

Impact of groundwater level variations induced by climate change on the mobilization of light refined petroleum hydrocarbon contaminants (LNAPLs)

Amélie Cavelan¹, Fabrice Golfier², Stéfan Colombano³, Noële Enjelvin⁴, Hossein Davarzani³, Jacques Deparis³, Catherine Lorgeoux², Anne-Julie Tinet², Constantin Oltean², Pierre Faure¹

Additional informations

Tuesday, 27 April 2021

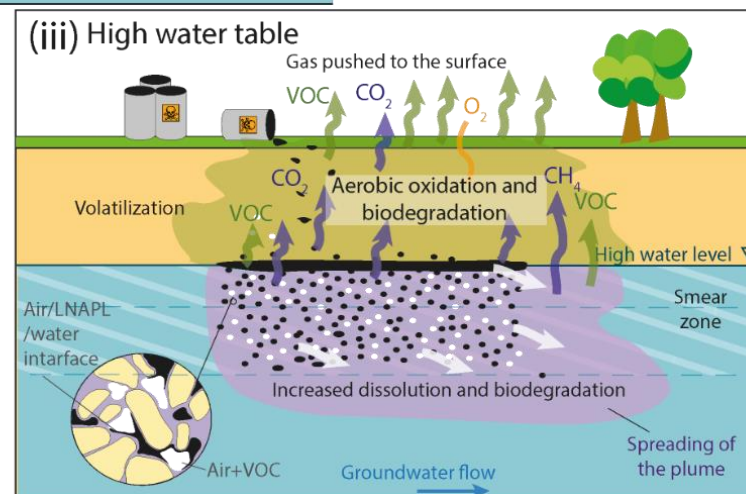
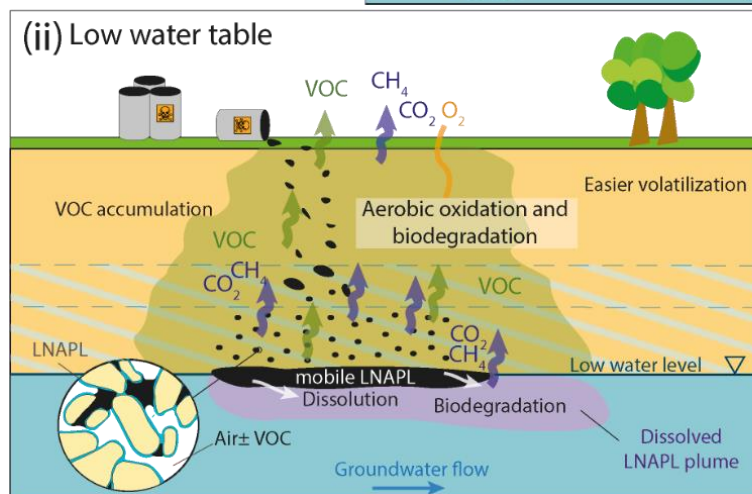
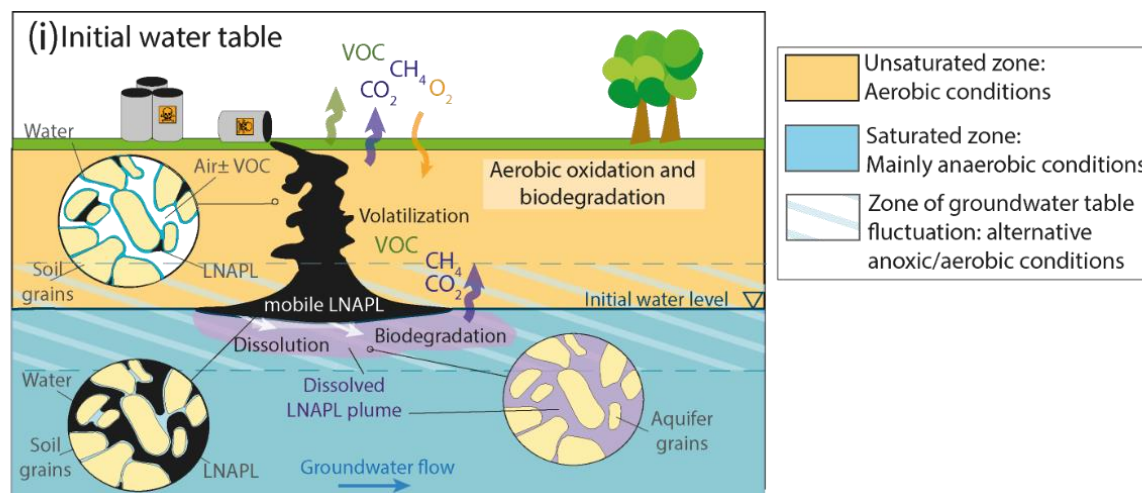
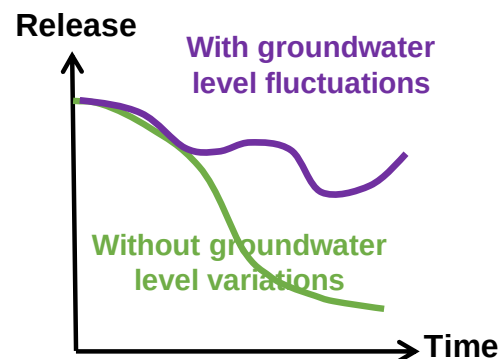
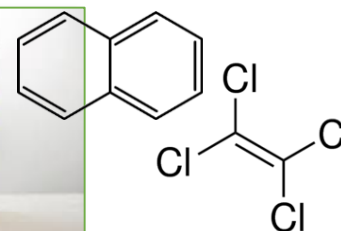
CONTEXT AND ISSUES

LNAPLs or "Light Non-Aqueous Phase Liquids"

- Derivatives of light petroleum compounds (diesel, fuel oil etc.)
- 37% of soil and groundwater pollution
- Accumulate at the top and move with the groundwater table



lower density than water



Effect of climate change by 2080?
(IPCC, 2014)

- + winter precipitations
- + summer droughts
- + extreme rainfall events

Increase in the amplitude and frequency of groundwater fluctuations.

- More intense LNAPLs remobilization?
- More rapid natural attenuation?
- More important short-term risks?

How do these extreme variations influence the distribution, mobilization and lifetime of these contaminations?

MAIN ISSUES

Complex LNAPLs contaminations

- Strong (bio)geochemical evolution (type of metabolism, redox conditions...)
- Great variation of saturation level and composition

The release of LNAPLs depends on:

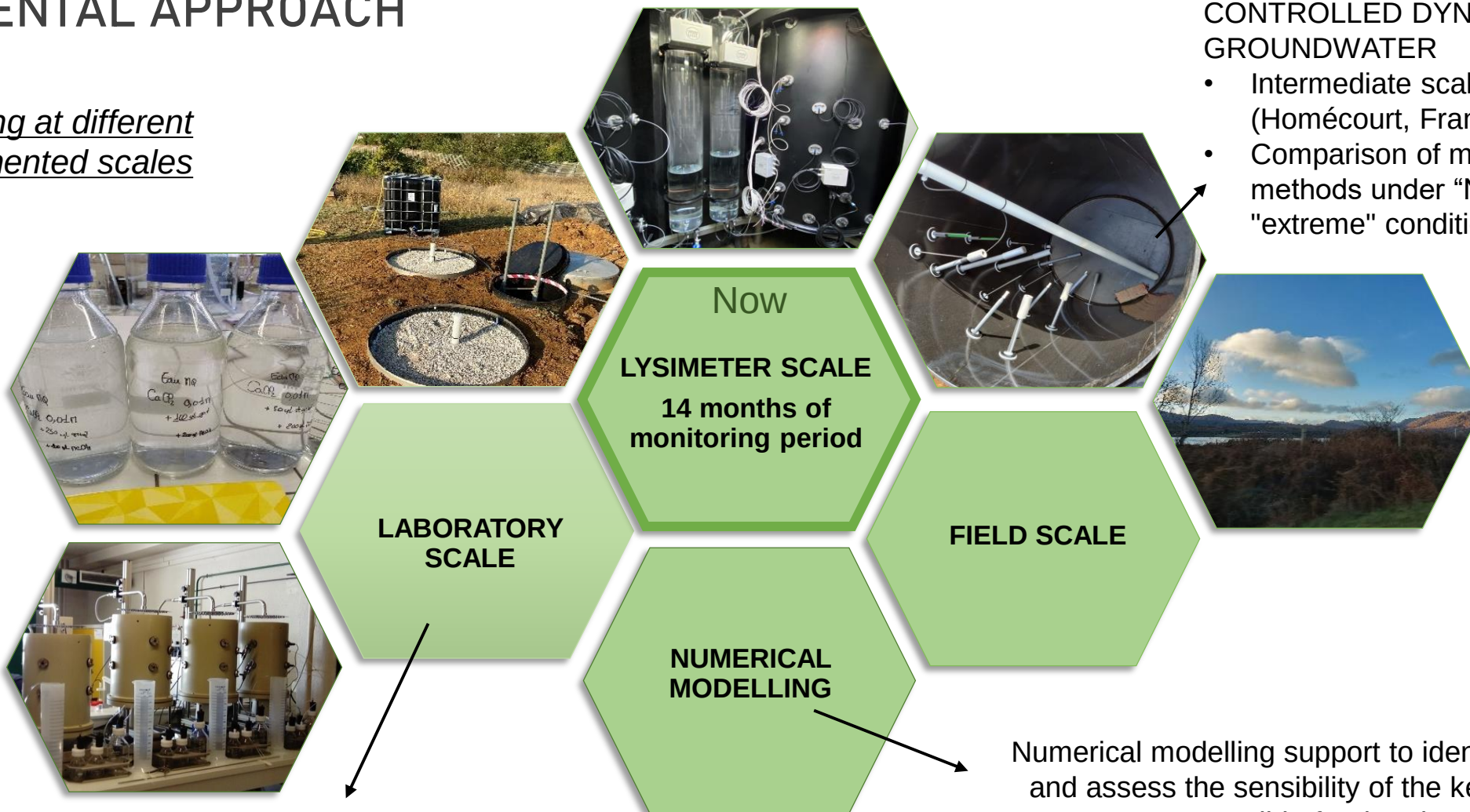
- characteristics of the porous medium (type, permeability ...)
- the physical-chemical characteristics (composition, solubility ...) of the residual LNAPL saturations
- the surface extent of water/LNAPL/air interfaces in soil
- variations in the groundwater table level

Climate change

- could increase the frequency and the amplitude of groundwater table level variations
- could strongly impact the remobilization of LNAPLs and their release into the environment

EXPERIMENTAL APPROACH

Monitoring at different
complemented scales



CONTROLLED DYNAMIC OF THE
GROUNDWATER

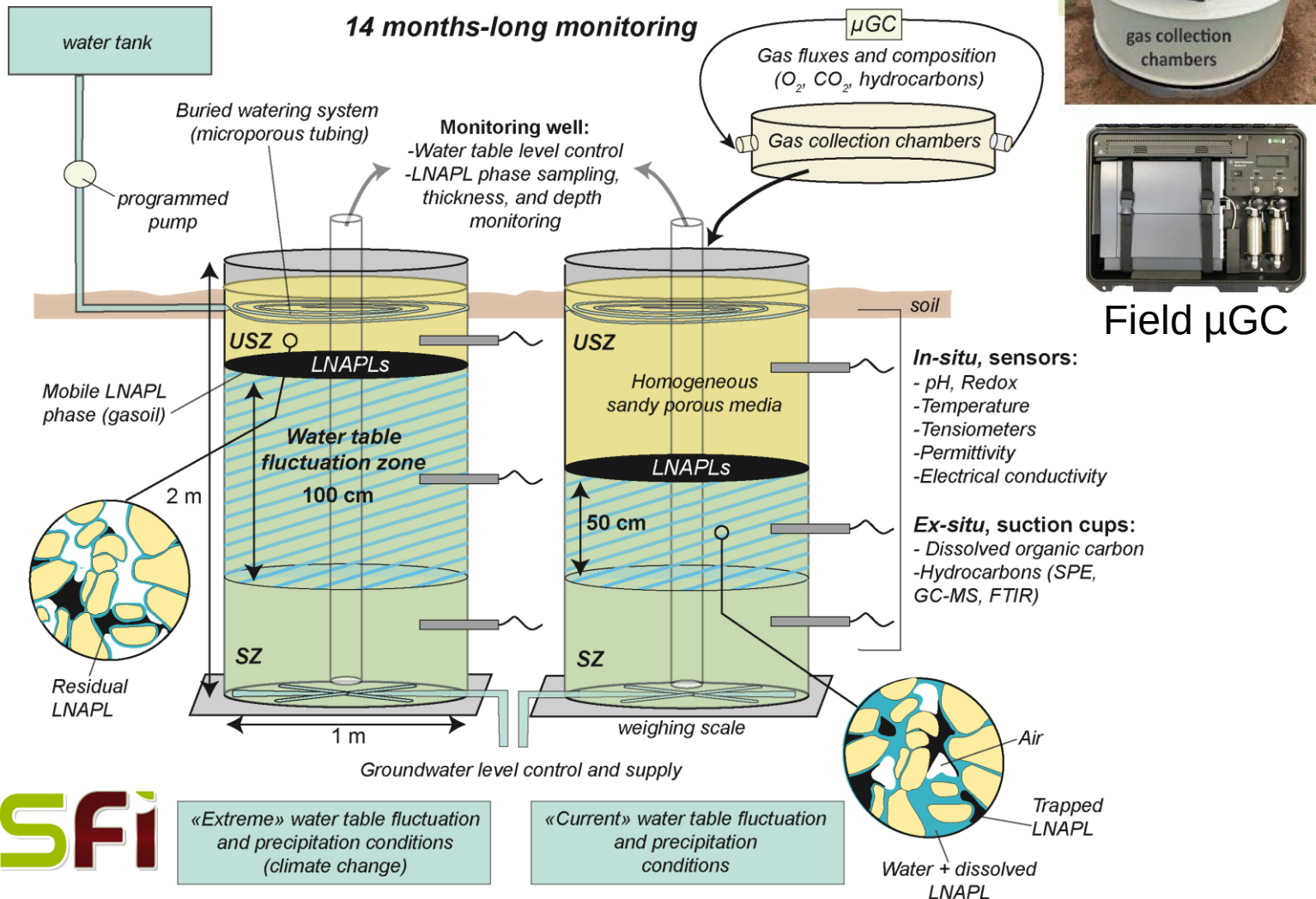
- Intermediate scale, GISFI station (Homécourt, France)
- Comparison of monitoring methods under "Normal" and "extreme" conditions

CONTROLLED SATURATED AND UNSATURATED CONDITIONS

- Monitoring the physical-chemical behavior of LNAPL (partitioning, biodegradation kinetics...)
- Identify individual mechanisms under contrasting water table conditions

Numerical modelling support to identify and assess the sensibility of the key parameters responsible for the observed phenomena

EXPERIMENTAL SETUP



OUR OBJECTIVES

Improved monitoring methods:

- Evaluate the capability of different monitoring methods.
- Finely characterize the distribution of LNAPL saturations

Understand the impact of groundwater fluctuations (frequency/amplitude) on:

- LNAPL distributions
- LNAPL remobilization
- Release terms (water/air)
- LNAPL source zone longevity

This project should allow to:

- Predict the evolution of these sites in the coming decades
- Decision support for the actors of the remediation

An innovative experimental device:

- Coupled monitoring techniques (geophysics, geochemistry, pH, T, RedOX)
- Monitoring of releases (air, water) during different scenarios of water table fluctuations (extreme and normal).

Some pictures of the installation at the GISFI station, Homécourt (France)...



Removal and emptying of old columns



Product of UGT
"more than standard"
<https://www.ugt-online.de/>



Installation of new HDPE columns



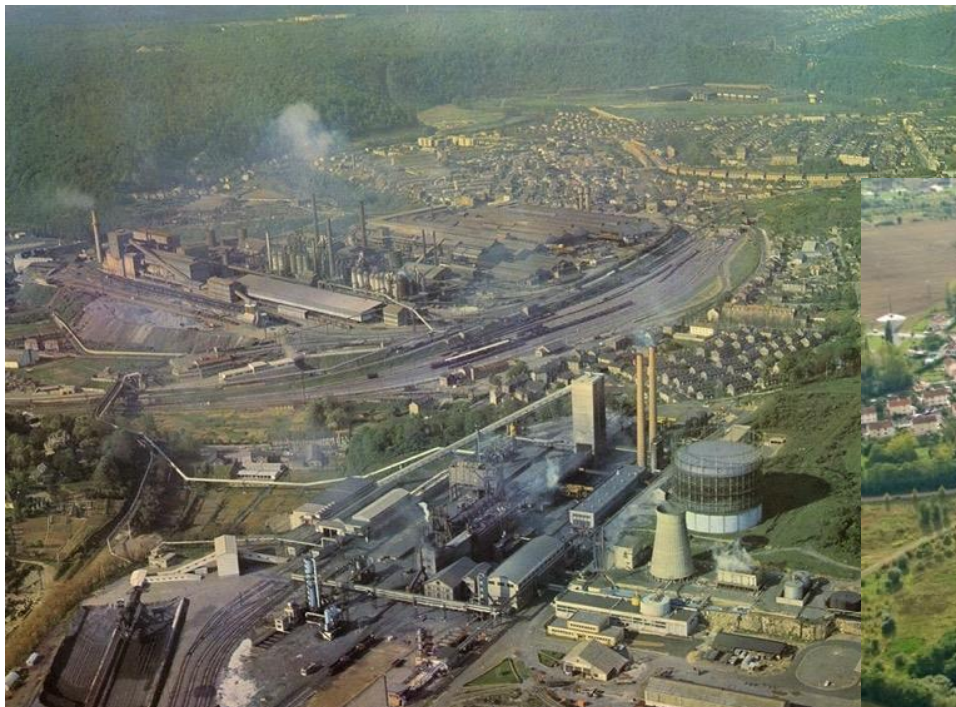
Sensors



Filling of columns and installation of electrical resistivity sensors

The « Groupement d'Intérêt Scientifique sur les Friches Industrielles »

What is the GISFI ?



The scientific interest group on industrial wastelands

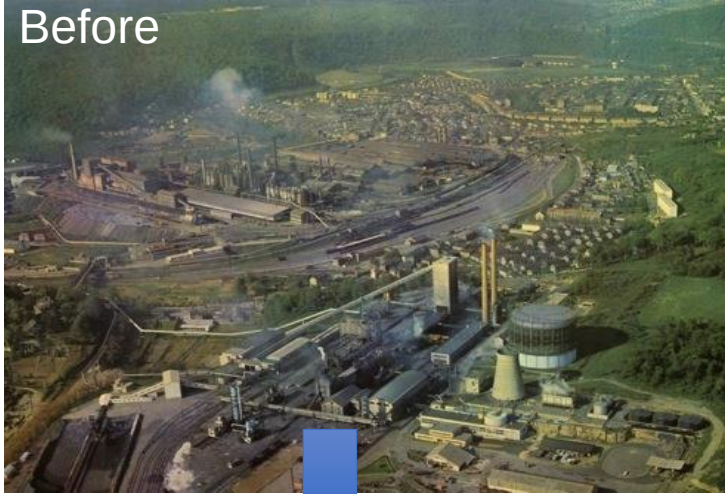


<http://gisfi.univ-lorraine.fr>

Soil Remediation

– Context and Challenges

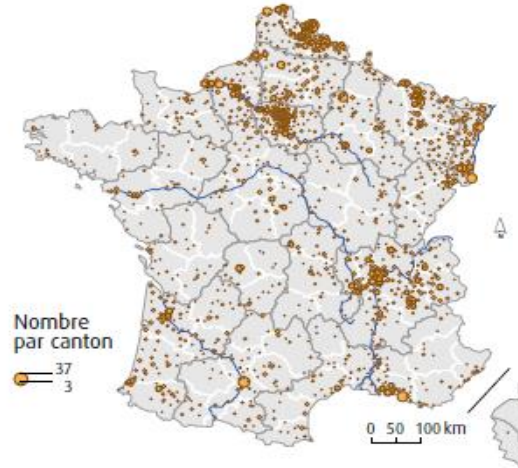
Before



Now



Contaminated sites in France (2012)

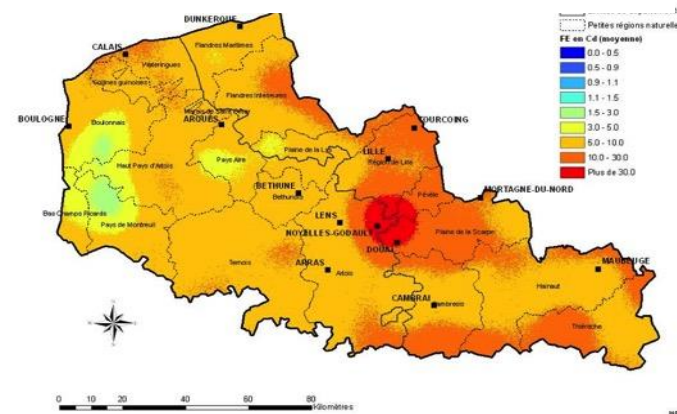


- Context: 70's to 90's
 - strong economic and industrial shift in Europe
 - closing of heavy industry – steel, coal, textile
 - 340 000 contaminated sites in Europe
 - **sites of vast surface areas**
 - restoration of former industrial sites for economic redevelopment
- Challenges
 - increase scientific knowledge about contamination dynamics in soils and ecosystems
 - develop eco-technologies for remediation and recycling of degraded and contaminated sites

GISFi

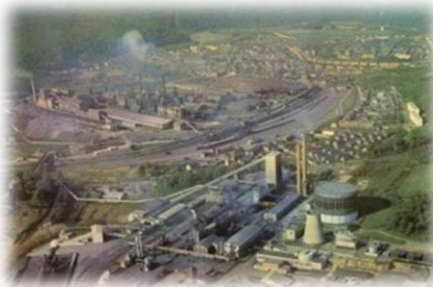
- scientific consortium (10 research groups) dedicated to the study and the remediation of brownfields
- partnership : research - industry

Cd contaminated in Northern France > 10 000 ha



GISFI

- Created in 2002 by 5 members
 - Lorraine University, CNRS, INRAE, BRGM, INERIS
- 10 research groups
 - geosciences, biology, ecology, chemistry, chemical engineering, risk, innovation, psychosociology
 - LSE, GEORESSOURCES, LIEC, LCPME, LRGP, BEF, ERPI, INTERPSY, INERIS-Pôle RISK, BRGM-3SP(D3E)
- Industrial partners
 - site owners, soil remediation,
 - Arcelor Mittal, Brézillon, Colas, Elementerre, EODD, Antéa,, Microhumus, Progepi, SEA-Marconi, Serpol, Sita-FD, Sol Environment, Soleo-Services, Solvay, Tauw France, Total, Valterra...



- Context : economic shifts and environmental issues
 - development of brownfields
 - steel industry, coal mining, military bases
 - threat on the soil resource
 - contamination, urbanization
- Objectives: restoration of degraded sites
 - fate, effects and treatment of pollutions
 - ecosystem services provided by degraded and polluted land
 - long-term observation
- General method
 - multidisciplinary and partnership
 - research – companies – public partners
 - thematic groups
 - diagnostic, physico-chimie, biologie, filières
 - pluri-partner projects
 - e.g. MULTIPOLSITE (ANR); LORVER (AME); BIOXYVAL (PIA)
 - Contribution à LabEx « Ressources21 »
- Experimental platform
- GISFItech - PROGEPI



Objectives and strategy

- Increase knowledge regarding degraded and contaminated soils
- Develop eco-technologies for the remediation of **sites of vast surface area**
 - *in situ* treatment of persistent pollutants
 - e.g. HAP, metals
 - restoration of soil functions and ecosystem services to:
 - produce food, fiber, energy, metals;
 - increase biodiversity and C storage.

- **Pluridisciplinarity** and **partnership** with companies
 - biology, geosciences, chemistry, engineering, social sciences / risk assessment, soil remediation,
- **Shared** scientific and technologic questions, objects and experimental sites
 - experimental platform



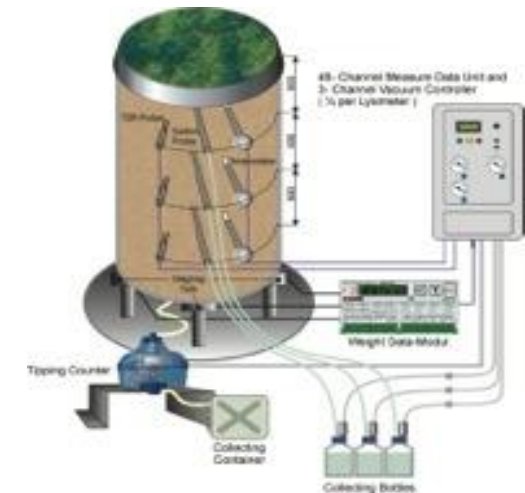
Experimental platform: lysimeters



Lysimeter plots : *pedogenesis and treatment of Technosols
(in situ chemical oxidation, soil construction, phytoremediation, natural attenuation, agromine)*



Lysimeter columns: *pollutant fate and treatment
(diagnostic, risk evaluation, in situ soil treatment, soil restoration)*



dispositif UGT

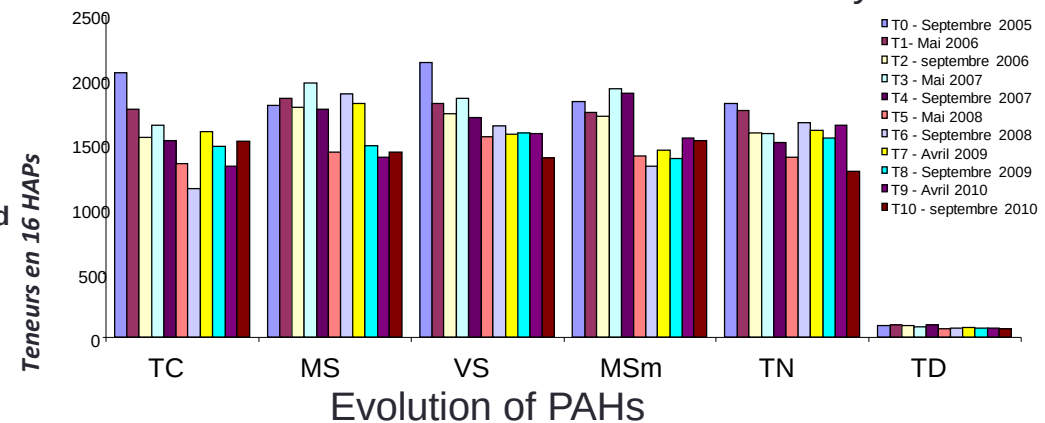
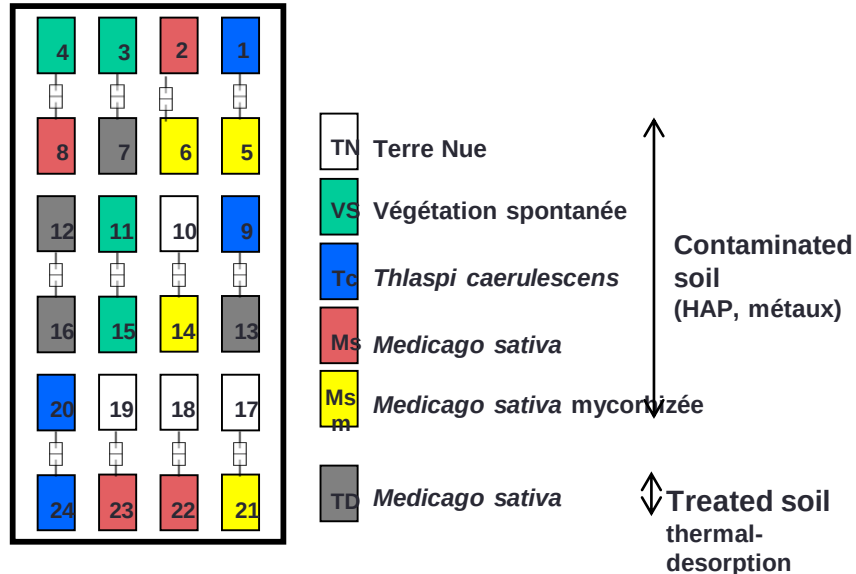
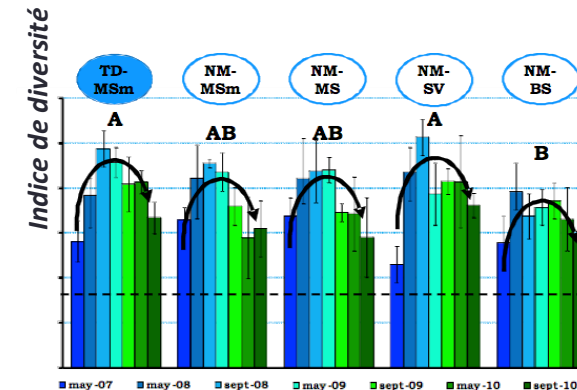


- Examples of other research projects

- Long term evolution of pollutants
- Natural attenuation
- Chemical oxidation
- Ecosystem restauration



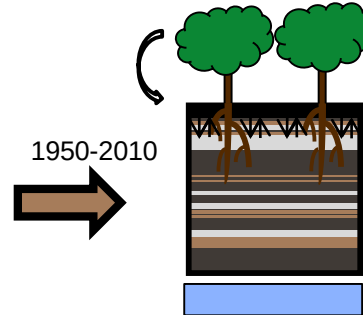
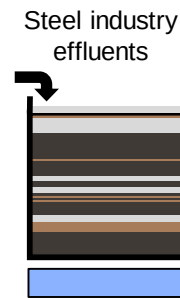
Long-term evolution of pollutants



Data-base

Coord. C. Leyval

Natural attenuation of an industrial decantation pond



10 m-deep - 2.6 ha
Pompey, Lorraine, France



Regulating services

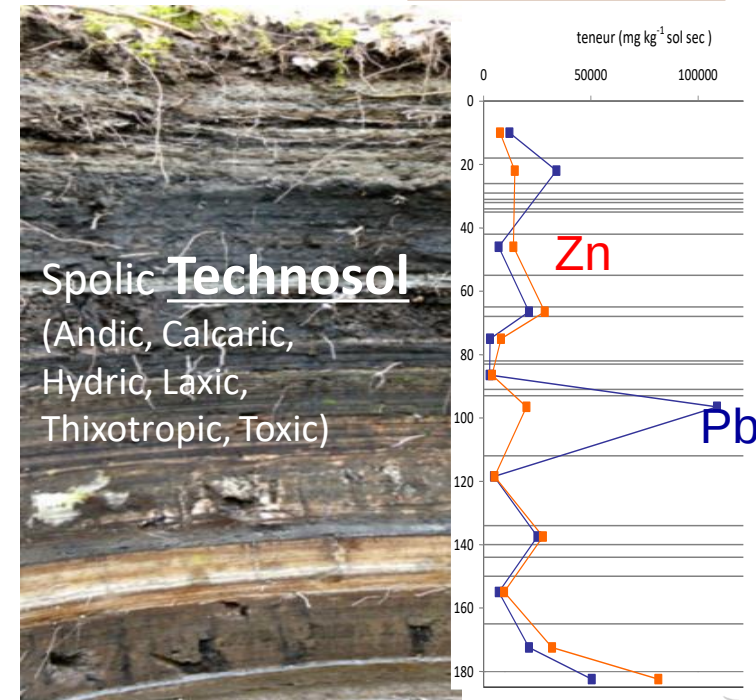
- treatment of industrial waste
 - water quality and quantity control (retention, evapotranspiration)
 - biodiversity
 - reservoir of raw materials: strategic metals

Provisioning services

- Biomass

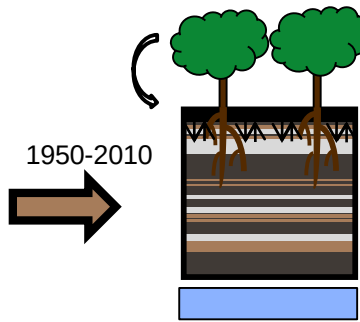
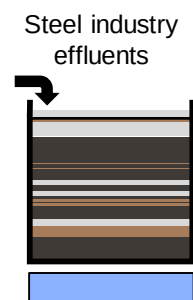
Cultural services

- archives of industrial activities

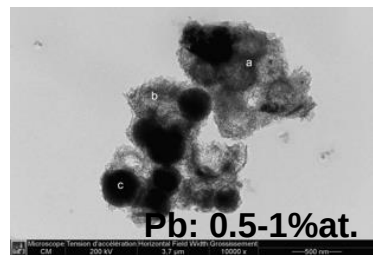
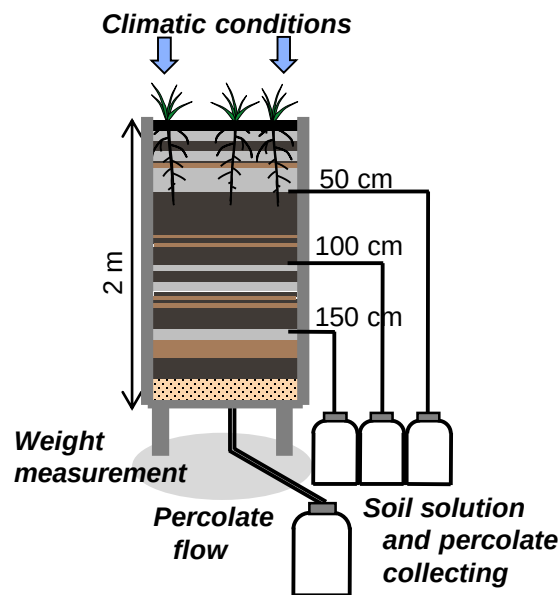


(after Huot *et al.*, 2013, 2014)

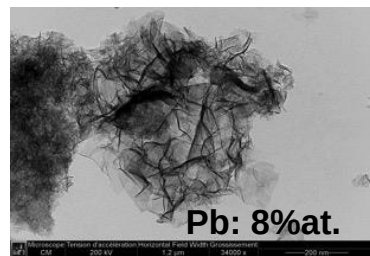
Natural attenuation of an industrial decantation pond



10 m-deep - 2.6 ha
Pompey, Lorraine, France



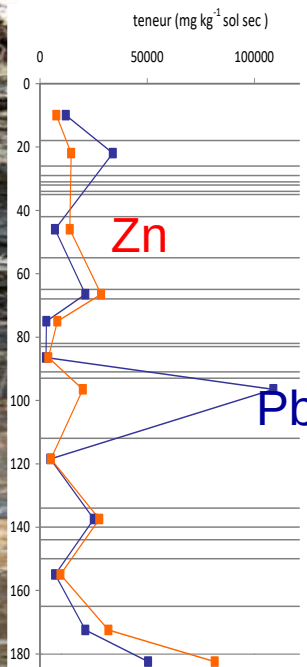
Amorphous aluminosilicates



Mn oxides



Spolic Technosol
(Andic, Calcaric, Hydric, Loxic, Thixotropic, Toxic)



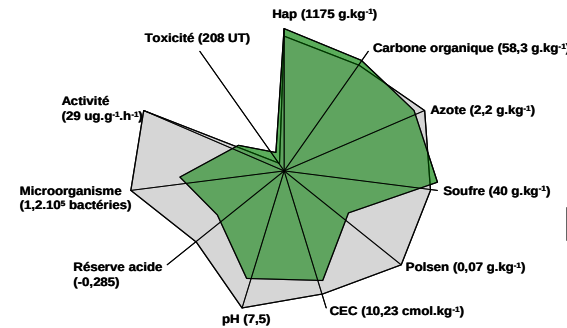
(after Huot et al., 2013, 2014)

Chemical oxidation and soil reclamation (OXYVAL/BIOXYVAL)

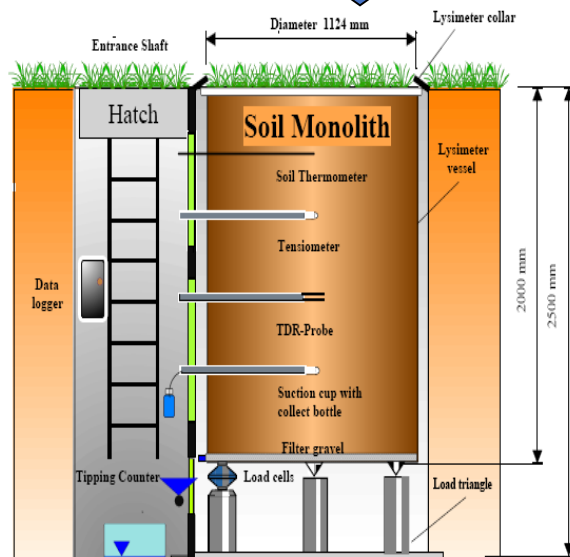


Injection oxydant

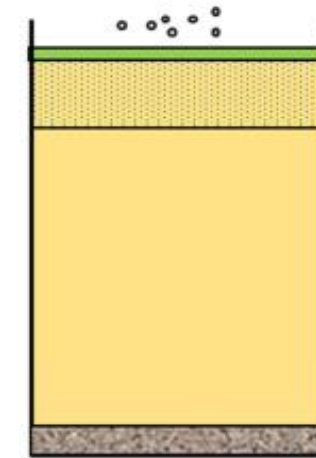
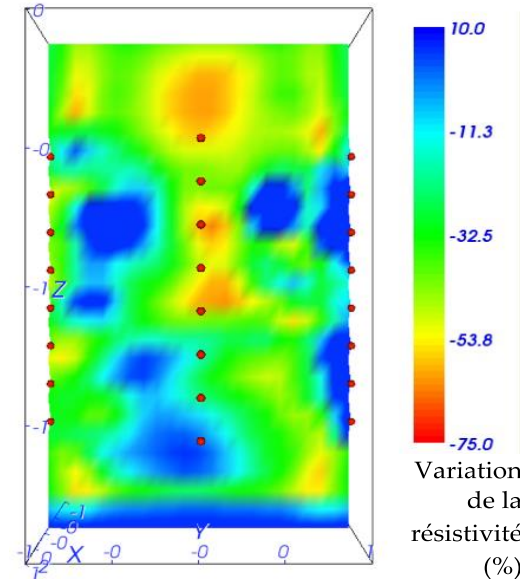
Evolution of soil functions



Requalification of soil functions



Monitoring of oxidation



Fenton amendé

Environmental monitoring
Evolution of residual pollution

Coord. J.L. Morel / L. Galdemas

Collaboration GISFI – BRGM – ArcelorMittal REF – Solvay – TVD

Chemical oxidation and soil reclamation (OXYSOL/BIOXYVAL)

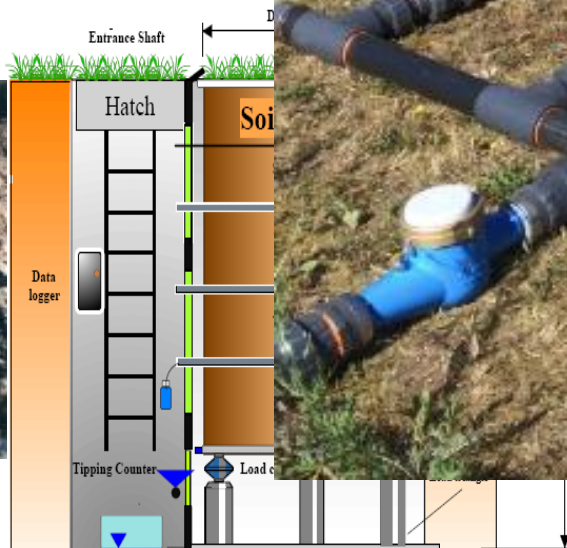
Evolution of soil functions

Requalification of soil functions

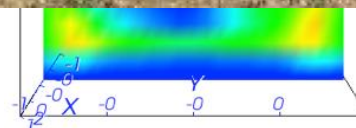


Hap (1175 g.kg⁻¹)

BIOXYVAL – scaling-up for field implementation
Injection of oxidant and heating
collaboration GISFI/ICF Environnement
Thesis : B. Ranc



Collaboration GISFI – BRGM – ArcelorMittal REF – Solvay – TVD



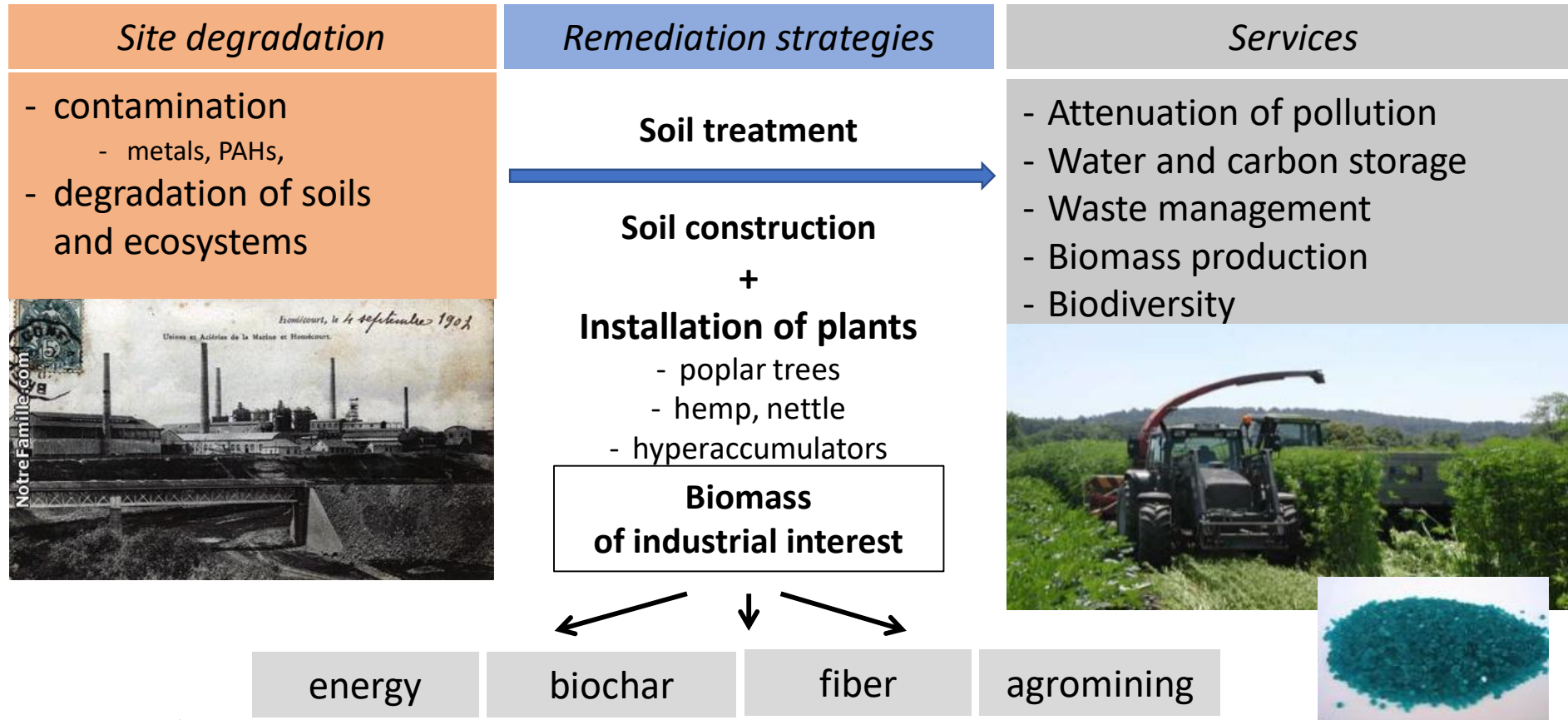
Variation
de la
résistivité
(%)

Environmental monitoring
Evolution of residual pollution

Coord. J.L. Morel / L. Galdemas



The LORVER project (2013-2018): production of biomass on abandoned sites



4 companies
5 research groups

energy biochar fiber agromining

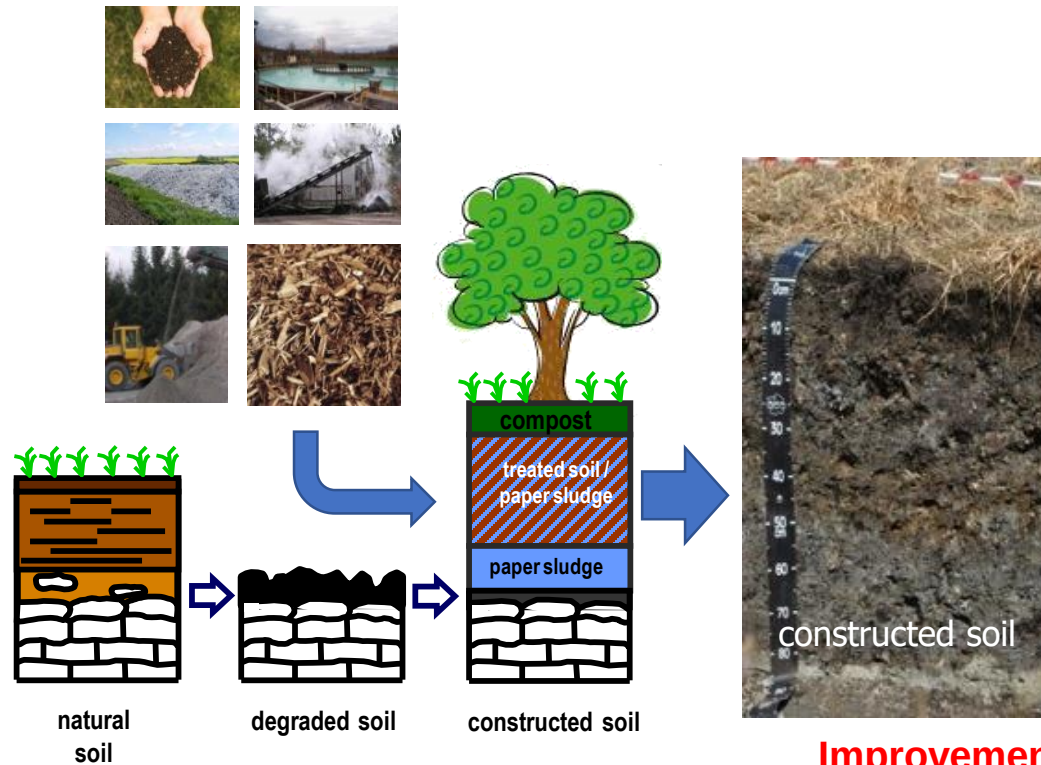
➤ *Challenge : build a chain of services
and control residual pollution on abandoned (contaminated) sites*

<http://www.lorver.org>

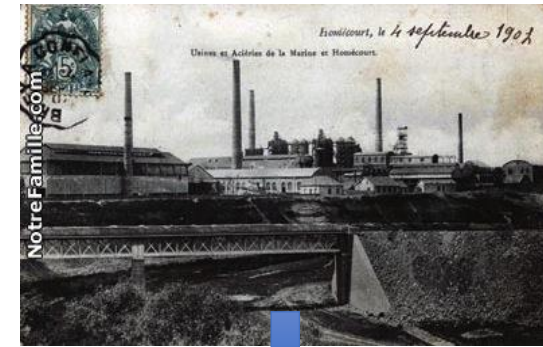
Reuse of brownfields for biomass production

⇒ **Multifunctional soils to ensure a large range of ecosystem services, similar to that of natural soils**

⇒ **provision** (biomass), **regulation** (filter/exchange, biodiversity, C storage, use of anthropogenic material to protect natural soil capital)



(Sere, 2007; Sere et al., 2007, J. Soils Sed.)



LORVER project



Improvement of provisioning and regulating services
(**biodiversity, C storage, waste management**)



GISFi

<http://gisfi.univ-lorraine.fr>

GISFi *tech* PROGEPI

<http://www.progepi.fr/gisfitech>

