and for human health

- Bioaccumulation
- Toxic effects at short and/or long term.

→ Management of these sites by ADEME :

Reduction of the risk associated with metals (frequently close to rivers) through different approaches :

Pollution control (excavation, extraction…), Confinement, Phytoremediation (Stabilization) …

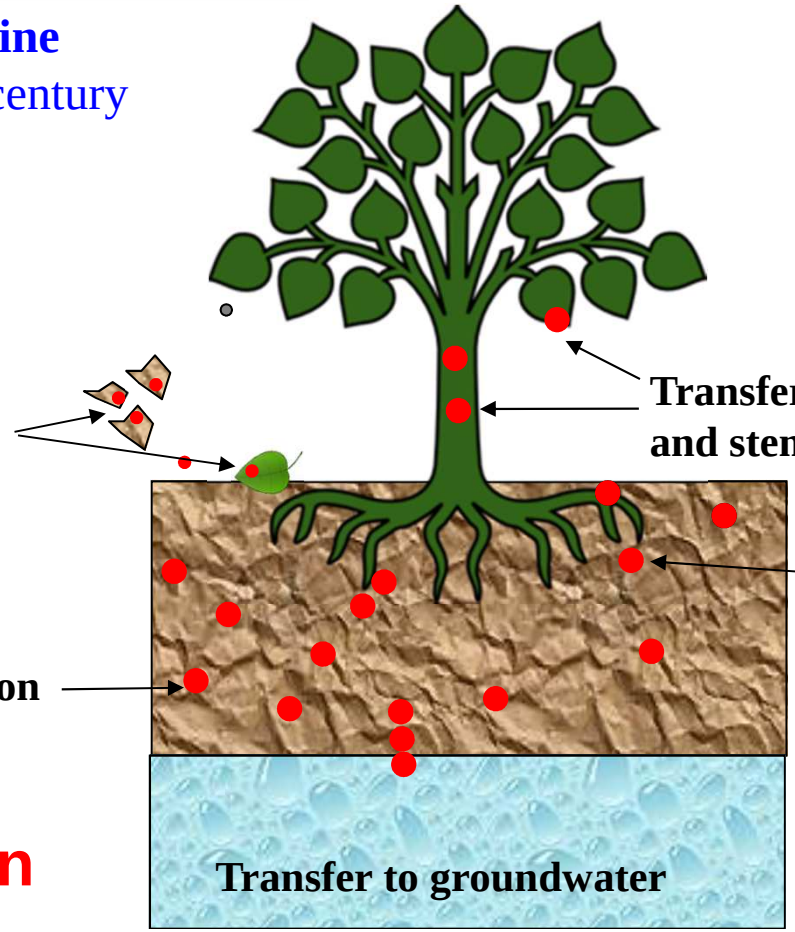
SYMETAL PROJECT : French ANR

Phytoremediation of the abandoned Zinc mine of St Laurent le Minier.

What is phytoremediation ?

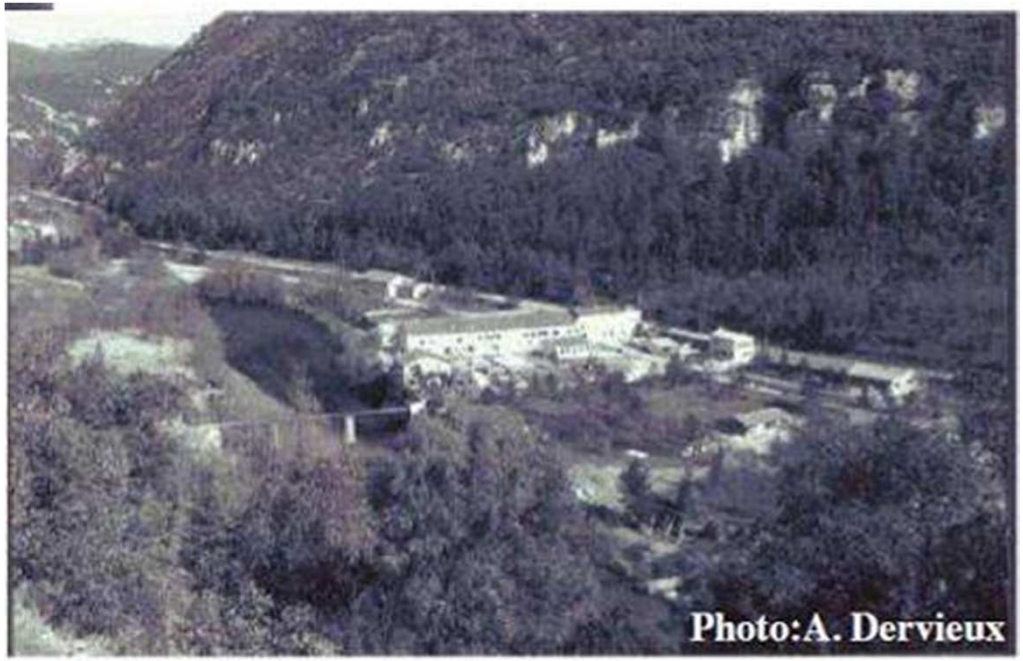
➔Accelerating nature action…

Petra Alba Zinc-Mine
abandoned in the 16th century



!!! Risk evaluation

Study site : Mine of the « Avinières »



Collection personnelle G. Debussche

Date : 1918

Tailing pounds

→ 200’000 tons of Zn ore extracted

→ Mine closed in the 1950s

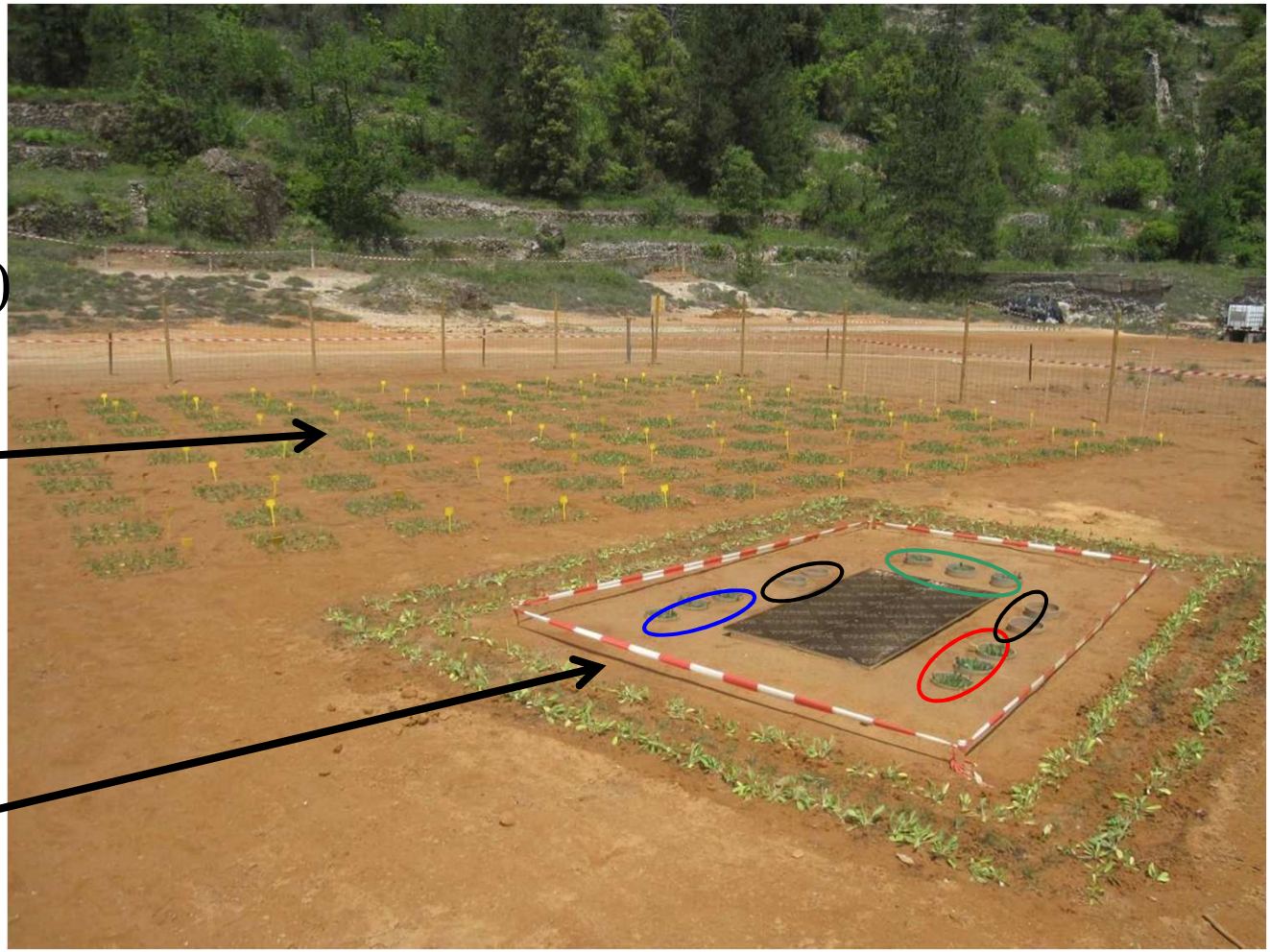
Health problems : Children victim of Saturnism (presence of Zn and Pb around houses).

➔ SYMETAL Project (ANR CESA) :

Mine tailings rhizo-stabilization by **METAL**licolous plants associated to **SYM**biotic micro-organisms.

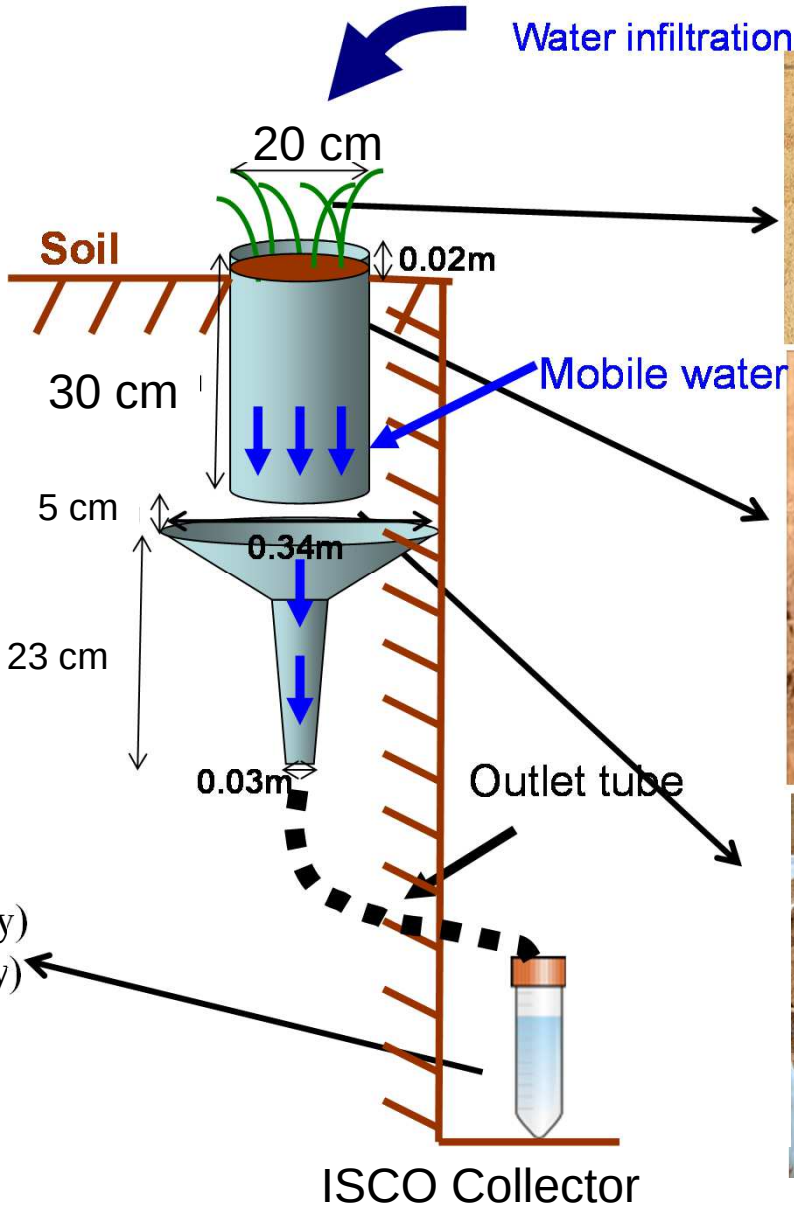
Optimization of the plant cover in small plots in real situation : Mycorhization and nodulation (N fixation)

Study of the effect of phyto-stabilisation on metals mobility (Zn, Pb et Cd)



Lysimeter set up

	[Me] (mg/kg)	Limit [Me] (mg/kg soil)
Cd	**745**	2
Pb	**39'305**	100
Zn	**129'032**	300



Analyses:

pH,
Alcalinity (acid-base titrimetry)
Anions (Ionic chromatography)
Cations (ICP-OES)
COD (TOC analysor)
MEB, …

The model plants : tolerant to metals

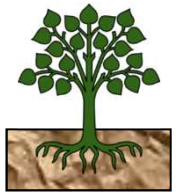
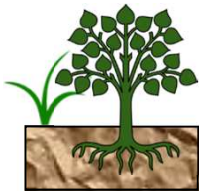
Anthyllis vulneraria

➔**Mesorhizobium**

➔**Mycorhization**

\+ ***Festuca* sp.** \+ ***Koeleria sp.***

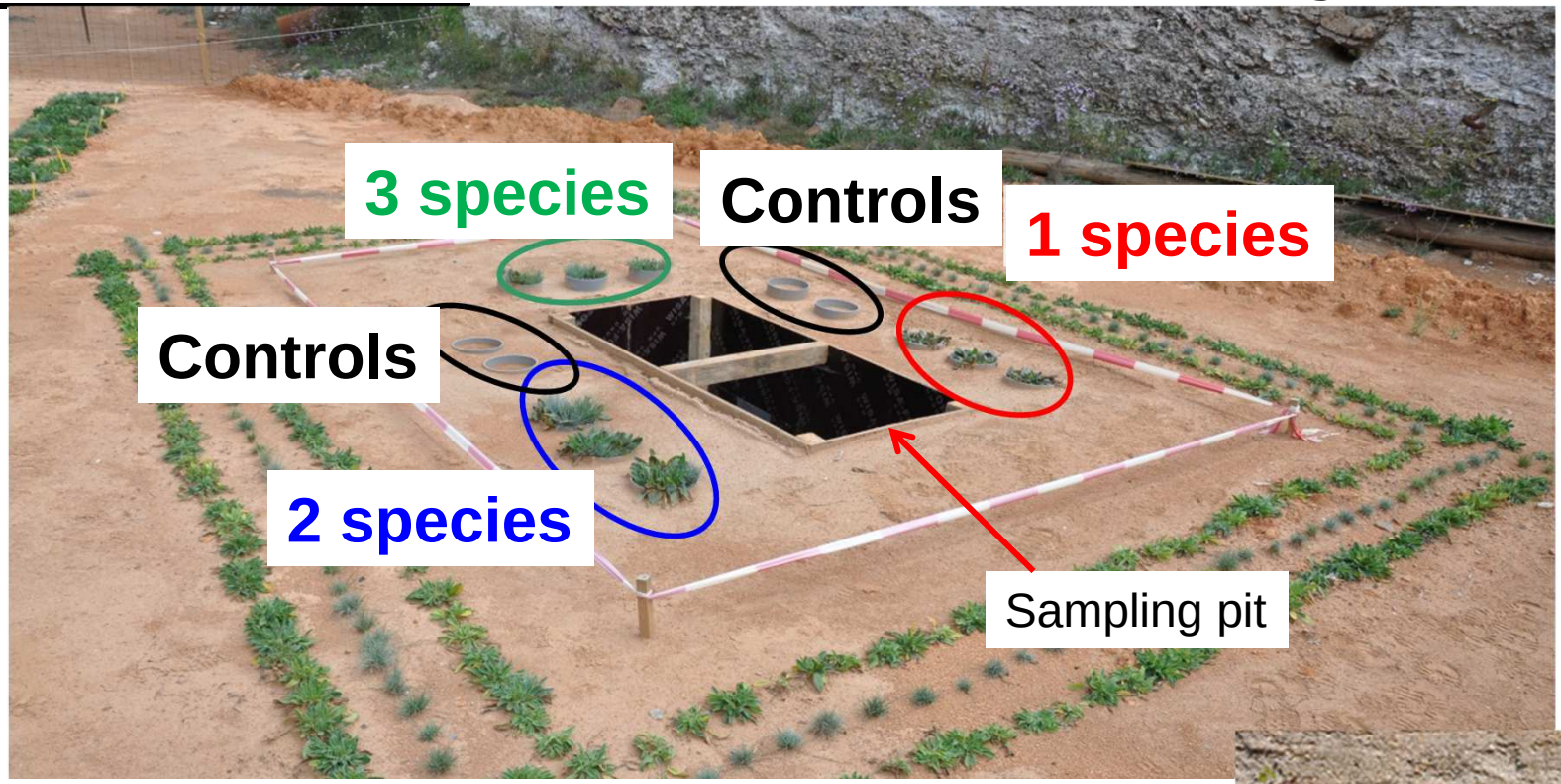
Conditions tested :

No plant	**1 plant**	**2 plants**	**3 plants**
Control			
	Anthylis vulneraria	***Anthylis vulneraria***	***Anthylis vulneraria***
		Festuca	***Festuca***
			Koeleria

RESULTS :

Anthyllis + Festuca + Koeleria

1P **2P** **3P**



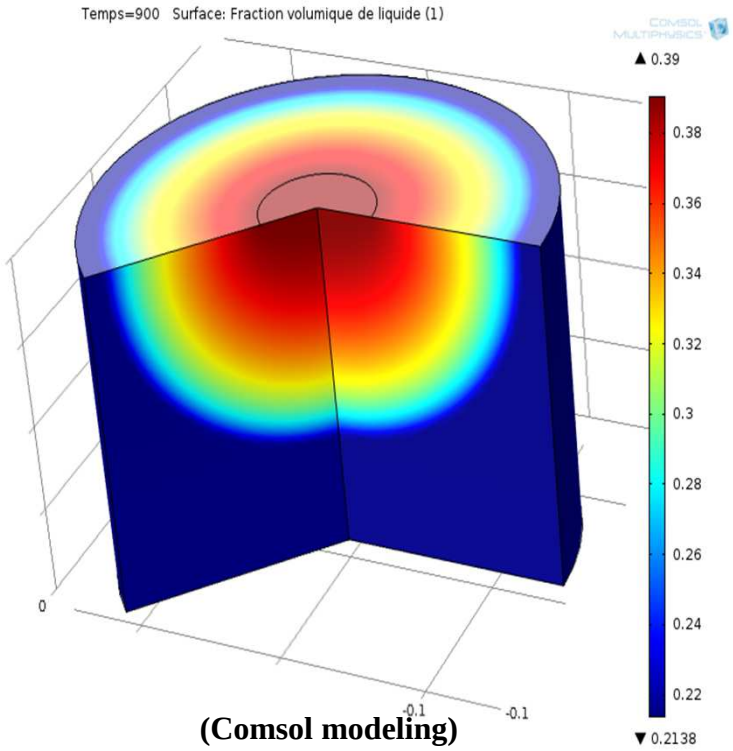
Monitoring over 3 years (04/2012 to 04/2015)

+ biannual metal leaching experiments

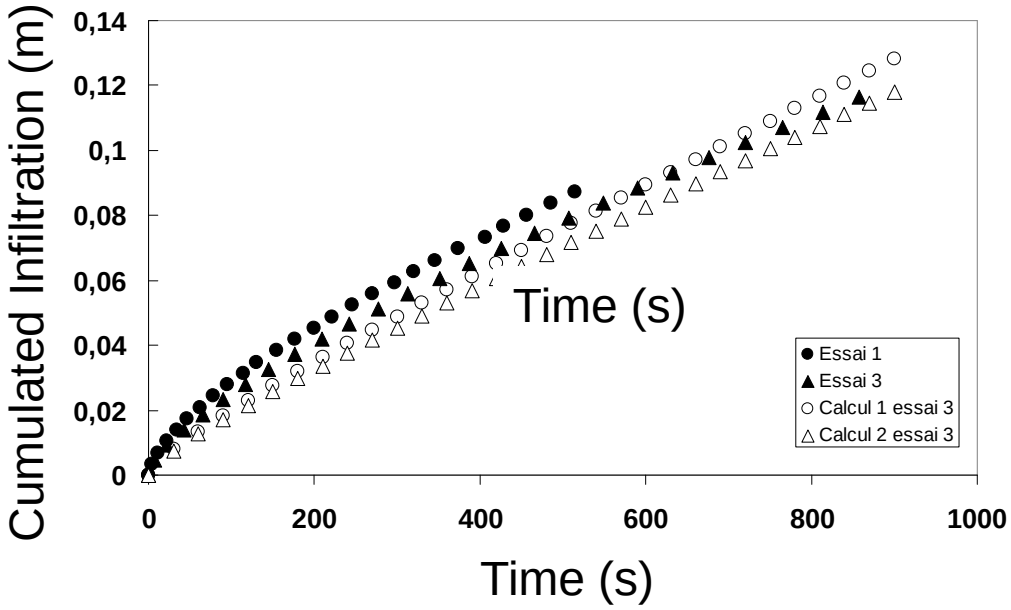
Plant cover installation and persistence

Anthyllis (1P)		*Anthyllis + Festuca* (2P)		*Anthyllis + Festuca + Koeleria* (3P)
	09-2012		09-2012	
	04-2013		04-2013	
	09-2013		09-2013	
	04-2014		04-2014	
	09-2014		09-2014	

Characterization of hydrodynamic parameters : Beerkan Test



(Comsol modeling)

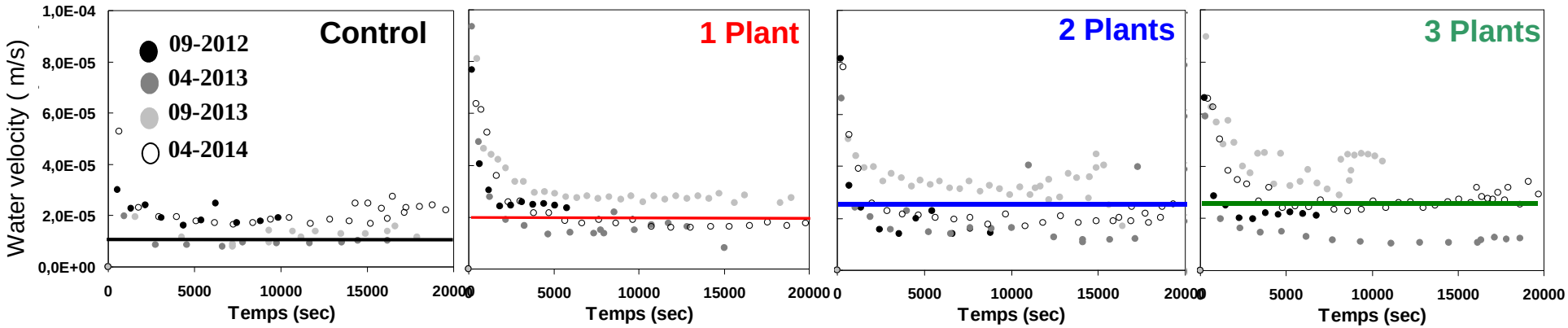


➔ Hydraulic conductivity of the undisturbed material :

$Ks = 1.1\ 10^{-5}\ m\ s^{-1}$

Hydrodynamic parameters characterization : Beercan tests

Infiltration ≈ 0,5 m of water



Disturbed material in lysimeters :

$Ks \approx 2.0\ 10^{-5}\ m.s^{-1}$

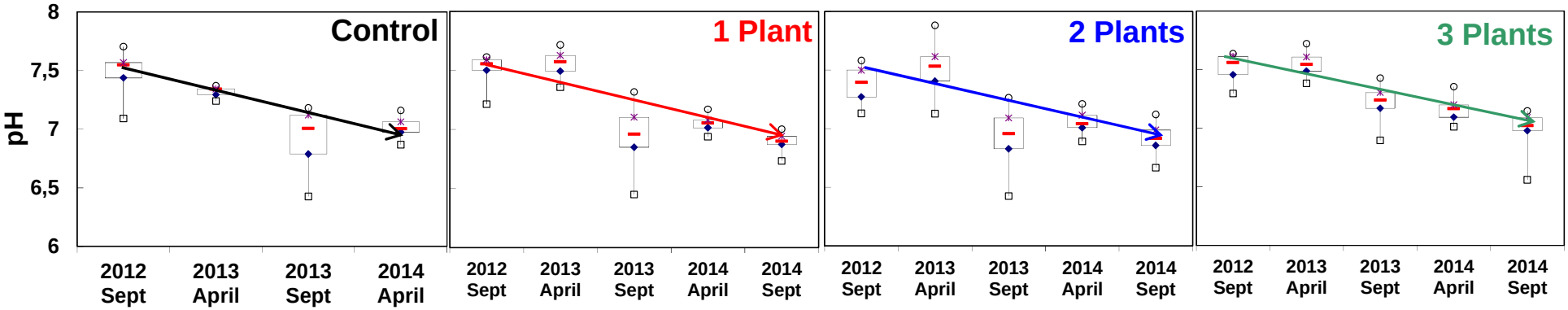
➔ Hydraulic conductivity is slightly higher in lysimeters / *in situ*

➔ No significant evolution of Ks during the 2 years, whatever the number of plant species installed

RESULTS :

2 years evolution of leachates composition

Temporal evolution of pH in lysimeters leachates

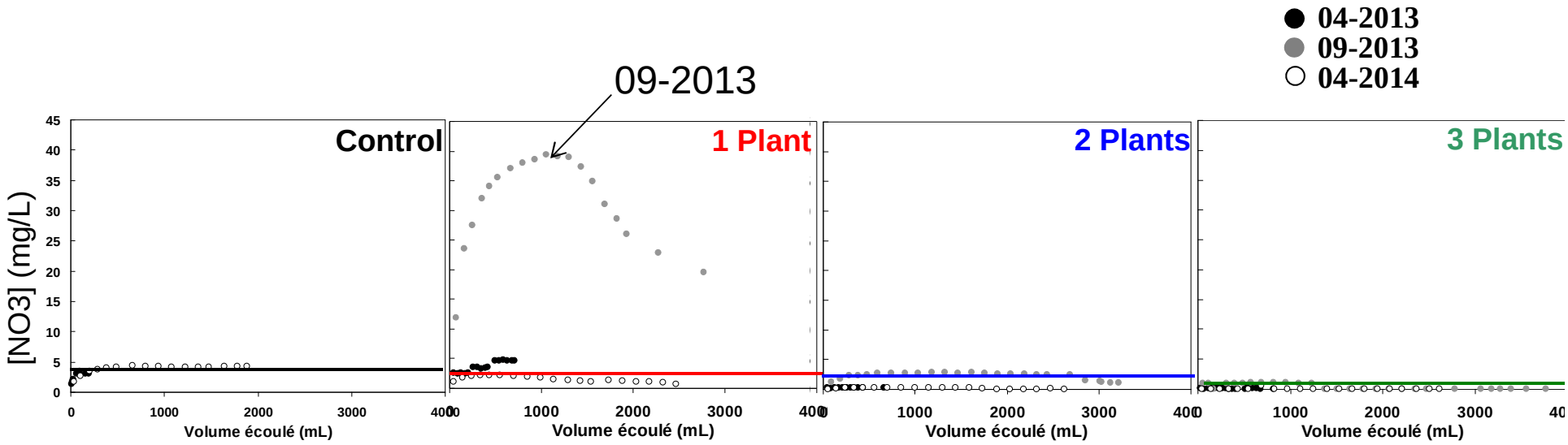


➔ **Decrease of pH in all lysimeters :**

Due to tailings mixing and oxidation, compost addition…

➔ **No significant effect of plant covers on pH**

Temporal evolution of [NO_3^-] in lysimeter leachates



➔ **Detection of [NO_3^-] in all lysimeters : due to inital addidtion of compost + fertilizer**

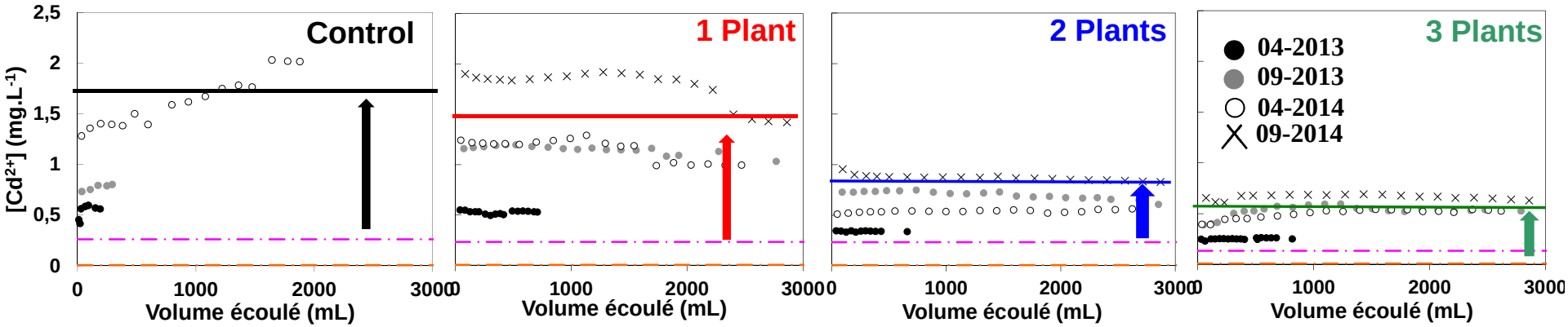
➔ **High [NO_3^-] in « 1 Plant » after the flowering (09-2013) :**

→ **oxydation of nitrogen fixed by Mesorhizobium > to plant consumption**

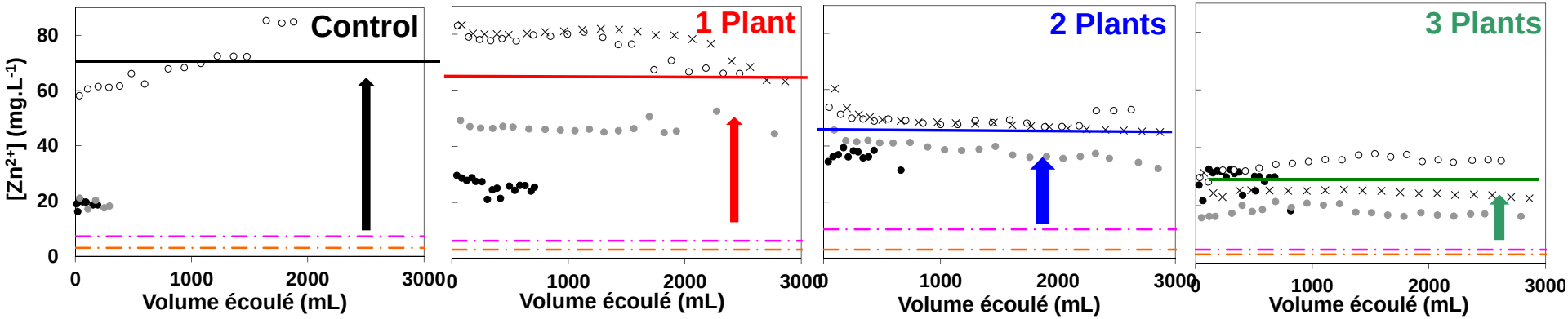
➔ **Nitrogen consumption by *Festuca* and *Koeleria* species**

Temporal evolution of [Cd] and [Zn] in lysimeter leachates

Cadmium



Zinc

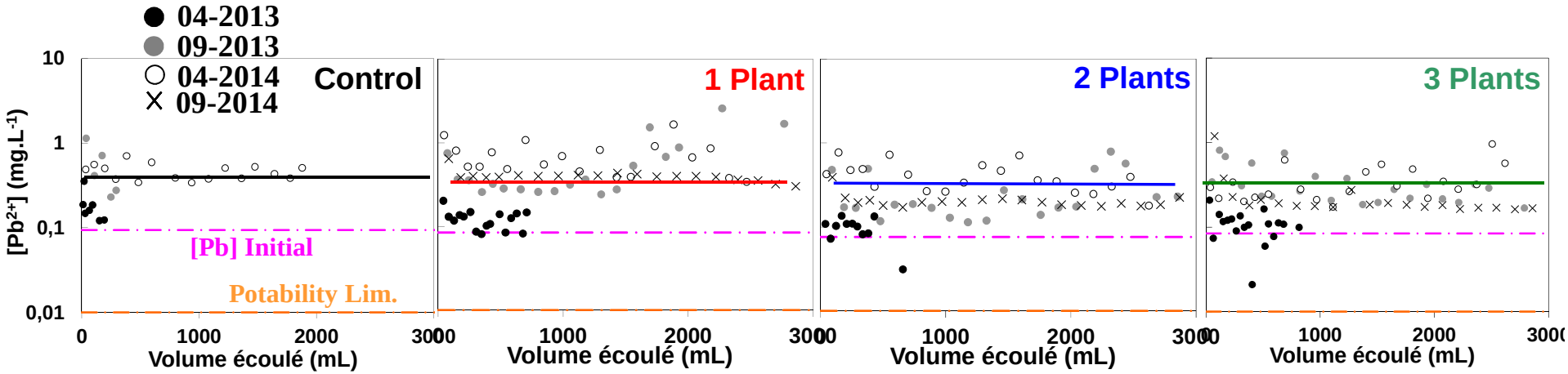


➔ [Me] >>> to potability norms

➔ Control : increase of $[Cd^{2+}]$ and $[Zn^{2+}]$ probably due to pH increase

➔ Beneficial plant effect on Cd and Zn mobilization

Temporal evolution of [Pb] in lysimeter leachates

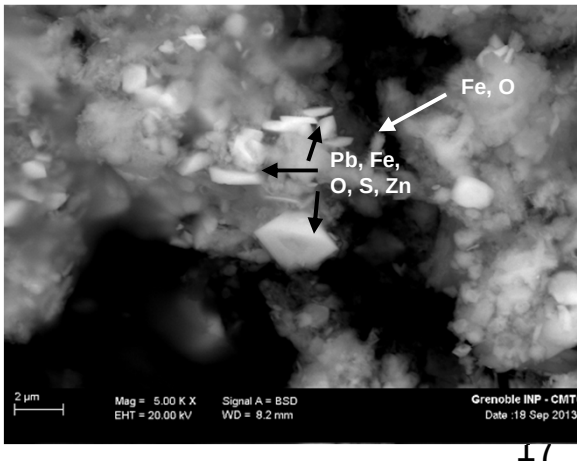


➔ **[Pb] highly > water potability limit (0,01mg/L)**

➔ **No temporal evolution of [Pb] in all conditions (vegetated or not)**

➔ **No significant effect of the plant cover on Pb leaching**

➔ Relates to a particle facilitated transport process of lead



CONCLUSIONS :

The study permitted to optimize conditions of ore residues phytostabilization !

Effect of plant cover installation on metals mobility :

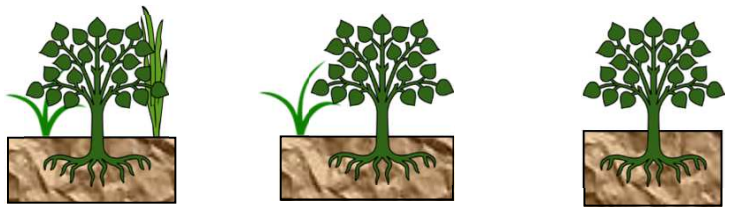
✓ pH modification in all situations: acidification due to compost addition …

✓No significant modification of material hydrodynamic properties

✓ Leached metal concentration are always >>> potability norms

✓ Better cover installation when *A. vulneraria* is associated with other plants

➔ 3P > 2P > 1P (observed in ancient mines)



Mutual benefits

✓ No modification of Pb mobility.

✓ Strong limitation of Cd and Zn mobility in the lysimeters with 2 or 3 species

➡ Leached metal concentration remain > potability norms

TransPore Group

Pau (F)

LSTM Montpellier (F)

Thank you