ORP-assisted phytoremediation of hydrocarbon contaminated sediments

Stéphanie OUVRARD, Pierre LEGLIZE, Joan DUPUY, Pierre FAURE,
Sophie GUIMONT, Charlène PIERRON, Jean-Christophe RENAT

Introduction

- Industrial site water run-off might be dealt with water treatment unit followed by settling channels before discharge in the environment
- Sediments heavily charged with hydrocarbons progressively accumulate in these channels
- Two management options might be considered:
  - Dredging and disposal
    BUT contamination is an issue
    AND industrial site nearby a natural resource protection area
  - *In situ* management by phyto-assisted treatment:
    → stabilization / degradation? assisted by ORP?

General approach

- Two-step strategy

  1st Anaerobic biodegradability assessment

  2nd Phytotoxicity evaluation

  – Possibility for rhizodegradation/phytostabilization

- Additional factors

  – Saturated conditions

  – Impact of oxygen release product (ORP) addition

Materials: *the sediment*

- Fertility

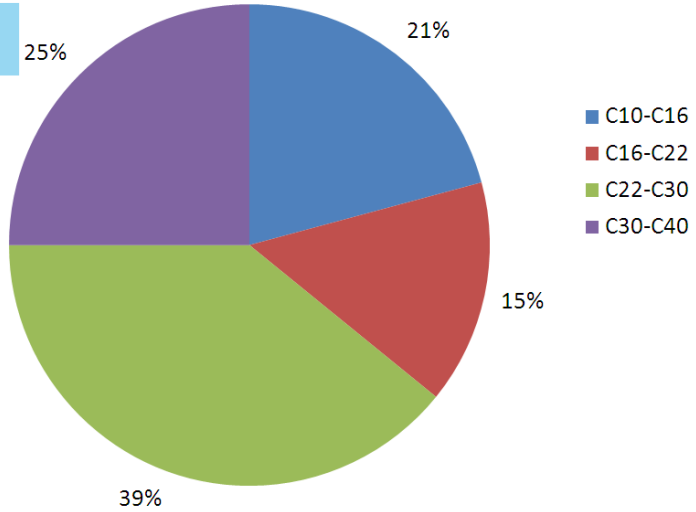
pH	C_{org} (%)	N_{tot} (%)	N_{org} (mg/kg)	CEC (meq/100 g)
7.67	8.39	0.658	5.98	24.3

- Trace elements *[mg/kg D.M.]*

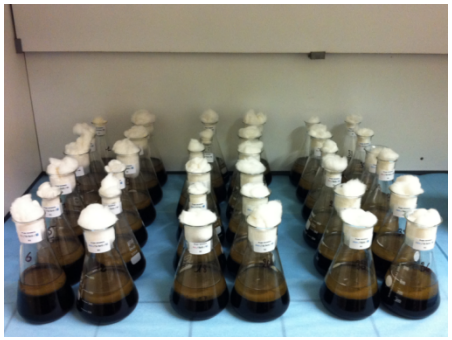
As	Cd	Cr	Cu	Ni	Pb	Zn
50	1.8	130	82	41	68	790

- Hydrocarbons *[mg/kg D.M.]*

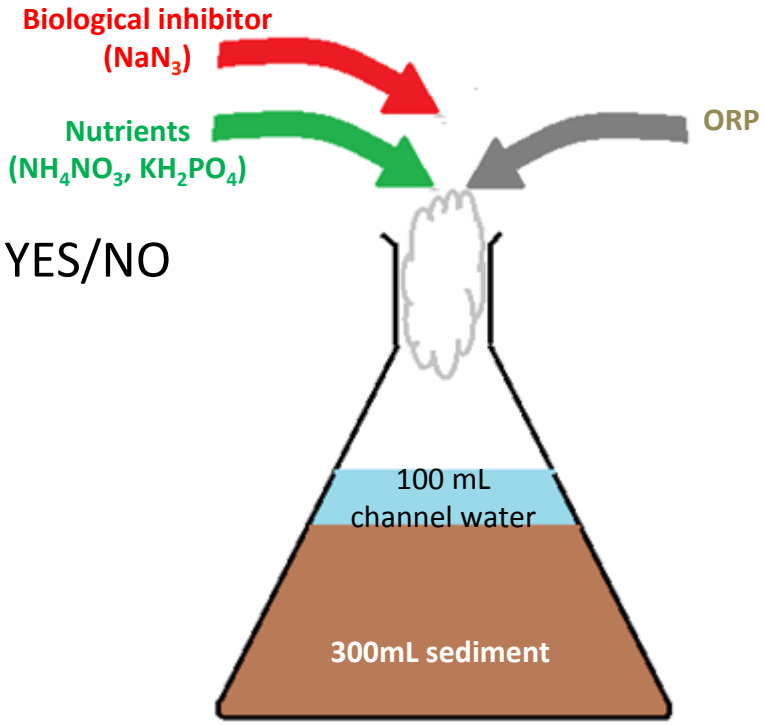
THC (C_{10}-C_{40})	C_{10}-C_{16}	C_{16}-C_{22}	C_{22}-C_{30}	C_{30}-C_{40}
8250	1715	1243	3225	2063



Methods: *in vitro biodegradation*



- 10 weeks, darkness, 20°C
- Treatments
  - 3 ORP (CaO_2, IXPER® 75C, Solvay) levels optimal = X2 ; X1 = X2/2 ; X0 = 0
  - Biological inhibitor (NaN_3 à 0,33% w/w): YES/NO
  - Nutrients (C/N/P = 10/1.5/1): YES/NO
  - Three replicates
  - ➢ 36 systems
- Analysis
  - pH, Eh, dissolved O_2
  - anions, cations, DOC
  - TOC, THC, microbial characterization



Methods: *plant growth assays (1)*

- Selection of five plant species based on:
  - literature: known phytoremediation efficiency, resistance to hydrocarbons toxicity
  - adaptation to aquatic environment and local climate
  - availability in green houses

Saururus cernuus

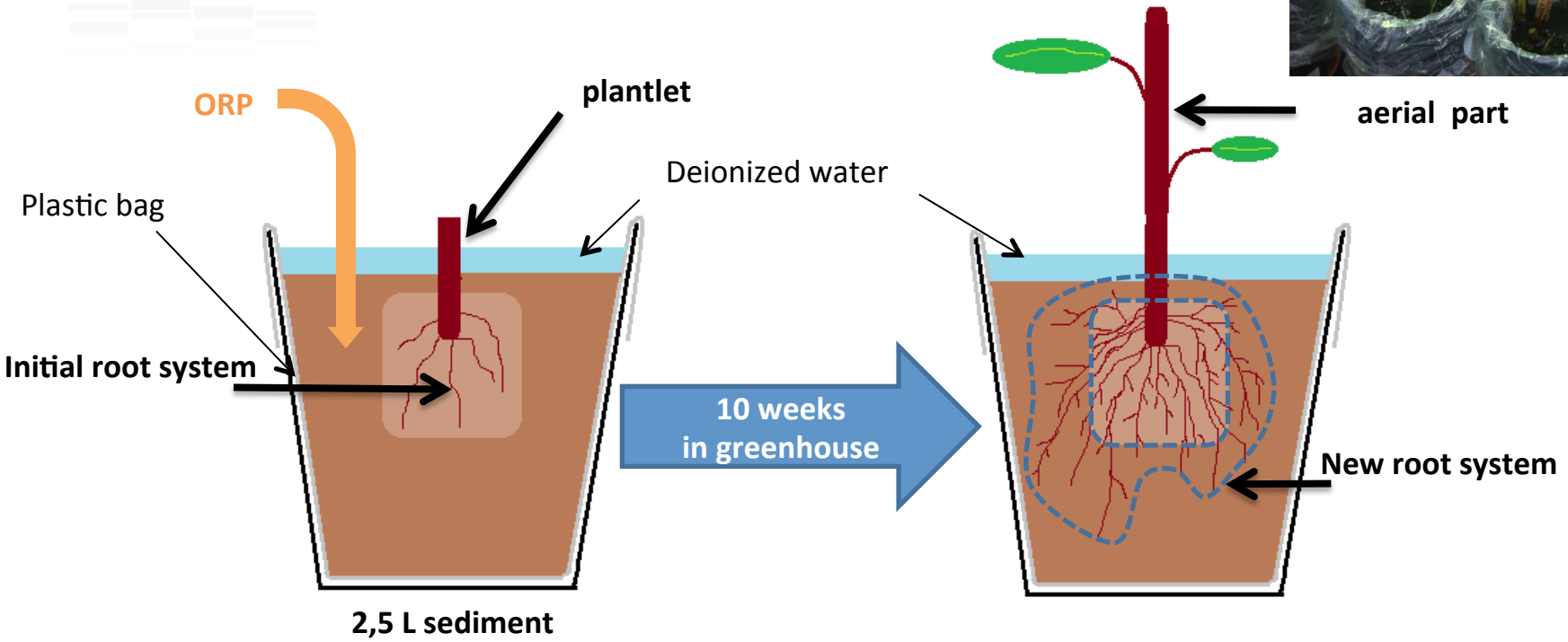
Scirpus lacustris

Thalia dealbata

Typha latifolia

Phragmites australis

Methods: plant growth assays *(2)*



- Treatments in 4 replicates (68 pots):
  - ORP or not; five plant species
  - Controls: no plant; un-contaminated substrate (commercial)
- Analysis: biomasses, microbial count, THC

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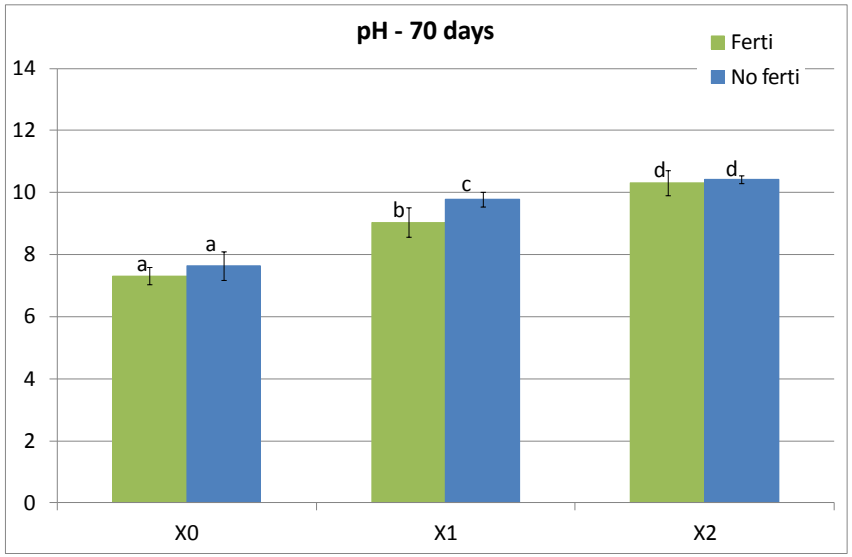
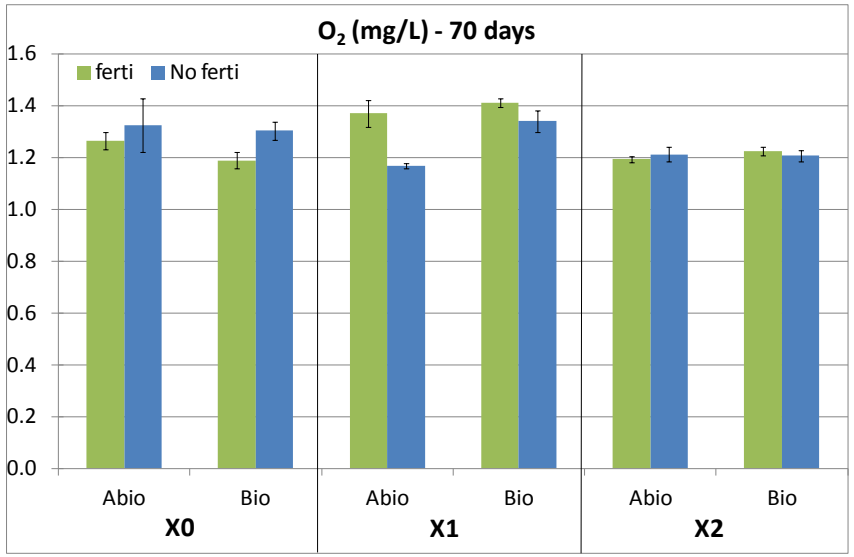
In vitro biodegradation

pH & dissolved O_2

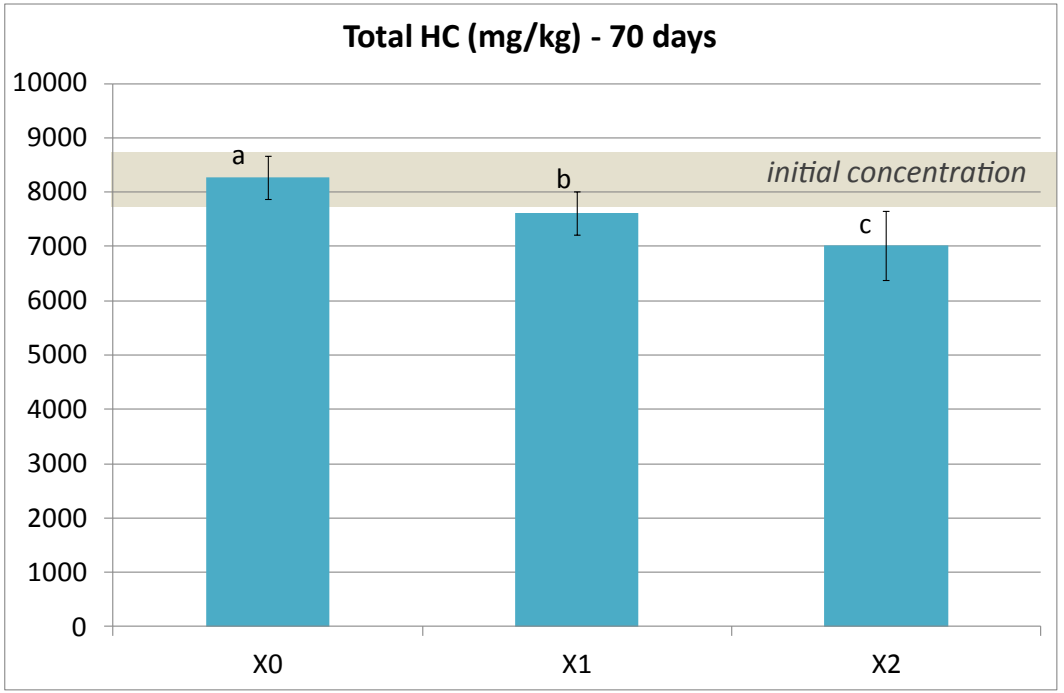
- Over 70 days periods ORP level is the main driver for physico-chemical variations
  - significant pH increase that might be an issue for biological activity
  - no significant effect over dissolved O_2, possibly due to consumption





Total HC

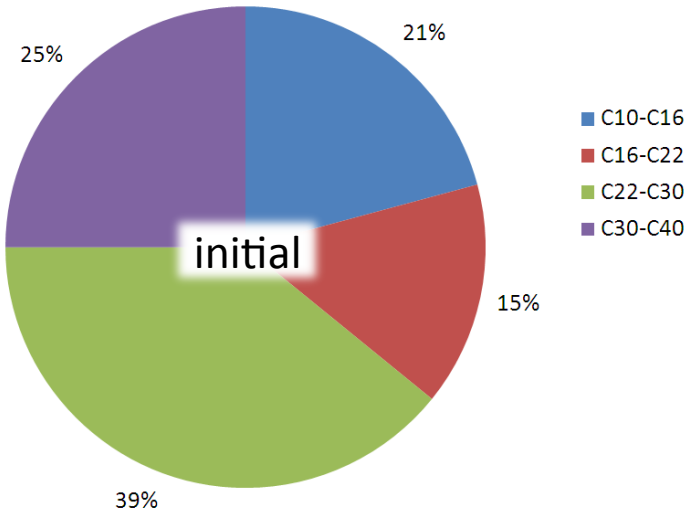
- ORP level is the only parameter of influence
  - no significant evolution without ORP
  - Respectivele 8% and 15% removal with X1 and X2 levels

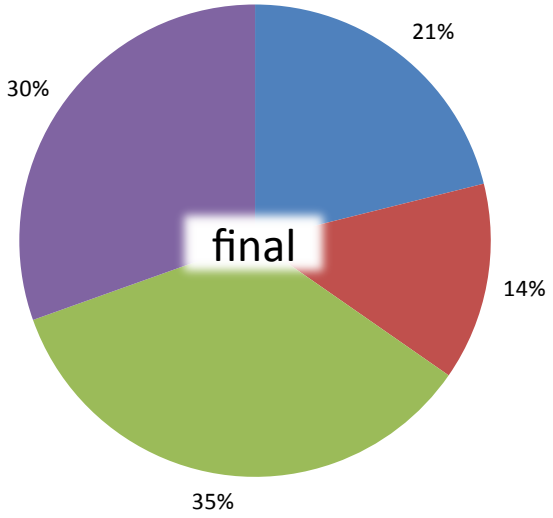


Detailled HC degradation with X2

- Maximum degradation is observed for the C_{16}-C_{30} fraction

	HCT (C_{10}-C_{40})	C_{10}-C_{16}	C_{16}-C_{22}	C_{22}-C_{30}	C_{30}-C_{40}
initial	8250	1715	1243	3225	2063
X2 – 70 days	7017	1482	952	2447	2137
Yield (%)	15	14	23	24	0

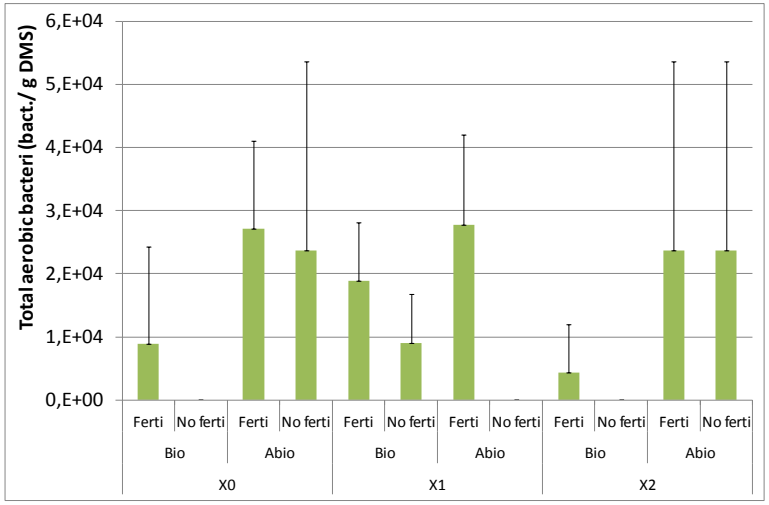




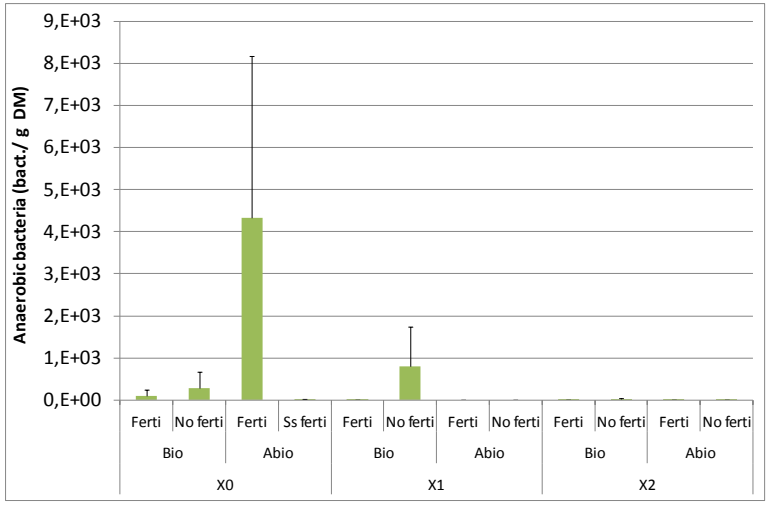
Microbial counts

- Bacterial levels are generally low especially for anaerobic bacteria
- For aerobic bacteria, physico-chemical conditions modifications have no significant effect
- For anaerobic bacteria, pH increase due to ORP addition seems detrimental

Total aerobic bacteria



Total anaerobic bacteria



Plant growth assays

Plant development

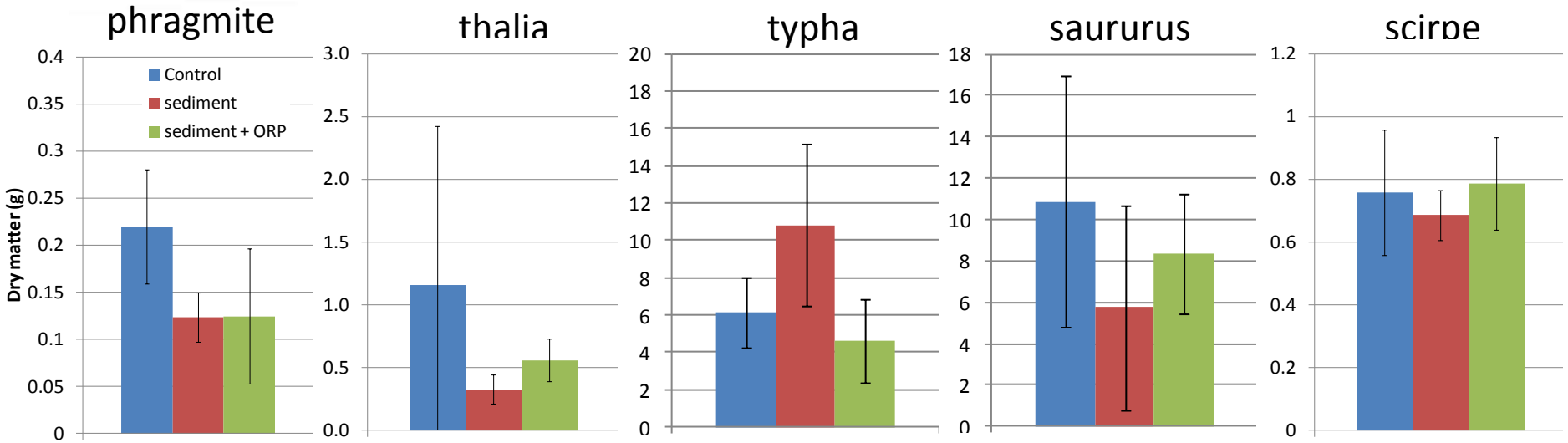
Example: *Saururus cernuus*

control

sediment +ORP

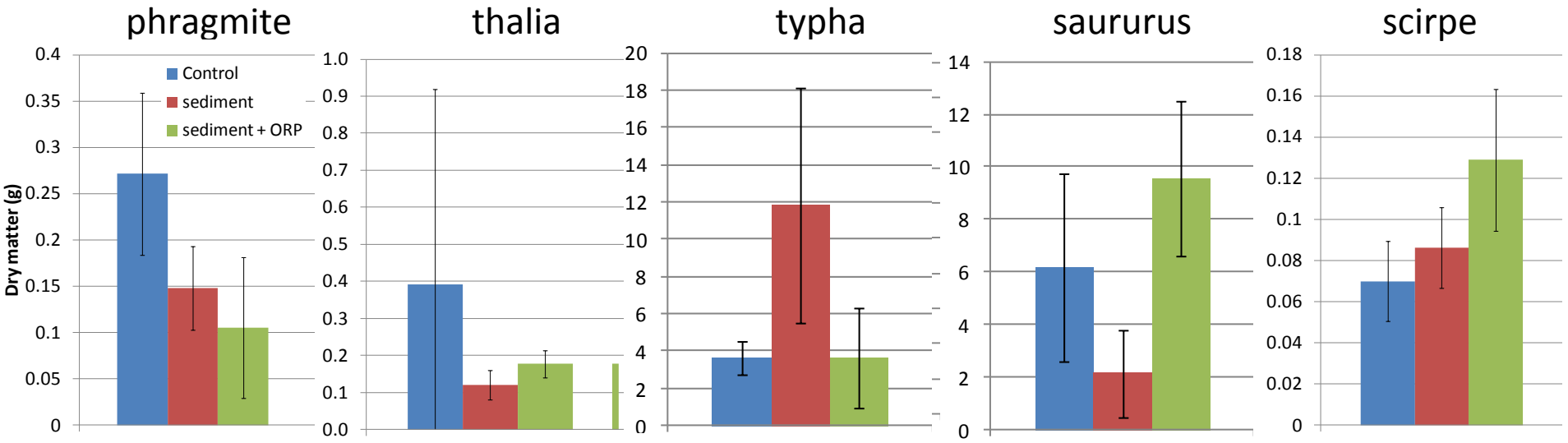
sediment

Aerial biomass



- sediment toxicity for phragmite and thalia
- no or non significant toxic effect on typha, saururus and scirpe
- ORP tends to improve plant development and limits sediment toxicity impact (thalia, saururus)

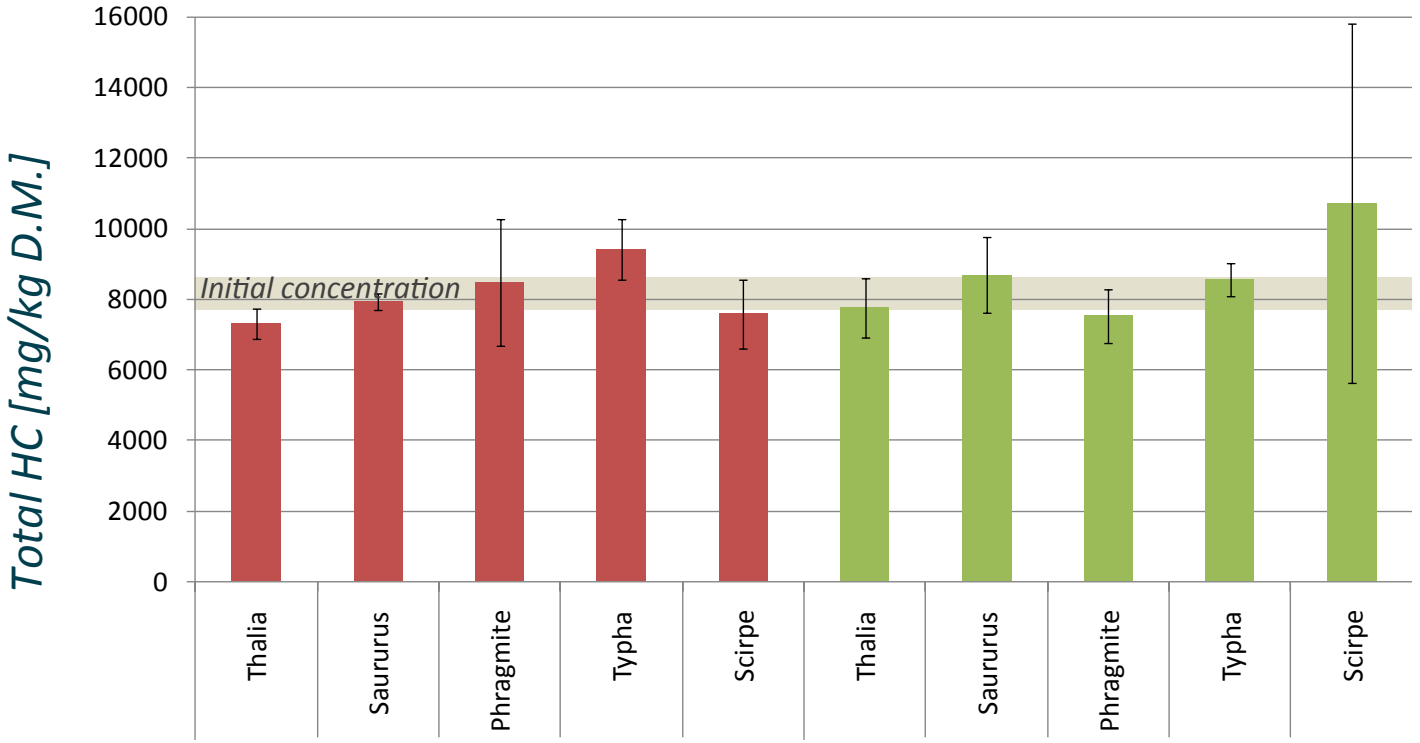
Root systems development



- sediment toxicity for phragmite and thalia
- non significant or small toxic effect on typha, saururus and scirpe
- ORP tends to improve plant development (scirpe) and limit sediment toxicity impact (thalia, saururus)

THC degradation

- No significant effect on THC concentrations



Conclusions

- Biodegradation of total hydrocarbons seems a very slow and difficult process
  (poor bacterial activity, HC low availability & recalcitrance)
- Excess ORP only helps decrease HC content
  => probable chemical oxidation
- Given the appropriate choice of species (typha and scirpe preferred), plant establishment is feasible
- ORP amendment might improve plant growth but excess addition is detrimental to pH

Perspectives

- *In situ* demonstration pilot
  - validate plant establishment
  - longer degradation times might lead to better remediation yields
- Complementary study exploring alternative management practice
  - feasibility of dredged sediments phytoremediation
  - evolution of HC under aerobic conditions
  - new soil formation, fertility and sustainability