On the use of lysimeters and ecotrons to study the fate of pollutants in soil plant ecosystems

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Terrestrial ecosystems are strongly affected by human activities and environmental changes.

- **Fate and impact of polluants**, a major concern for human and environment health

What to do with contaminated sites and soils ?

-> Soils are limited ressources
-> Need for long term studies, integrated and pluridisciplinary approaches

Characterization
Impact of pollution

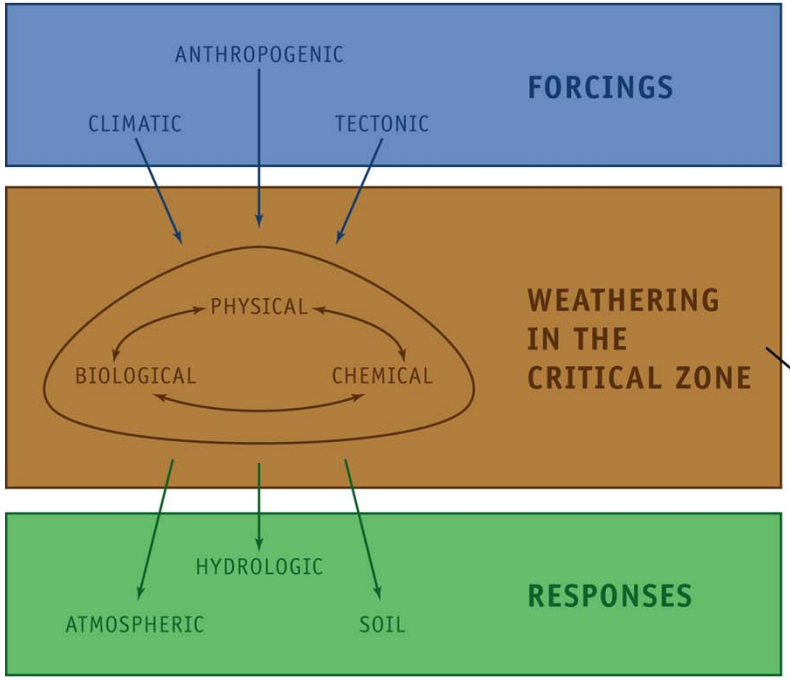
Remediation

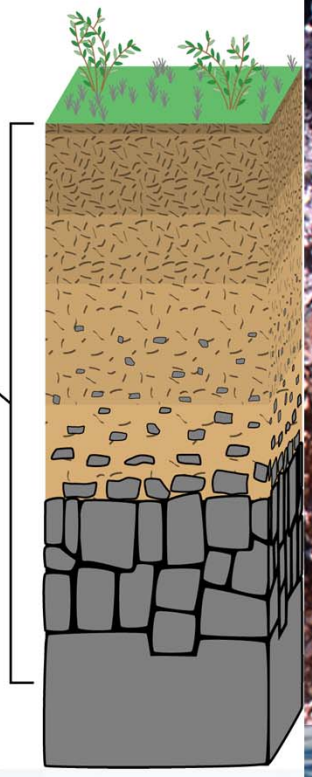
Restoration of soil properties
Refonctionnalisation

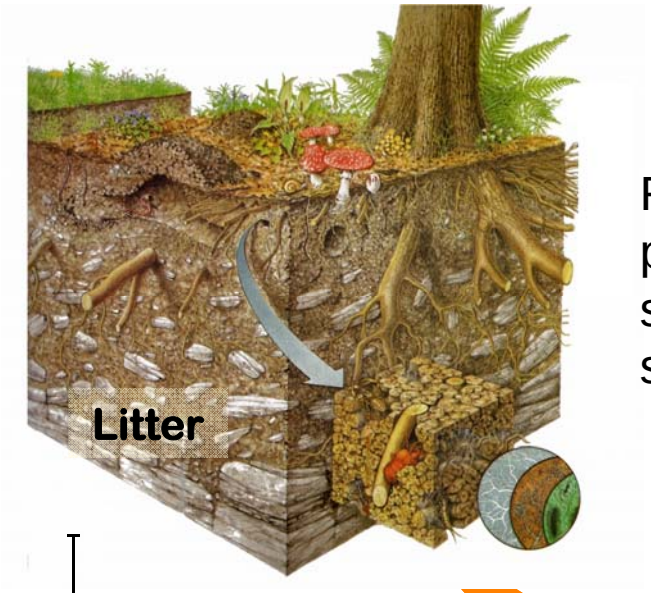
Ressource

Ecosystem services (energy, biodiversity, food…)

The « critical zone » for humans

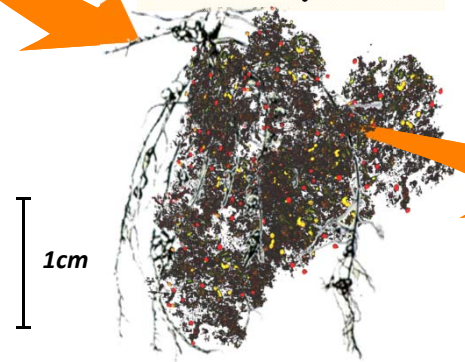




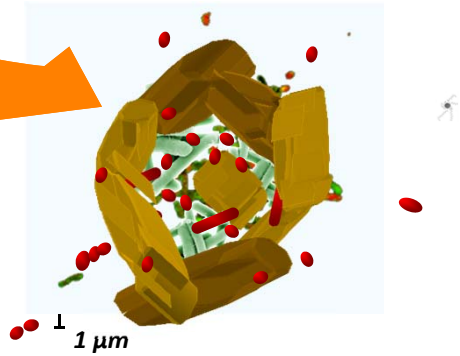


Research has progressed on transfers, processes, including modeling aspects at small (micro- and nano- scales) and large scales (> 1000 km)

Rhizosphere

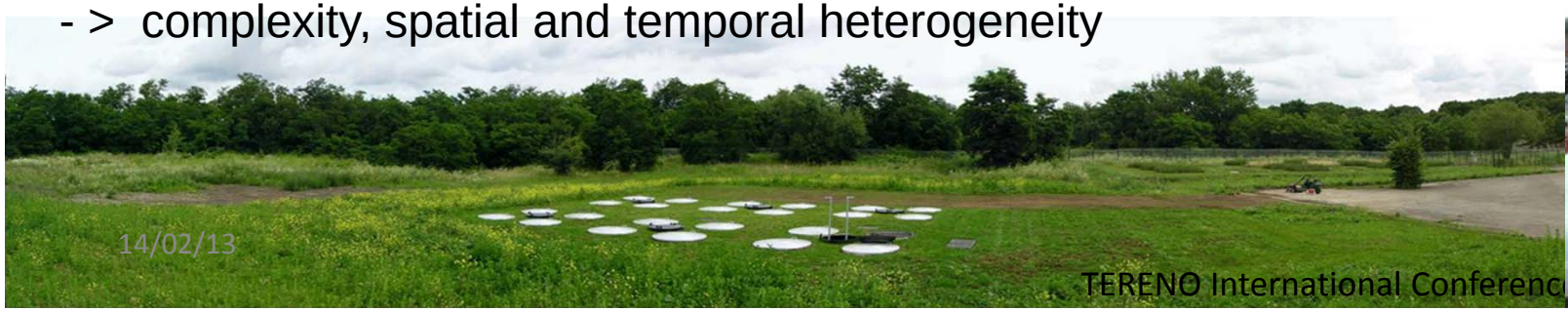


Micro-niche

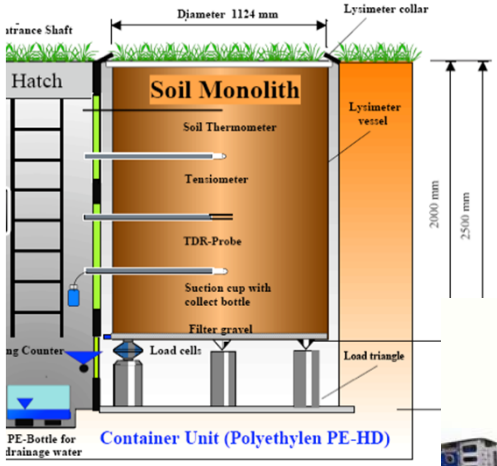


The meso-scale (block of soil to catchment scale) still requires investigation.

- > complexity, spatial and temporal heterogeneity



Lysimeters: are tanks (weighable or not) filled with soil commonly used in studies of crop evaporation and movement of water and chemicals in the soil profile



Ecotrons: Experimental devices to study and model how ecosystem and organism functioning, and biodiversity respond to environmental changes

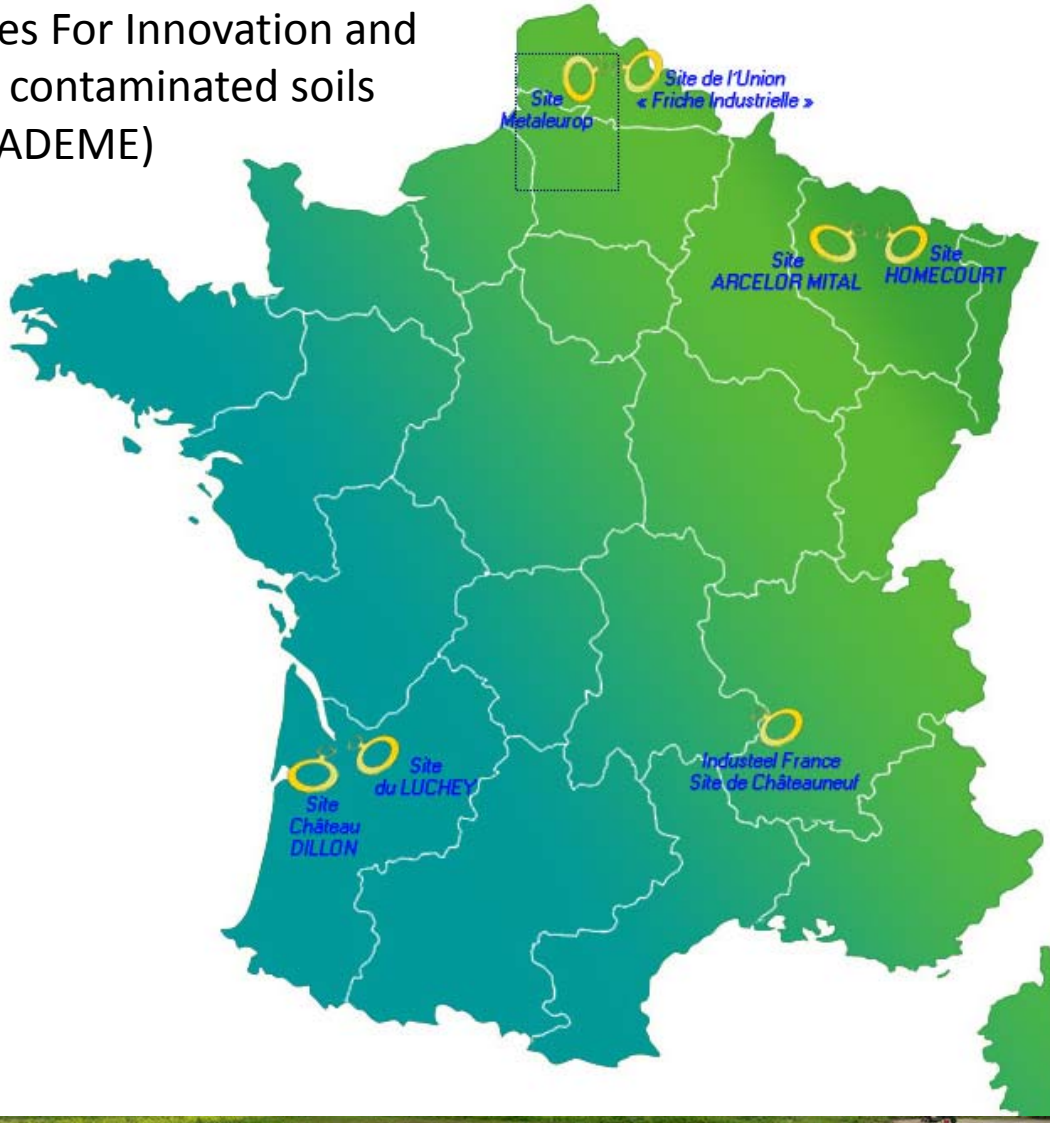
Ecotron Montpellier, TGIR

Ecotron and lysimeters are complementary approaches to study « on site » processes

Observation on

- impact of global change on ecosystem functionning
- processes : remediation, restoration, constructed soils

Network of Sites For Innovation and Research on contaminated soils (ADEME)



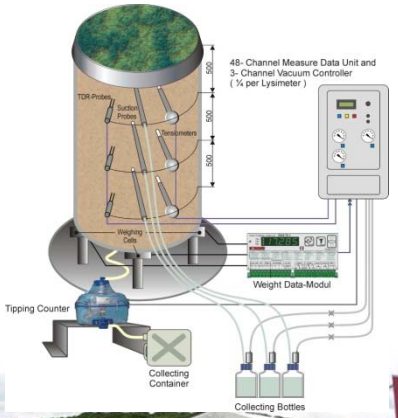
- Contaminated sites and experimental station
- 10 academic laboratories and industral partners

Experimental station, Homécourt, France

dedicated to contaminated and degraded soils:

- Analysis of pollutants, availability, toxicity, fate of pollutants, risk evaluation, soil quality
- Natural attenuation, chemical and biological remediation, phytoremediation and phytomining, soil construction

24 lysimeters



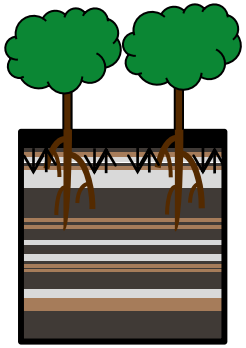
Fate of contaminants under natural attenuation in a tailing pond from steel industry

Plant and biological colonisation

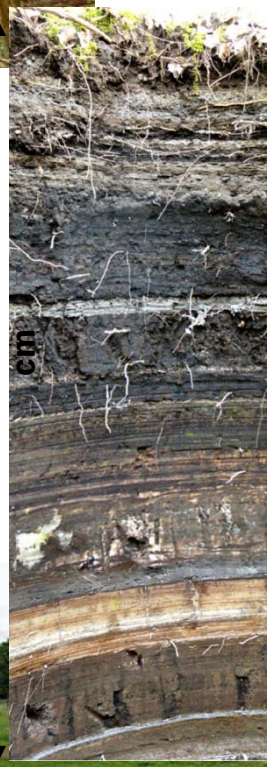
Steeel industry effluents

decantation

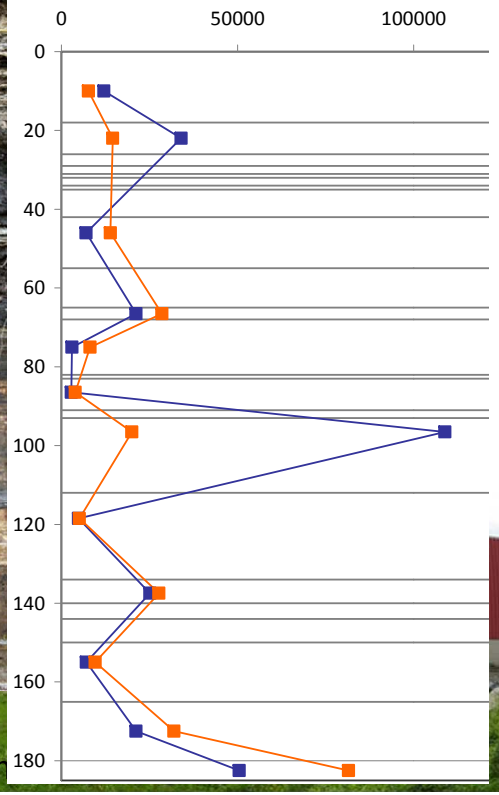
1950-60



180 cm



teneur (mg kg^{-1} sol sec)



Natural attenuation

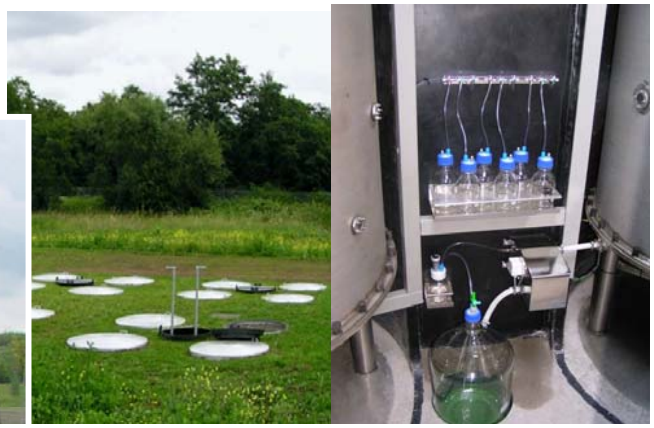
Huot et al 2013, 2014.

Collaboration GISFI – ArcelorMittal REF

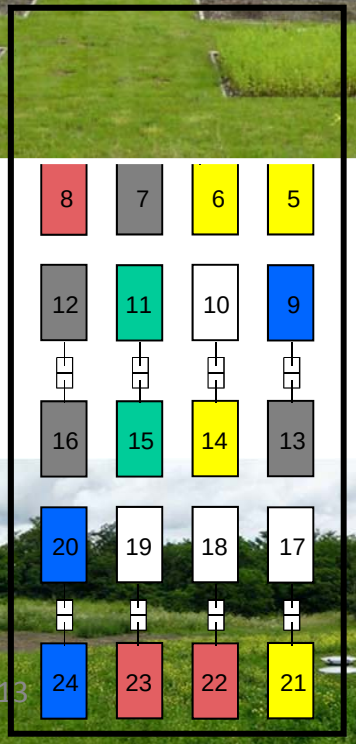
TERENO Internation

Plant assisted long term attenuation of PAH contamination in coking plant soil (Multipolsite project)

Long term on site experiment (2005- 2013, Ouvard et al., 2011)



	NM contaminated soil	TD treated soil
TEXTURE		
Sand (%)	66	70
Silt (%)	22	19
Clay (%)	12	11
Organic matter (%)	11	10
total N ($g.kg^{-1}$)	2.7	0.9
C/N	23.4	62
Phosphore (P2O5) ($g.kg^{-1}$)	0.05	0.08
pH	7.1	8.0
Total PAH ($mg.kg^{-1}$)	1915	106
Heavy Metals ($mg.kg^{-1}$)		
Zn	2101	2745
Cd	2.6	2.1
Pb	488	673



TN Bare soil

VS Spontaneous vegetation

Tc Hyperaccumutaive plant

Ms Medicago sativa

Ms m Medicago sativa + mycorrhiza

TD Medicago sativa+ mycorrhiza

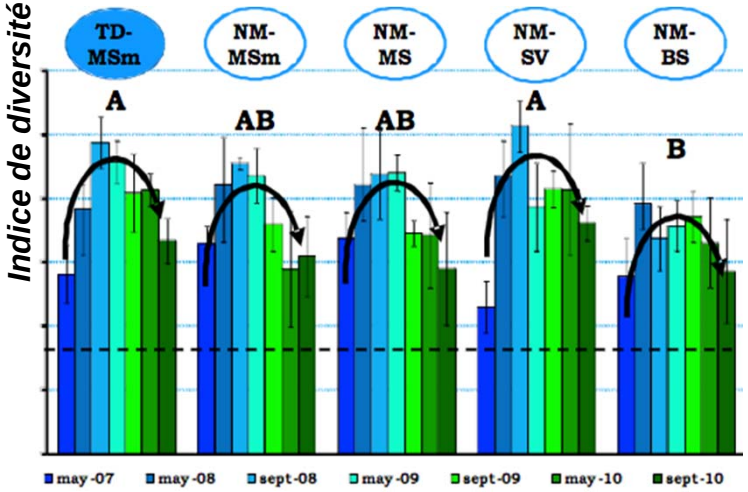
Contaminated s
(HAP, heavy metals

Thermal desorpt
treated soil

TERENO Inte

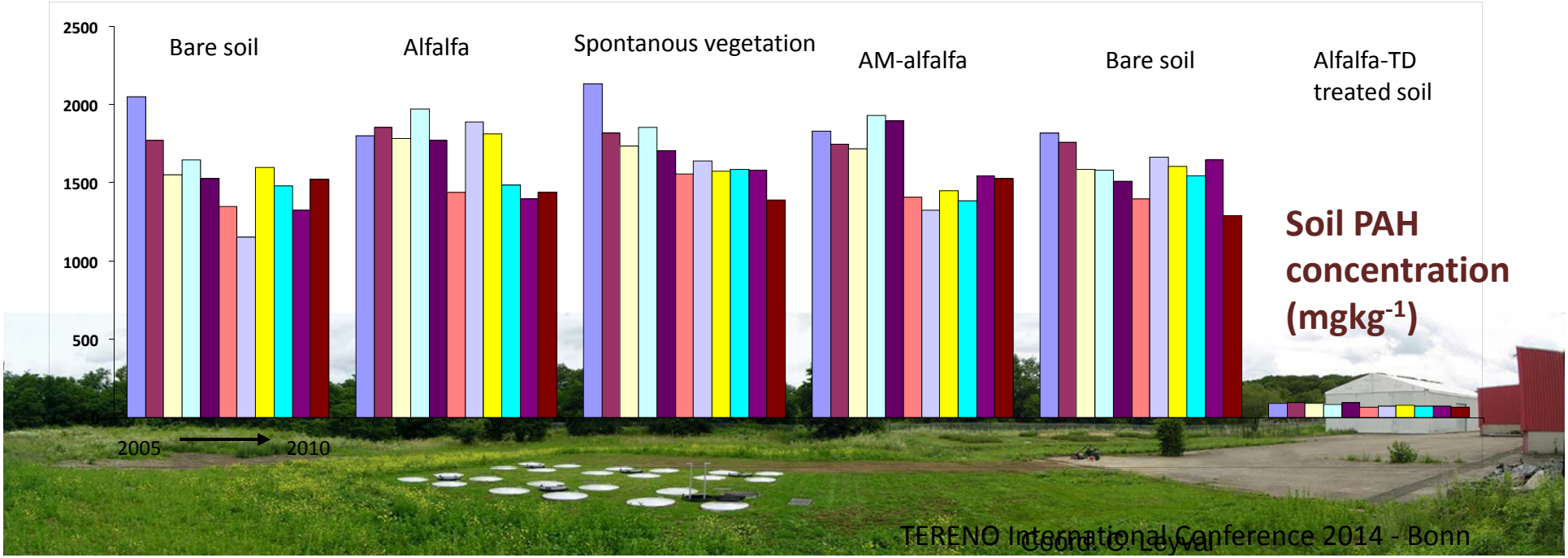
Plant assisted long term attenuation of PAH contamination in coking plant soil (Multipolsite project)

Fungal diversity index

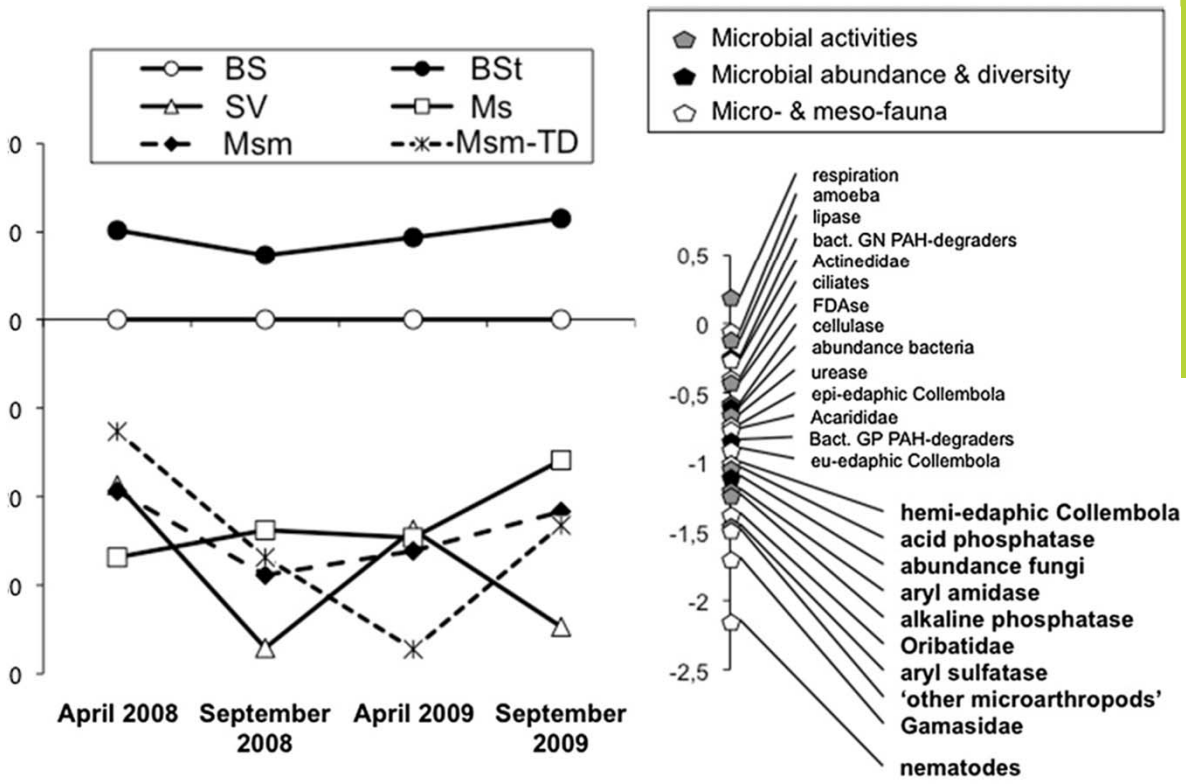


Microbial (fungal) diversity evolved with time in lysimeter plots

PAH concentrations slowly decreased with time, no sign. difference between treatments (only 1-2% available PAHs)



Plant assisted long term attenuation of PAH contamination in coking plant soil (Multipolsite project)



Data analysis using principal response curve (PRC) :

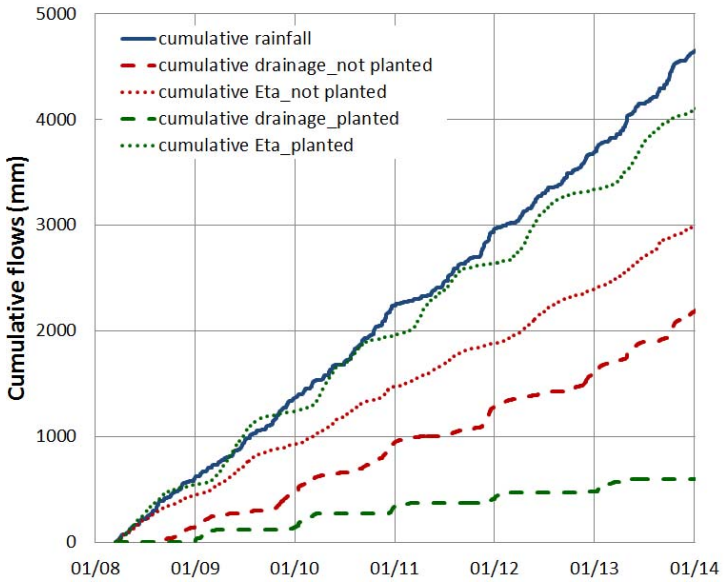
microbial, micro- and mesofauna diversity, activities, abundance

Plots mainly discriminated by the presence of plants -> higher abundance of fungi and fauna, and enzymatic activity PAH-degrading bacteria

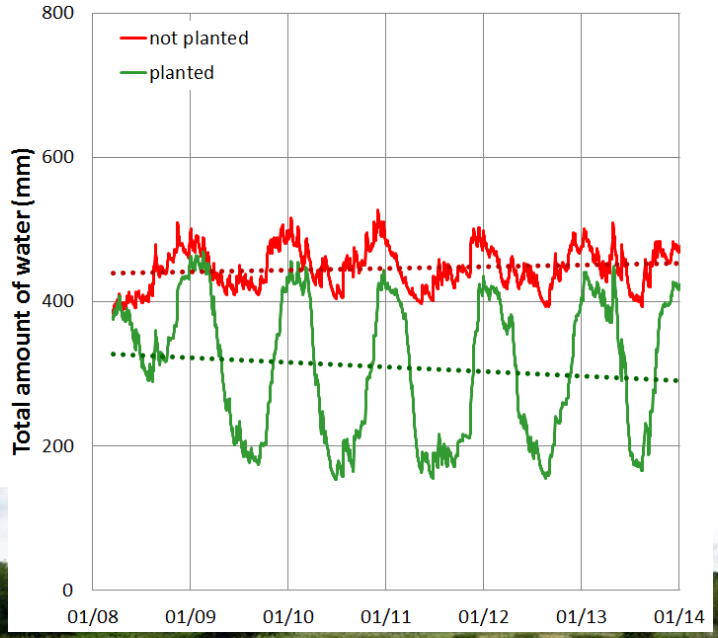
Cébron et al, 2011
Thion et al, 2012

Plant assisted long term attenuation of PAH contamination in coking plant soil (Multipolsite project)

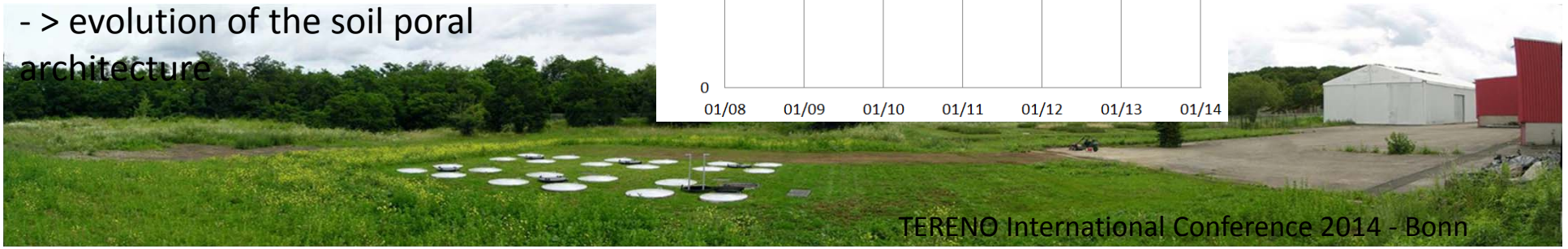
Water budget over 6 years in lysimeters



- Seasonal variations
- Influence of vegetation, *e.g.* evapotranspiration ↗, drainage ↘



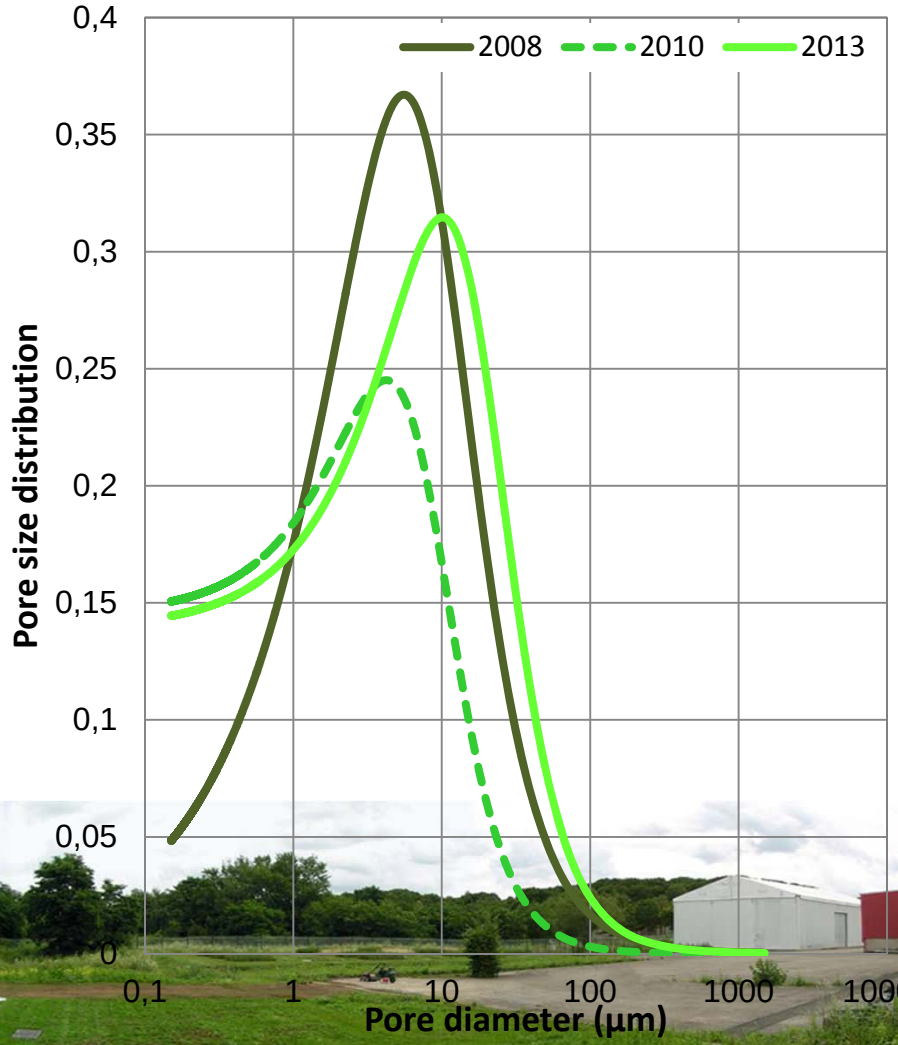
- Seasonal fluctuations of the total amount of water are increased by the presence of vegetation
  - > evolution of the soil poral architecture

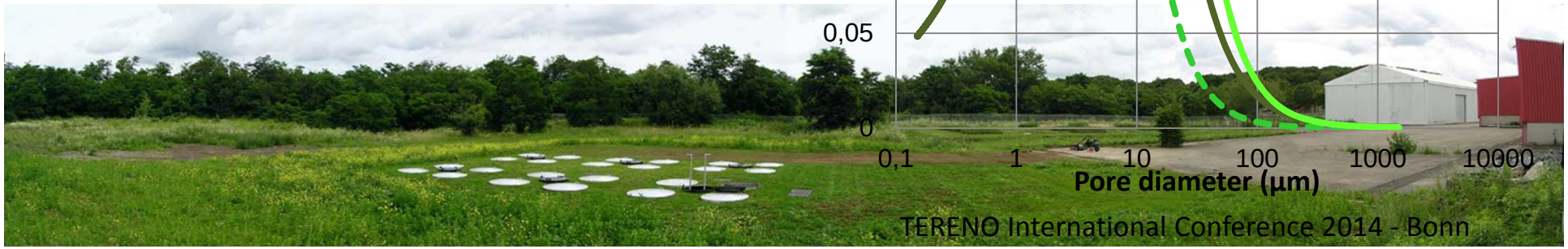


Plant assisted long term attenuation of PAH contamination in coking plant soil (Multipolsite project)

Modelling of pore size distribution

- An inverse modelling approach was conducted on the hydrodynamic monitoring data (water content, outflow) to estimate the evolution with time of the pore size distribution for the planted soil (**Sere et al.)**





Combination of in situ chemical oxidation (ISCO) and soil restoration: OXYSOL project

Contaminated soils
(PAHs and metals)

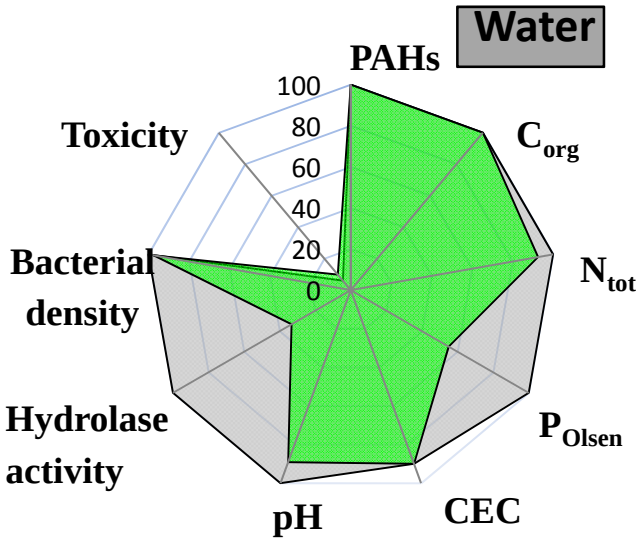
ISCO
Monitoring (geophysical methods)

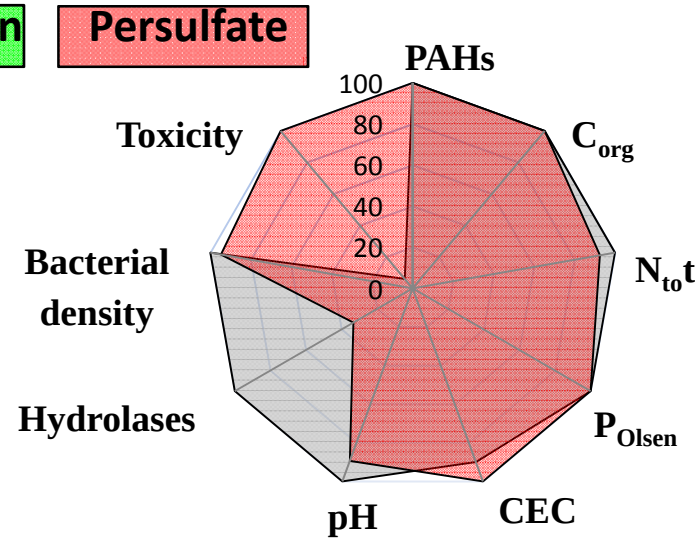
Characterisation of the treated soil

Restoration of soil functions

Clean functional soils

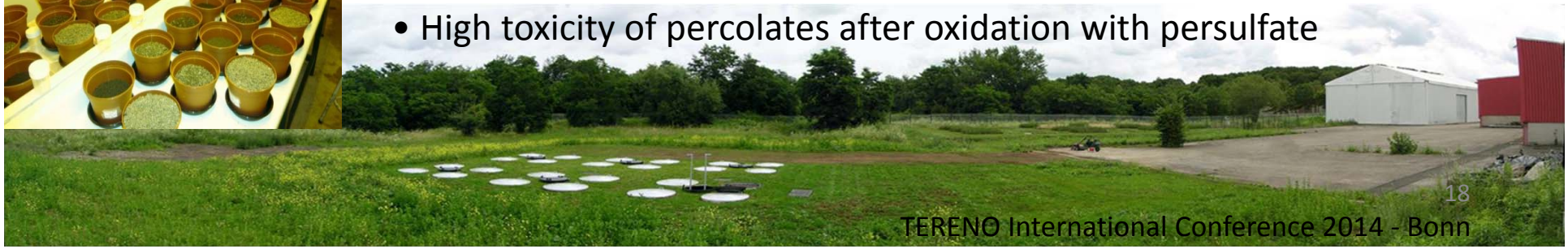
Chemical oxidation and organic amendment at **column and pot scale**





Oxidation with modified Fenton and persulfate:

- Slight PAH concentration decrease in an industrial /spiked soil
- Slight pH and Olsen P decrease, and CEC variations
- Slight decrease of culturable bacteria and strong decrease of hydrolase activity
- High toxicity of percolates after oxidation with persulfate



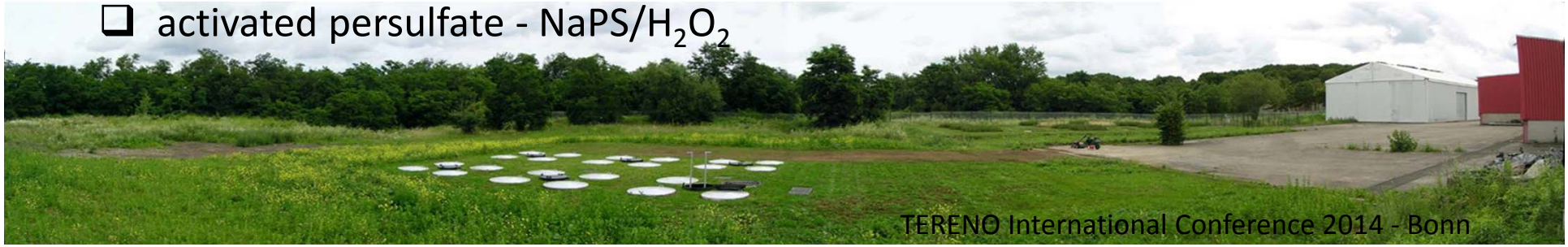
In situ chemical oxidation



Soil from a former steel coking plant (Lorraine); TOC ≈ 71.5 g kg^{-1} ; 16 USEPA PAHs ≈ 2.0 g/kg

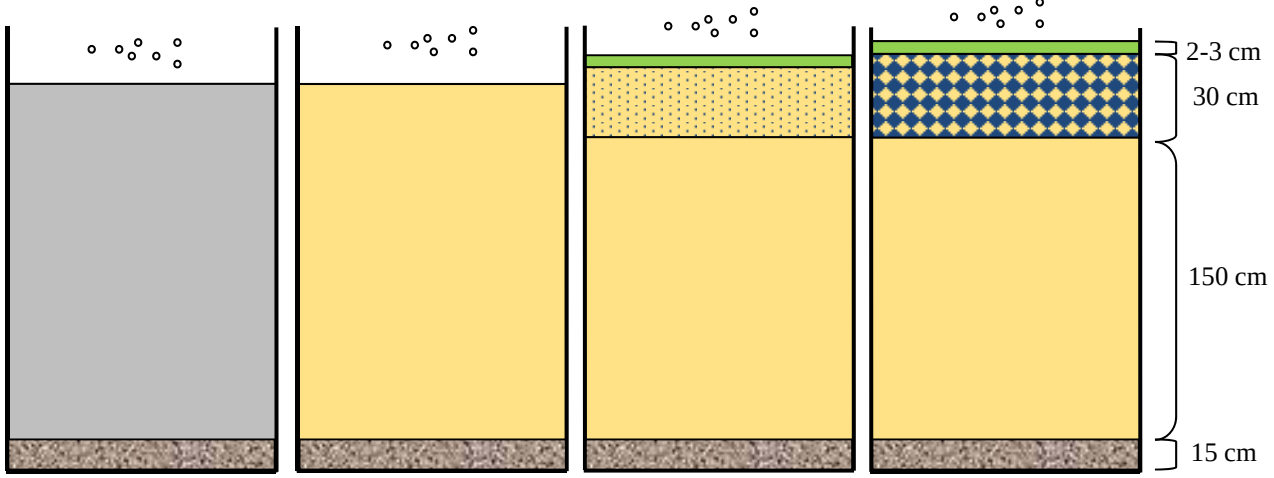
- 4 lysimeters: 2 m^3 (3.2 t soil core)
  - ❑ no oxidant – H_2O
  - ❑ Fenton - $H_2O_2/FeSO_4$
  - ❑ Fenton - $H_2O_2/FeSO_4$
  - ❑ activated persulfate - $NaPS/H_2O_2$

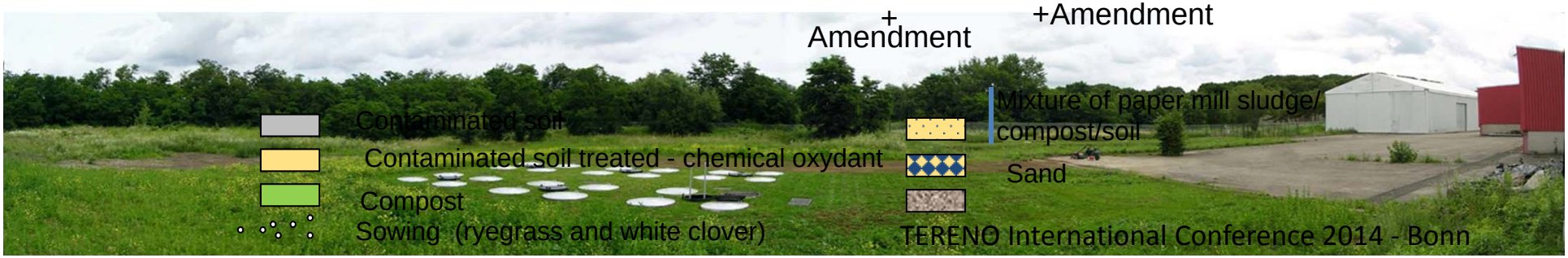
Gradual, alternate feeding
- ❑5 to 8 SMR
- ❑400 – 500 L feed solution
- ❑5-7 days



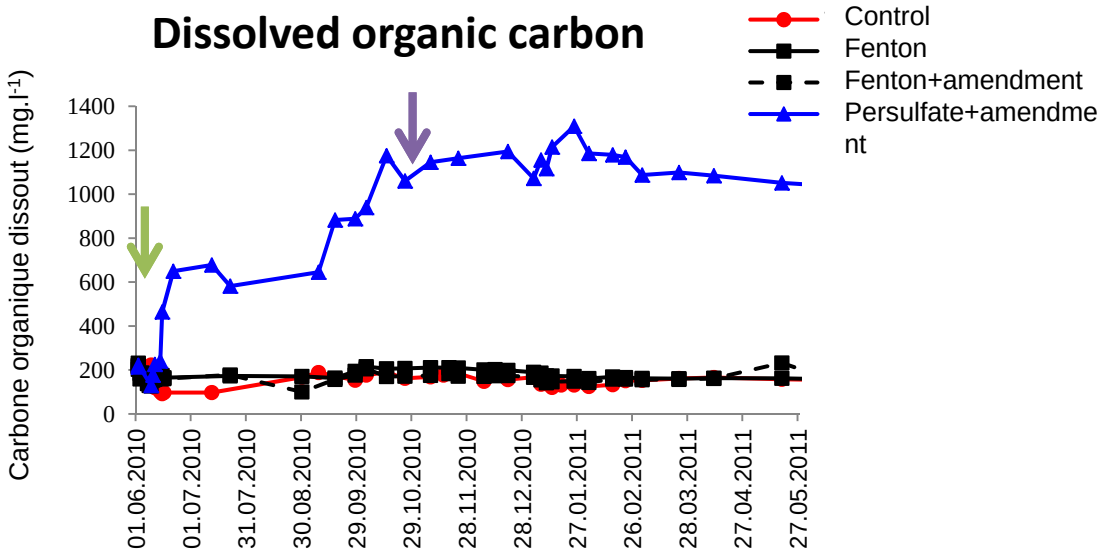
Restoration of soil functions : addition of organic amendments and sowing

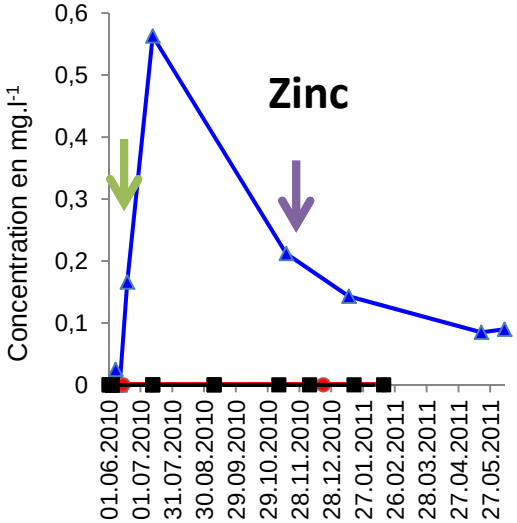
Mixing of the 15 upper cm with amendment

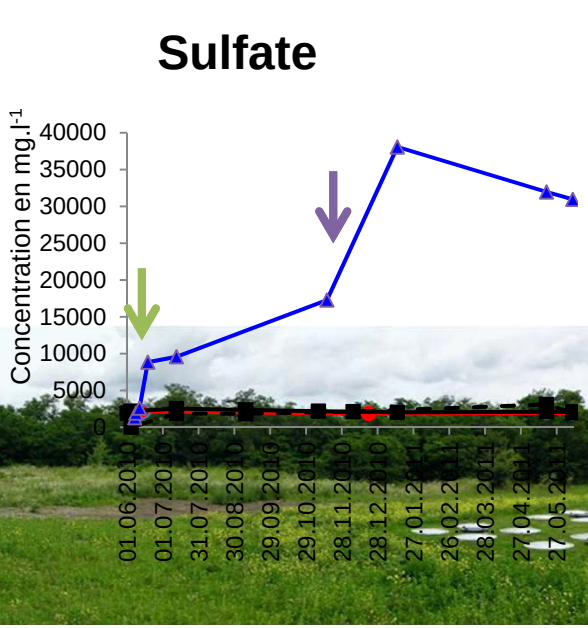


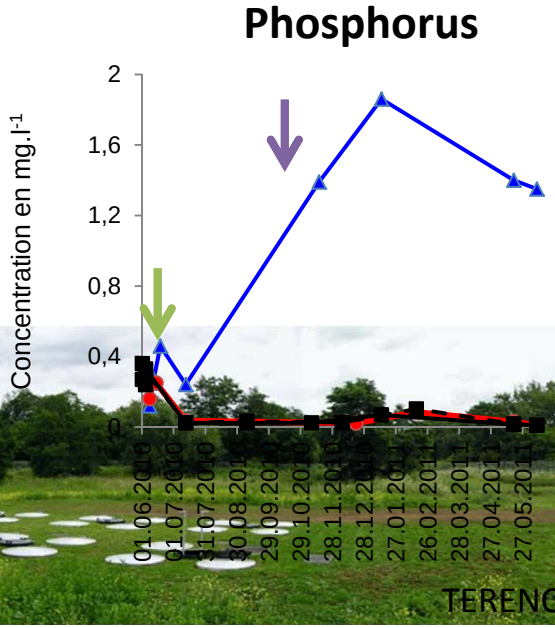


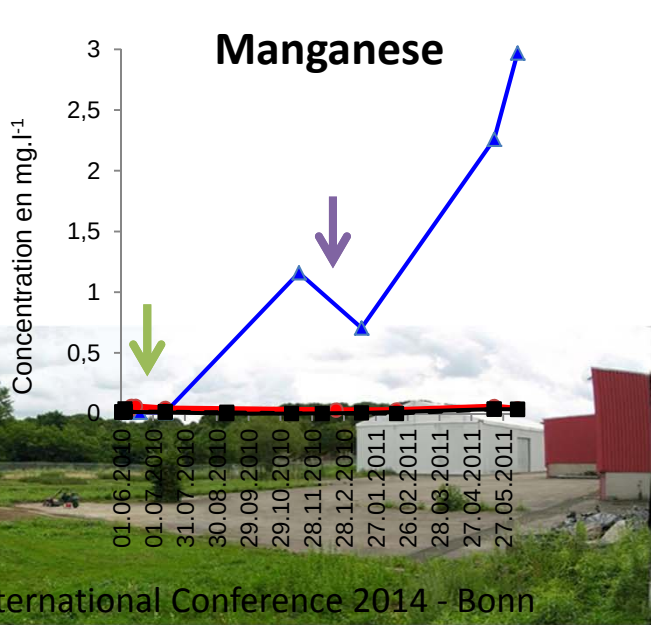
Leaching of compounds and elements following oxidation and amendment





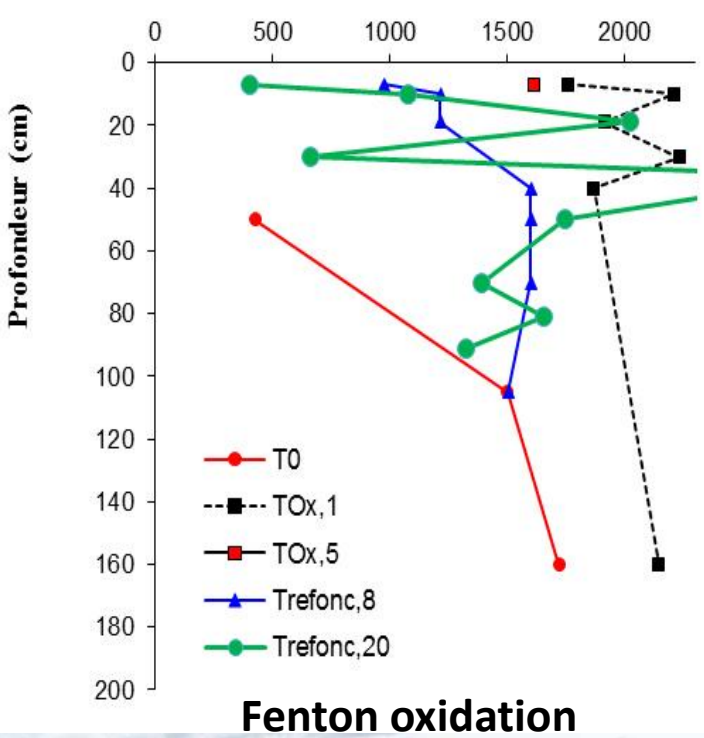




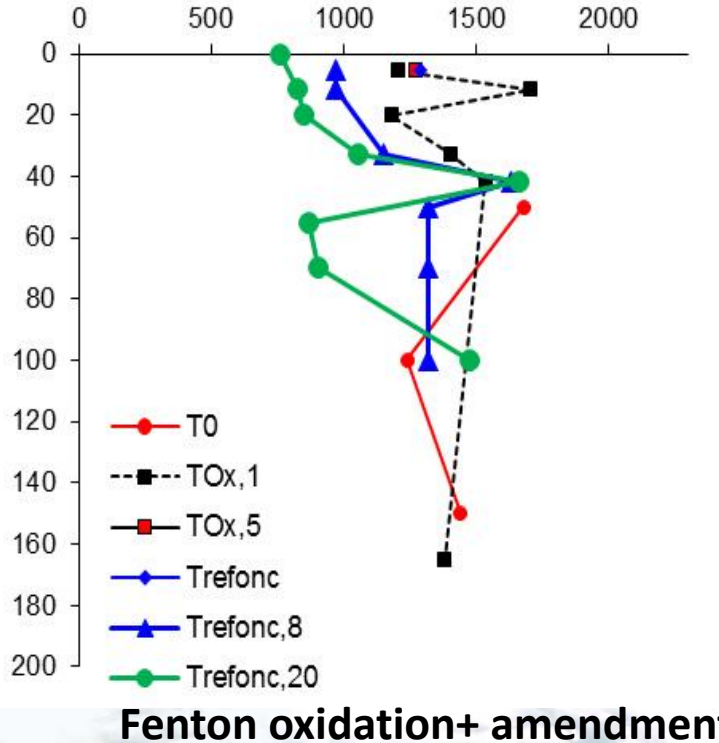


Fate of PAH in lysimeters

- after Fenton oxydation (TOx.1, TOx.5)
- 8 and 20 months after amendment (Trefonc. 8, Trefonc 20)

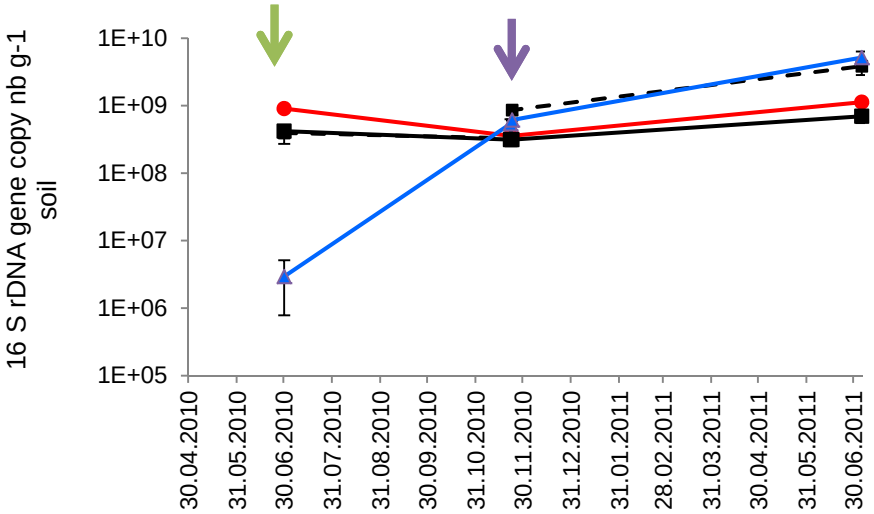


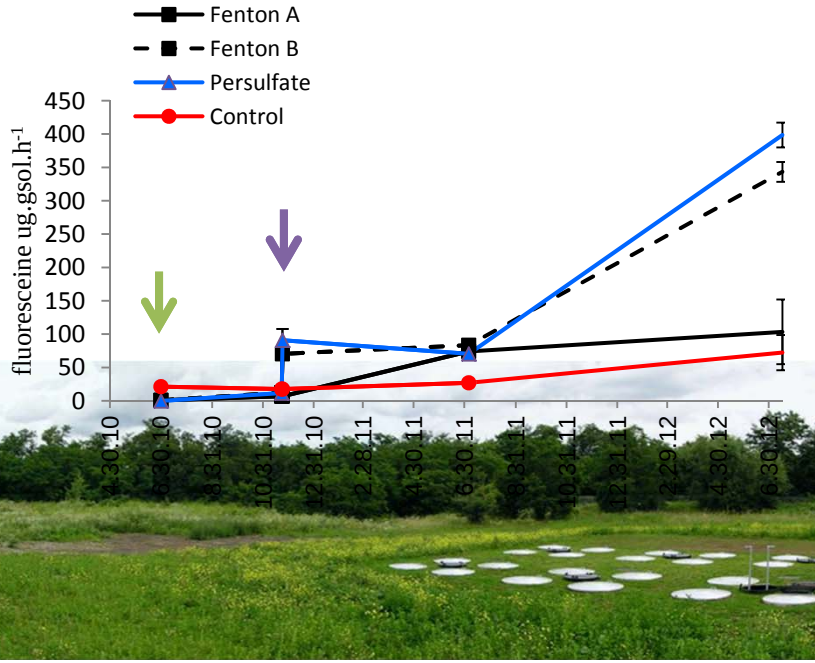
Fenton oxidation



Fenton oxidation+ amendment

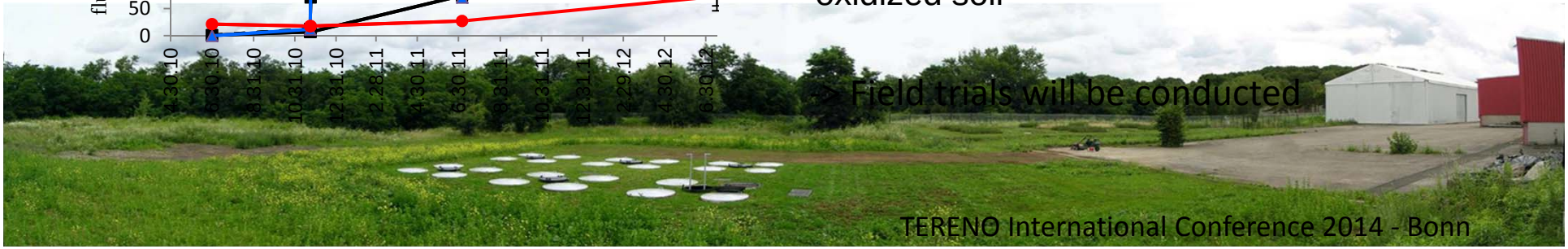
Impact of amendment and plants on bacterial density and enzymatic activity





Higher plant growth in amended lysimeters
Lower growth in persulfate than in Fenton oxidized soil

> Field trials will be conducted



On the use of lysimeters and ecotrons to study the fate of pollutants in soil plant ecosystems

- Complementary approaches to laboratory and field studies
- Long term projects and collaborative projects
- Limitations: replicate numbers, sampling strategies, and maintenance costs
- Further developments to include atmosphere aspects (volatile compounds, biogeochemical cycles coupling), and social and human aspects
- Data management under development
- Interest for lysimeter network studies and collaborations – Observatory on contaminated soils

Acknowledgements

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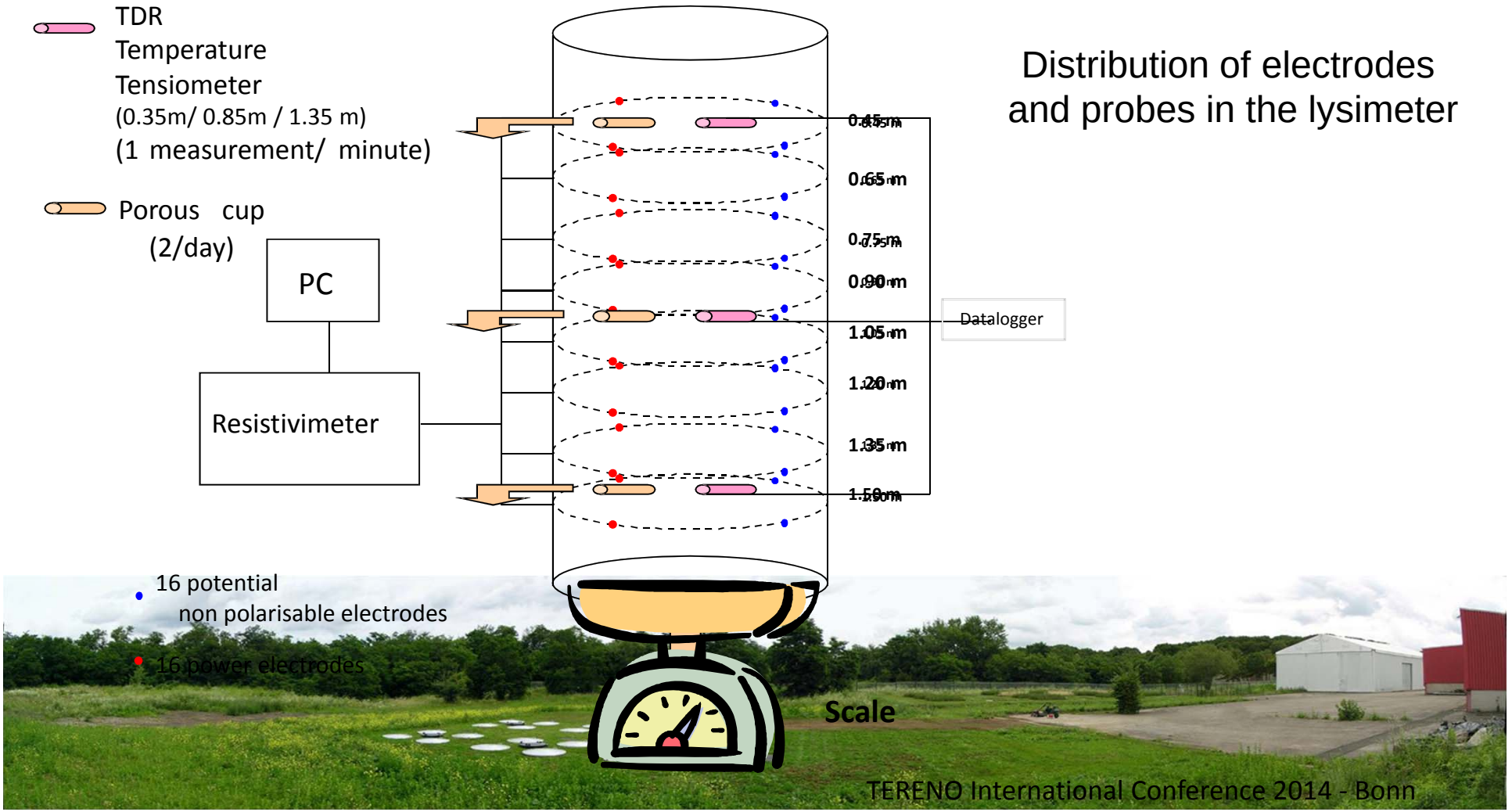
GISFi

http://www.gisfi. fr

Geophysical monitoring of oxidation process



Distribution of electrodes and probes in the lysimeter

Variation of resistivity and chargeability during the oxidation process

- Fenton
- 4 days
- 3 depths :
  - black 0.45 m
  - blue 0.90 m
  - purple1.35 m

A clear response is obtained from the injection