Tauw

Cost / Carbon footprint / Efficiency evaluation for the treatment of TPH contaminated soils: off-site disposal vs. on site Bio- or Rhizo-degradation

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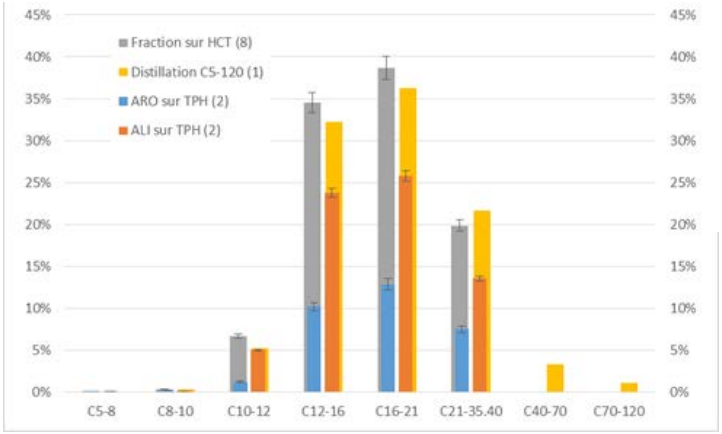
Context

Soils contaminated by drilling mud/slurry from oil extraction wells

- Mud / slurry fluidized with oil
  - diesel-like product, mainly C13-C25, 70% aliphatic HC
  - Average conc. ~ 30,000 mg/kg DW
- Site configuration:
  - Limited space, rural zone, no access to energy
  - Land to be restored by 2026
  - 16,000 m^3 soil/sludge stock

→ **Treatment options?**



Comparison metrics of treatment options

How to evaluate cost – duration – efficiency?

- Off site solutions: Thermal Desorption vs. Biological

  Cost – duration – efficiency = given by treatment facilities
- On site solutions: Thermal Desorption vs. Biological with / without vegetation growth

  Cost – duration – efficiency = given by contractor for TD … but for biological ???

→ Field scale feasibility study (biopiles) to better evaluate actual design parameters and treatment conditions

- **Biodegradation** (aerobic) vs. **Biodegradation enhanced by vegetation**
- Monitoring for ~2 years period
- Performance criteria: reduction in TPH conc. & toxicity, cost / duration / carbon footprint

Configuration of the field pilots (~100m³ each)

based on previous lab. exp. performed by MicroHumus

Biopiles “A” : biodegradation (21 months)

- Aeration by mechanical mixing every 2-3 months
- Under cover (rain-evaporation & light preservation)

Rhizopiles “C” : bio- (4 months) + vegetation (17 months)

- 0-4 months: same as Biopiles “A”
- @ 4, 10 and 15 months: (re)seeding Ray-grass and Alfalfa
- >4months : undisturbed and uncovered

*arable soil planted @2 months

Mixture (%DW)	A&C 4/6	A&C 4/6a	A&C 2/8	A&C 2/8a	Polluted Control	Arable soil*
Soil/sludge	**64,9%**	**64,8%**	**84,3%**	**84,1%**	**100%**	
Arable soil	31,2%	31,1%	13,2%	13,1%		100%
Compost	3,8%	3,8%	2,5%	2,5%		
Limestone	-	0,26%	-	0,25%		
Urea	0,02%	0,02%	0,02%	0,02%		

Compost	proportion
Pine bark 10/25 mm	70 %
Green vegetation 0/10 mm	30 %

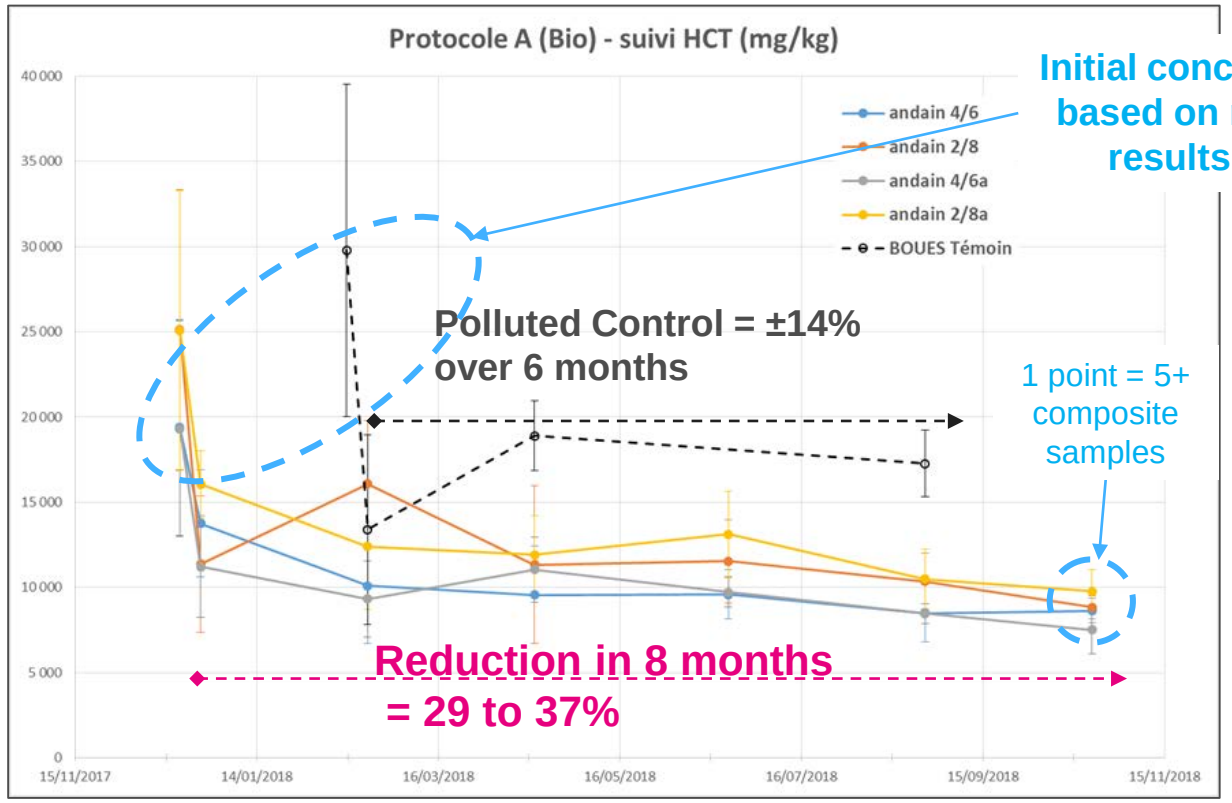
Monitoring program and partnership

Compare all treatment conditions: sampling every 2-3 months for 21 months

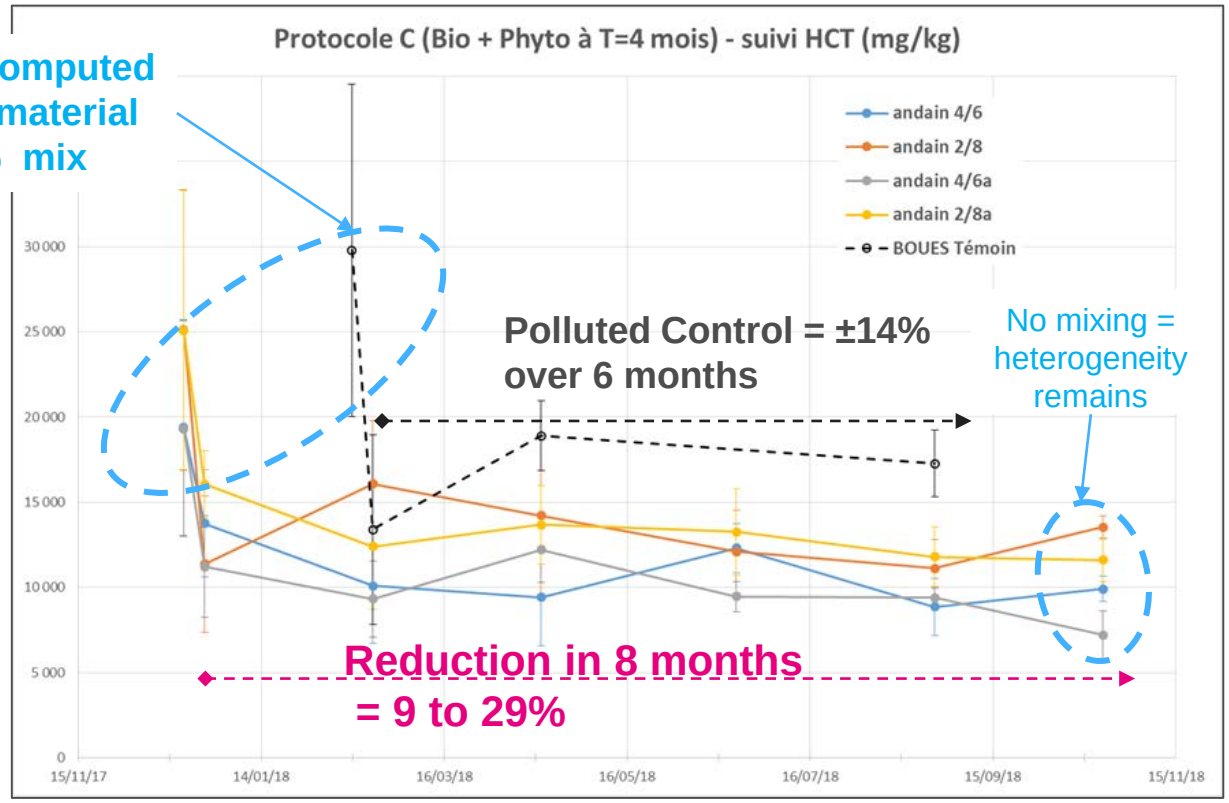
- **In-situ measurement** in piles: pH, Temperature, and biogas production (CO2-O2-CH4) → Tauw France
- **TPH concentrations** in replicate samples, distribution with depth in the piles (0-30 / 30-60 / 60-100 cm),
- **General soil quality**: metals, N/P/K balance and speciation, cationic exchange capacity, alkalinity, TOC,
  → Synlab
- **Microbial analysis**: RISA on Bacteria and Fungi, qPCR on total bacteria and total Fungi, qPCR on functional genes (TPH degraders) → Enoveo
- **Nematodes** index and diversity (NF/ISO 23611-4) → Elisol
- **Plants development**: sampling after plant growth
  - Plant growth (root and stem), biomass production → Tauw France
  - Omega 3 analysis in leaves (XP X31-233) → LEB-Aquitaine
  - TPH analysis in the biomass (plant uptake and accumulation) → Eurofins
- **TPH advance analysis & availability in soil matrices**: in-depth chromatography, thermodesorption lab tests → Univ. Lorraine (LIEC/Géoressource)

Performance monitoring: TPH results

Biopiles “A” : biodegradation (8 months)



Rhizopiles “C” : bio- (4 months) + vegetation (4 months)

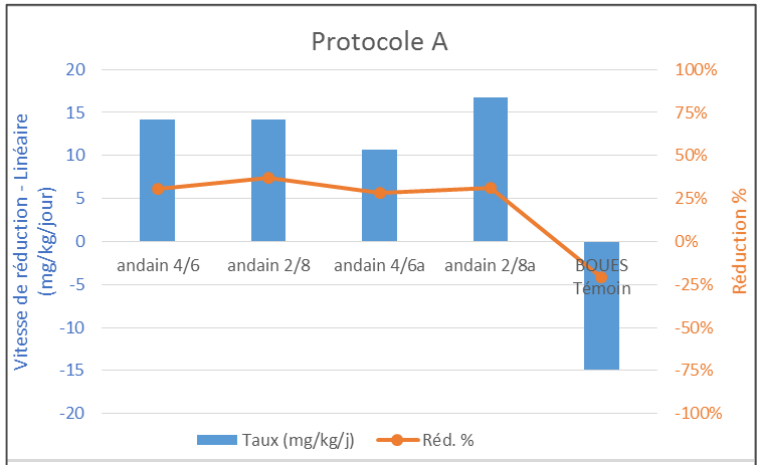


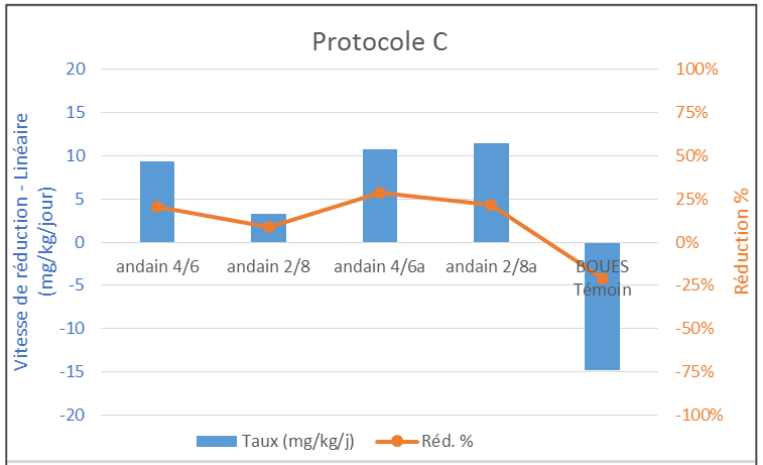
Is it biologically active or is there “something else” ? Do plants help ? Any matrix effect ?

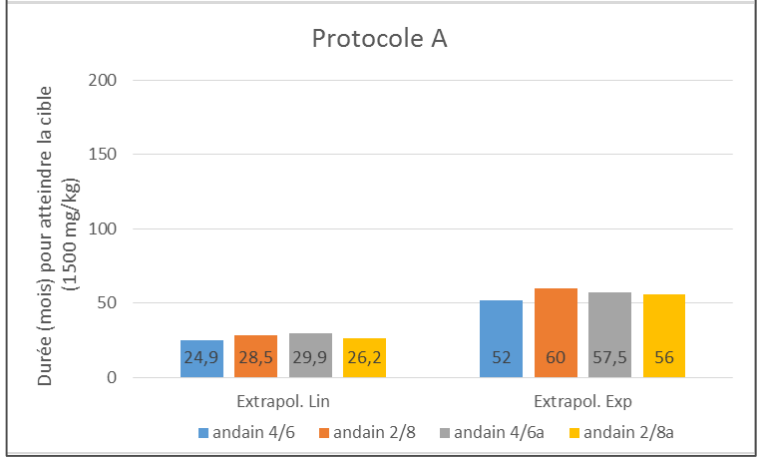
Extrapolation for « complete degradation »

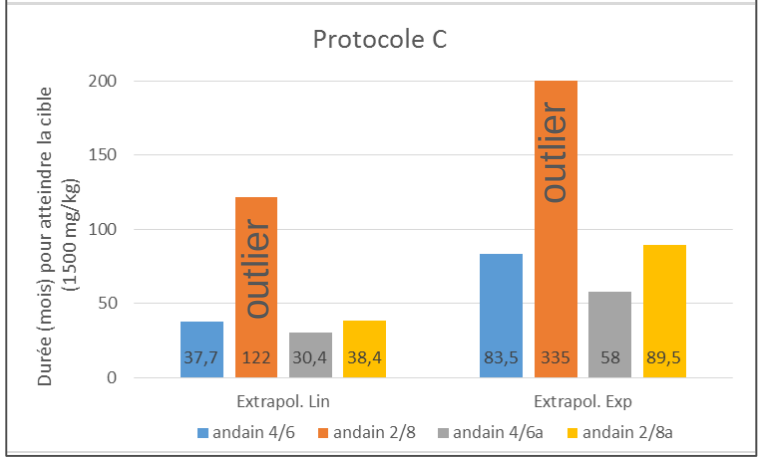
Theoretical treatment target = 1 500 mg/kg DW

Estimated duration (in months) of treatment based on 10 months monitoring (only)







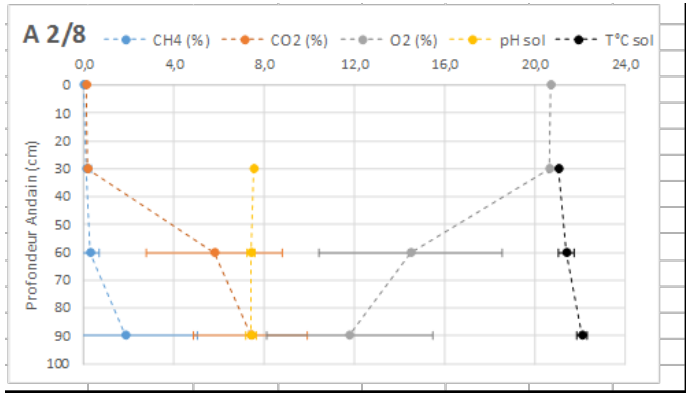


- **Expected treatment duration?**
  - Biopiles: no significant differences
  - Rhizo-piles: same except for 1 pile
- **Enhancement by vegetation?**
  - Longer expected treatment duration with vegetation (w/o mechanical mixing): +45% to + 60%
  - No mixing & Heterogeneity in soils
- **Reduction in Toxicity (restore agriculture use)?**
- **What is the achievable residual concentration?** → all TPH fractions 100% degradable?

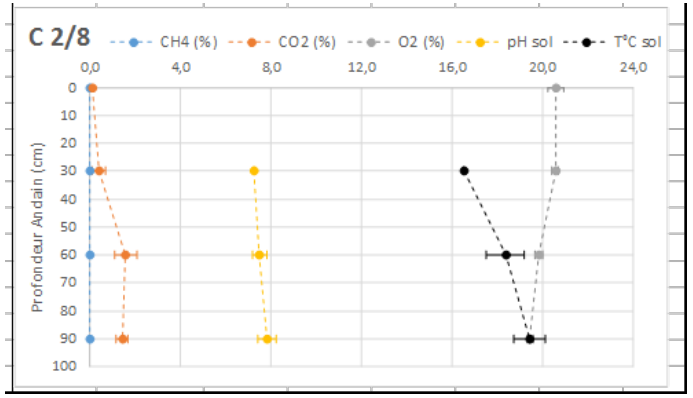
Indicators of biodegradation in the piles (after 10 months)

In-situ gas monitoring

BioPiles A



RhizoPiles C



In-situ gas

- O_2 uptake and CO_2 production = higher efficiency in Biopiles
- Rather stable pH

Good aeration relies on mechanical mixing (biopiles A) or root development (rhizopiles C)

Biomarkers

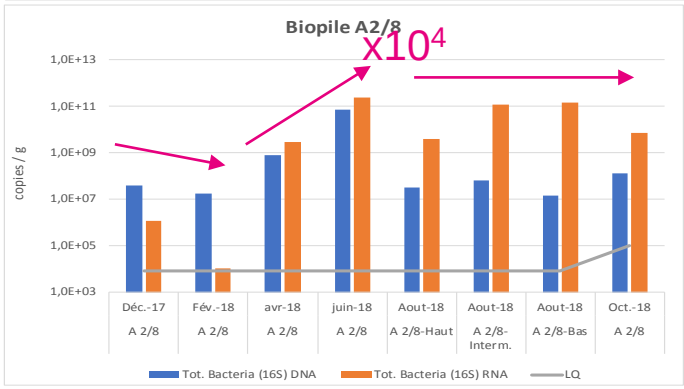
- Increase in total bacteria : higher in amended biopiles
- Evolution in specific genes (degraders for C5-C20 TPHs)
- Stable fungi and nematode populations

Bacterial population difference in Vegetated piles?

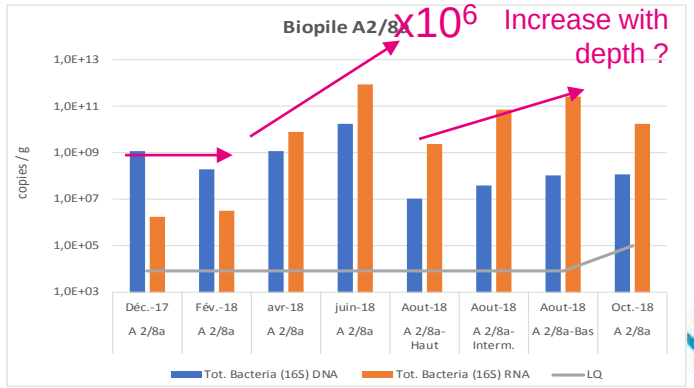
Chemical indicators as other proof of biodegradation processes?

Biomarkers monitoring

BioPiles

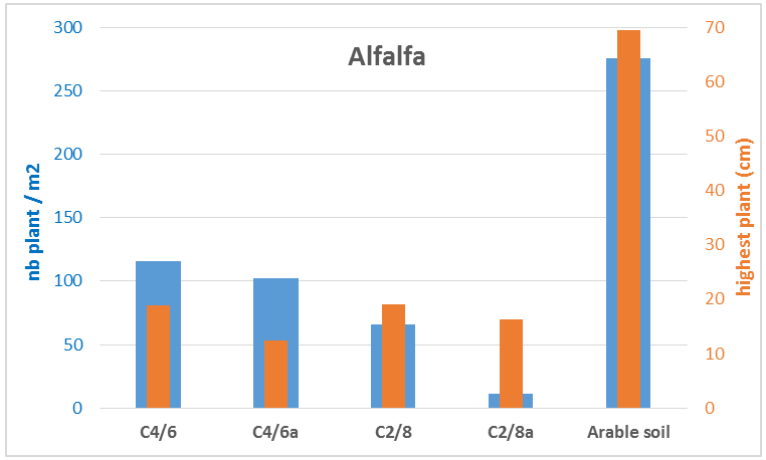


Amended BioPiles

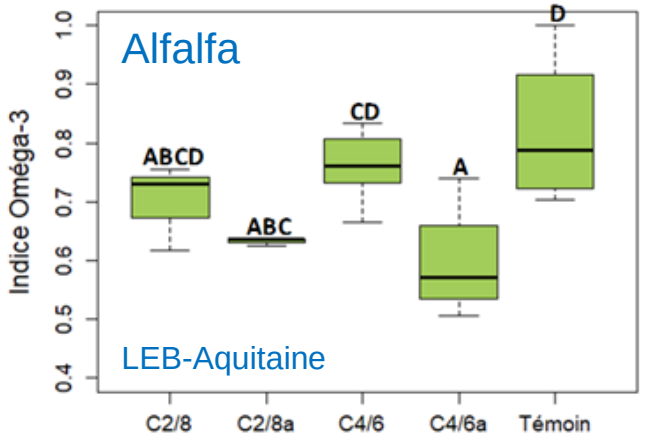


Vegetation development & Ecotoxicity
in Rhizopiles C (seeding in April-18)

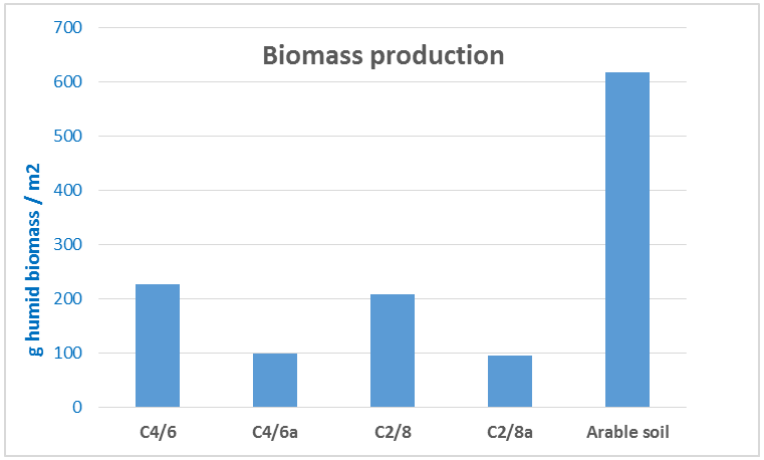
Density & height after 2 months (June-18)



Omega3 index after 4 months (Aug.-18)



Biomass production after 6 months (Oct.-18)

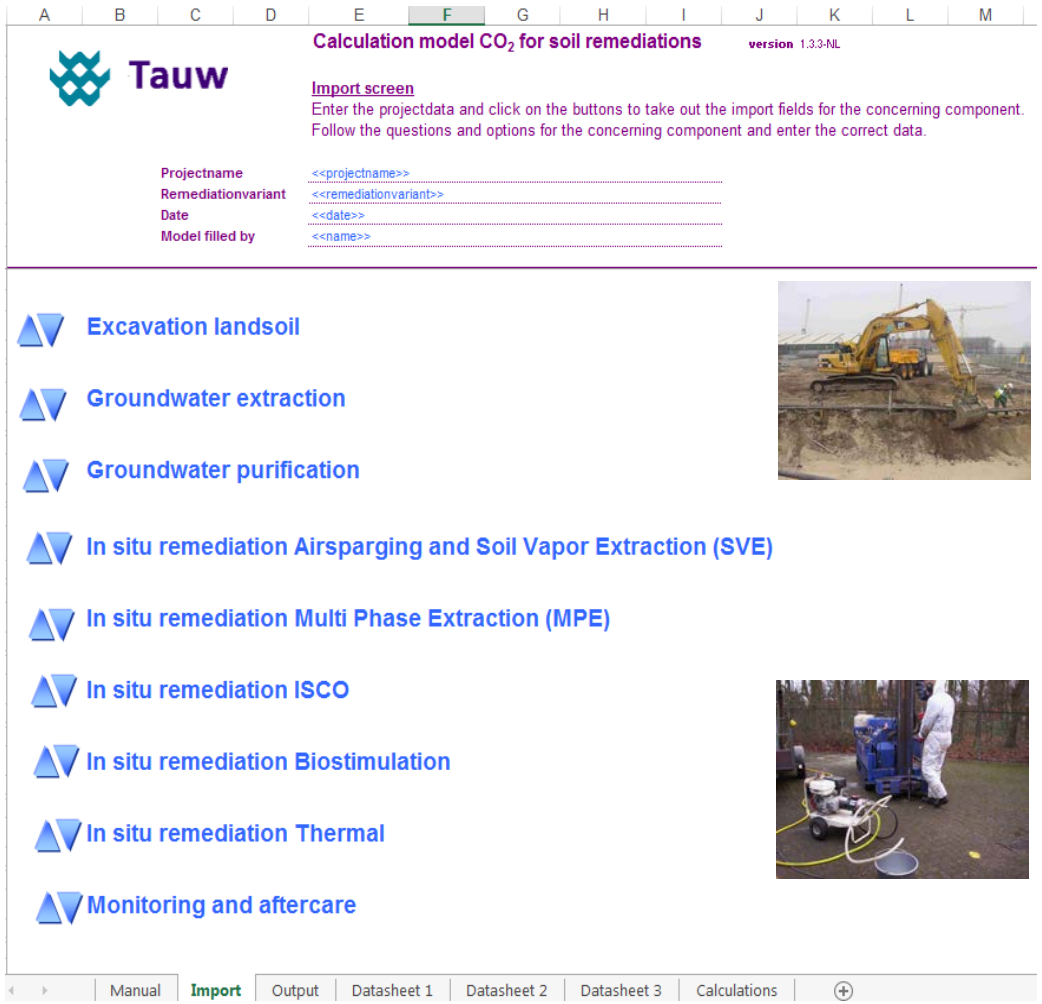


- Vegetation growth
  - → arable soil = reference for plant gowth
  - → lower Alfalfa density & Omega 3 as well as total biomass production with high TPH or limestone content
- Other ecotoxicity tests (earthworm, daphnia, Fischeri) = no difference in piles / arable soil / raw contaminated soil
- No TPH measured in biomass → **possibility to use soils as agricultural land after treatment?**

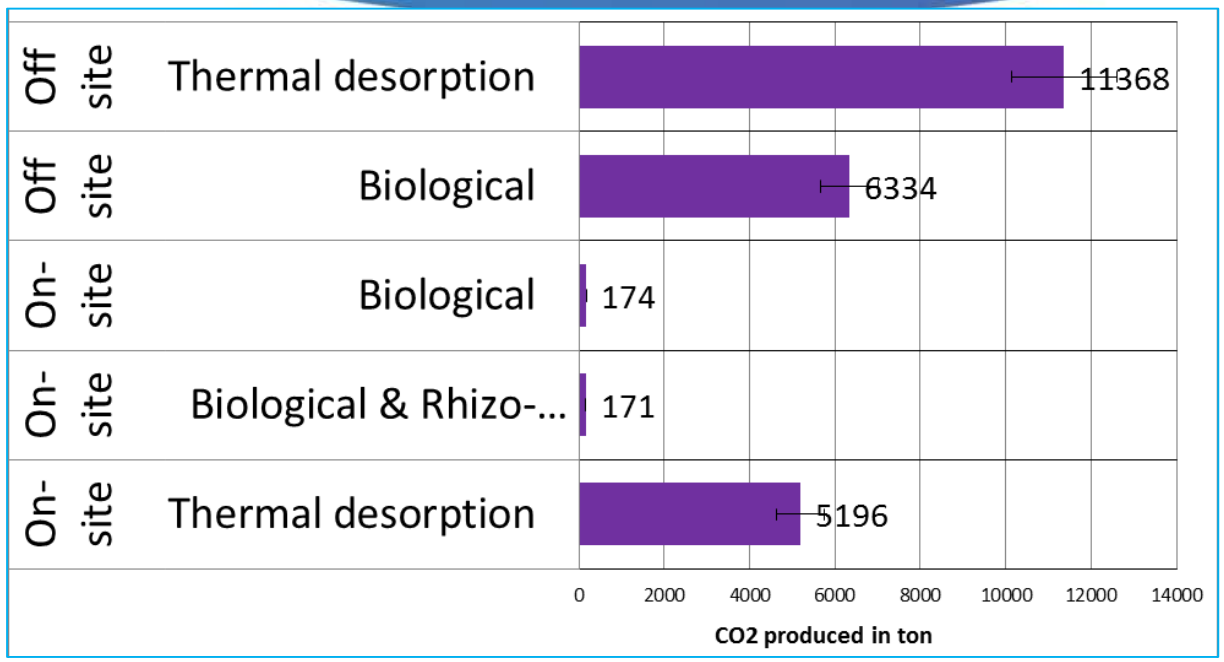
Carbon footprint of remediation options

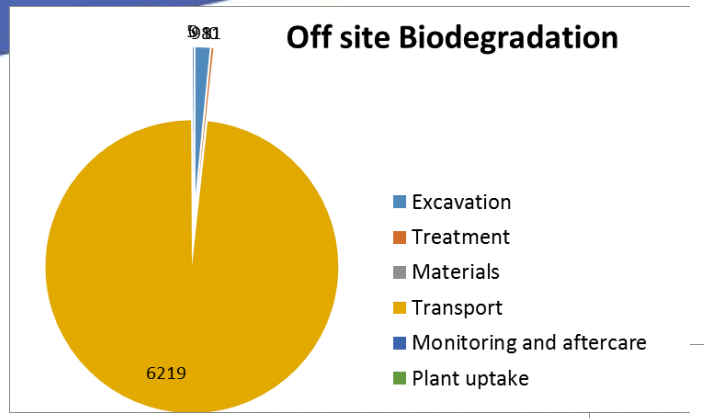
Carbon footprint computations

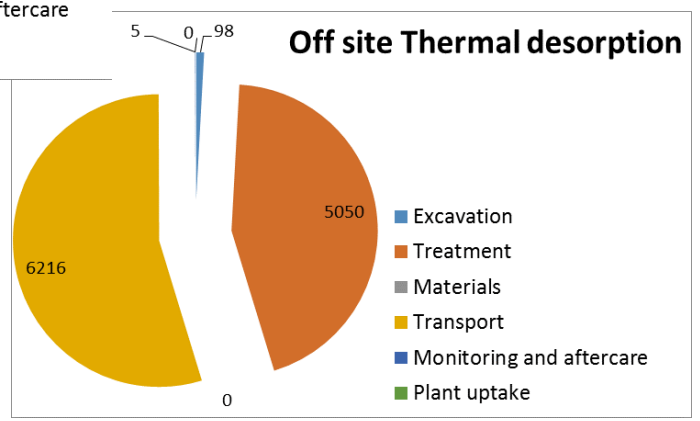
- REC model (Haselhoff et al., 2011)
- Dynamic spreadsheet for remediation options
- Inputs
  - Power source / nature (7 choices)
  - Consumption & fuels
  - Materials (pipes, sheets …)
  - Reactions (chemical / biological)
  - Pollutants and expected efficiency
  - …
- Output = CO2 emission
  - Equipement
  - Transport, vehicule type
  - Maintenance & monitoring
  - Raw material, wastes, effluents
  - …

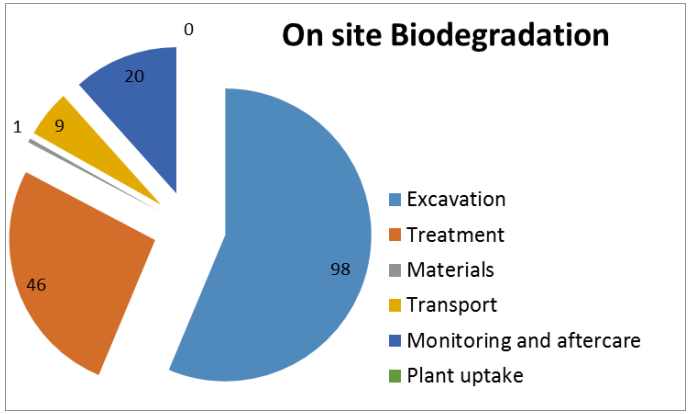


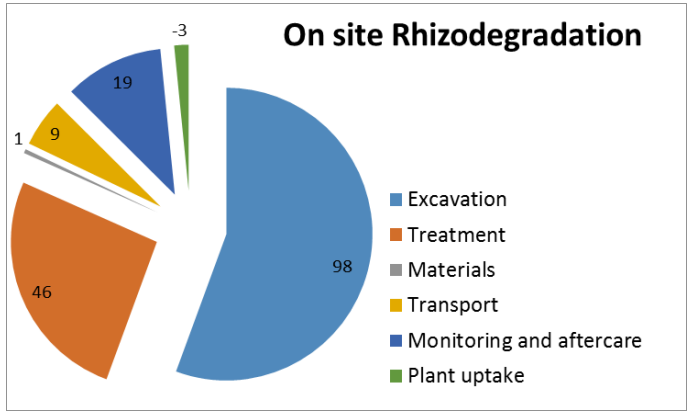
Carbon footprint results

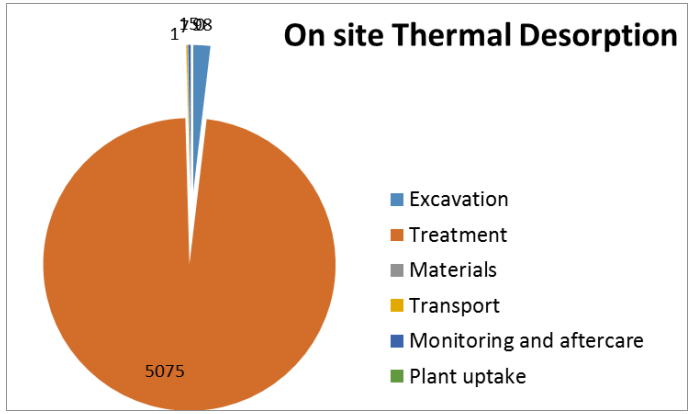












Overview of treatment alternatives for 16 000 m^3

	Treatment	Time	Cost (€)	Carbon footprint (tons of CO_2)	Remarks (+ / -)
Off site treatment	Thermal desorption	**4 months***	**3,8 M€**	**11 400 T CO_2** 55% due to transport, 44% due to treatment	+ Residual concentration < 50 mg/kg - Transport outside France (ship) - Loss in soil functions
	Biological	**4 months***	**2,8 M€**	**6 300 T CO_2** 98% due to transport	- Residual concentration # 500 mg/kg - Transport outside France (ship) +/- Increased value of soils?
On-site treatment	Biological	**5 months* + 2-3 years****	**2,4 M€**	**174 T CO_2** 56% due to excavation, 32% due to treatment	- Residual concentration # 1500 mg/kg - Treatment time x mechanical aeration +/- New use for treated soils?
	Biological & Rhizo-dégradation	**5 months* + 3-5 years****	**2,1 M€**	**170 T CO_2** 56% due to excavation, 32% due to treatment	- Residual concentration # 1500 mg/kg + Soil aeration due to roots growth - Longer treatment time + New use for treated soils: it seems so! + CO_2 captation by biomass growth (~3 T)
	Thermal desorption	**4 months* + 2 months****	**2,8 M€**	**5 200 T CO_2** 98% due to treatment	+ Residual concentration < 50 mg/kg - Losses in soil functions +/- Treated soil buried on site (excavation open pit)

* Duration for excavation & preparation works and soil loading (time for off site treatment not included).
** Duration of on-site treatment to acheive reduction in TPH concentrations (extrapolation from results gathered after 10 months monitoring)

Conclusions and pending work

CO_2 emission criterion = insight in Cost-Benefit Analysis for remediation options

- Shorter Time: Off-site treatment options save 2 to 5 years
- Lowest Costs: On-site Bio- / Rhizo- Degradation save > 1 M €
- Lowest Carbon footprint: On-site Bio- / Rhizo- Degradation save 5 to 10 K Tons CO_2
- Higher Efficiency: Thermal Desorption (Off- / On-Site) achieves residual < 1% initial

Questions to be addressed during remaining monitoring period (until Sept.)

- Design parameters & best treatment conditions
  - → Thorough statistical, correlation & tendency analysis
- Residual effects (Toxicity) and soil use / valuation (agricultural use)
  - → Other Ecotoxicity tests (functional responses & TPH transfer in agricultural crop)?
  - → Public / Authority acceptance?
- Lowest achievable residual concentrations with on-site bio- or rhizo-degradation?
  - → Bio-availability evaluation: thermal lab. essays (on-going work with GISFI-LIEC)

Thank you!

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