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CONTAMINATED SITES 2022

SENEC, SLOVAK REPUBLIC, 12 – 14 OCTOBER 2022

The activity has been implemented within the framework of national project
***Information and providing advice on improving the quality of environment in Slovakia**.*
The project is cofinanced by Cohesion Fund of the EU under Operational programme Quality of Environment.

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Remediation of a former mine technosol highly contaminated with As and Pb using (in)organic amendments combined with *Salix* species: a 5-year field study

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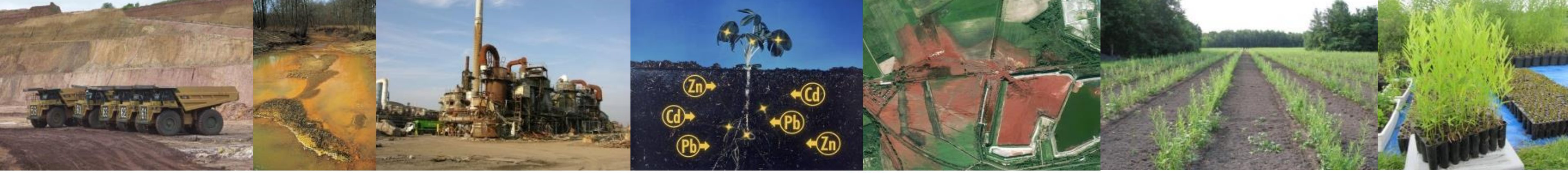

Laboratoire de Biologie des Ligneux et des Grandes Cultures
UPRES EA 1207

ARCHE
Arbres et Réponses aux Contraintes Hydrique et Environnementales

Remediation of a former mine technosol highly contaminated with As and Pb using (in)organic amendments combined with *Salix* species: a 5-year field study

Romain Nandillon[a], Manhattan Lebrun[ab], Yassine Chafik[a], Florie Miard[a], Sylvain Bourgerie[a], Domenico Morabito[a]

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Université d'ORLÉANS | UFR Sciences & Techniques

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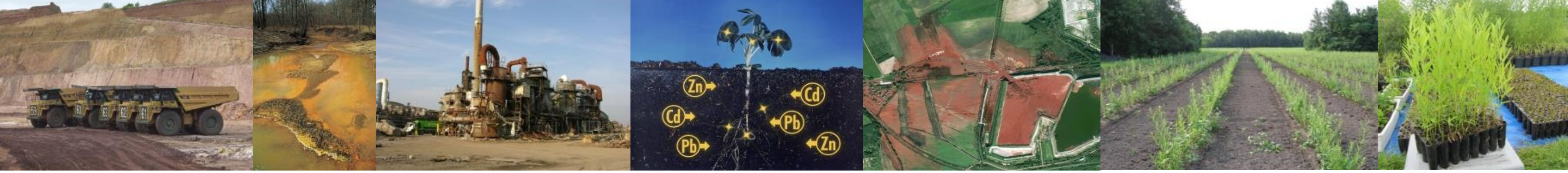

The contaminated site of Pontgibaud

- ✓ Pontgibaud district (Auvergne-Rhône Alpes, France)

- ✓ Former Pb-Ag extraction mine
- ✓ Exploitation until end of XIXth century

- ✓ Study site: deposit for crushing of ore (GPS: 45°47’27”N; 2°49’38”E)

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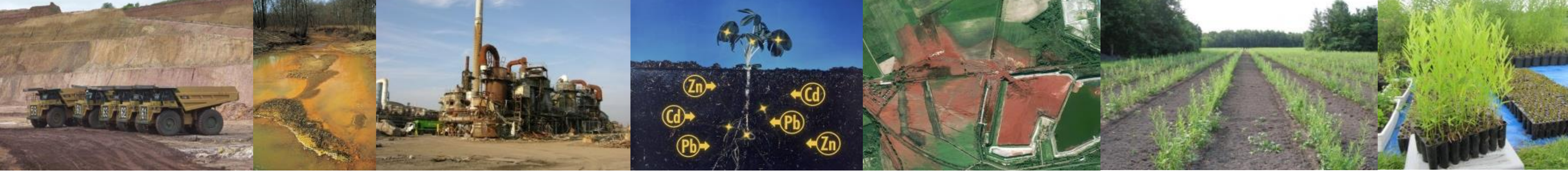

The contaminated site of Pontgibaud

Physico-chemical properties of Pontgibaud technosol (n = 3 ± SE)

	Value	Unit
pH	4.60 ± 0.02	
Organic matter	2.60 ± 0.7	%
Organic Phosphorus	465 ± 17	mg.kg^{-1}
Available Phosphorus	6 ± 1	mg.kg^{-1}
Total Nitrogen	75 ± 3	mg.kg^{-1}
Total Carbonates	0.7 ± 0.4	% $CaCO_3$
Cation Exchange Capacity	2.3 ± 0.1	cmol.kg^{-1}

→ **Acidic**
→ **Low fertility**

Metal(loid) content (mg.kg^{-1}) of Pontgibaud technosol (n = 3 ± SE)

	Value	Limits*
[Al]	2010 ± 187	NA
[As]	**1501 ± 326**	**20**
[Cd]	0.26 ± 0.00	3
[Cr]	5 ± 0	150
[Cu]	52 ± 5	140
[Fe]	6518 ± 1639	50000
[Mn]	7 ± 0	80
[Ni]	<DL	50
[Pb]	**19228 ± 1531**	**300**
[Zn]	284 ± 20	300

*Maximum permissible limit in soil (from Ashraf et al. 2019)
< DL = below detection limit (10 mg.kg^{-1} Ni)

Data from Lebrun et al. 2020 (LDD)

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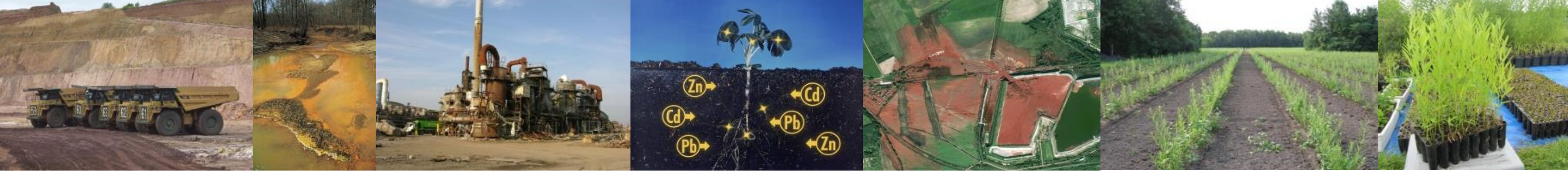
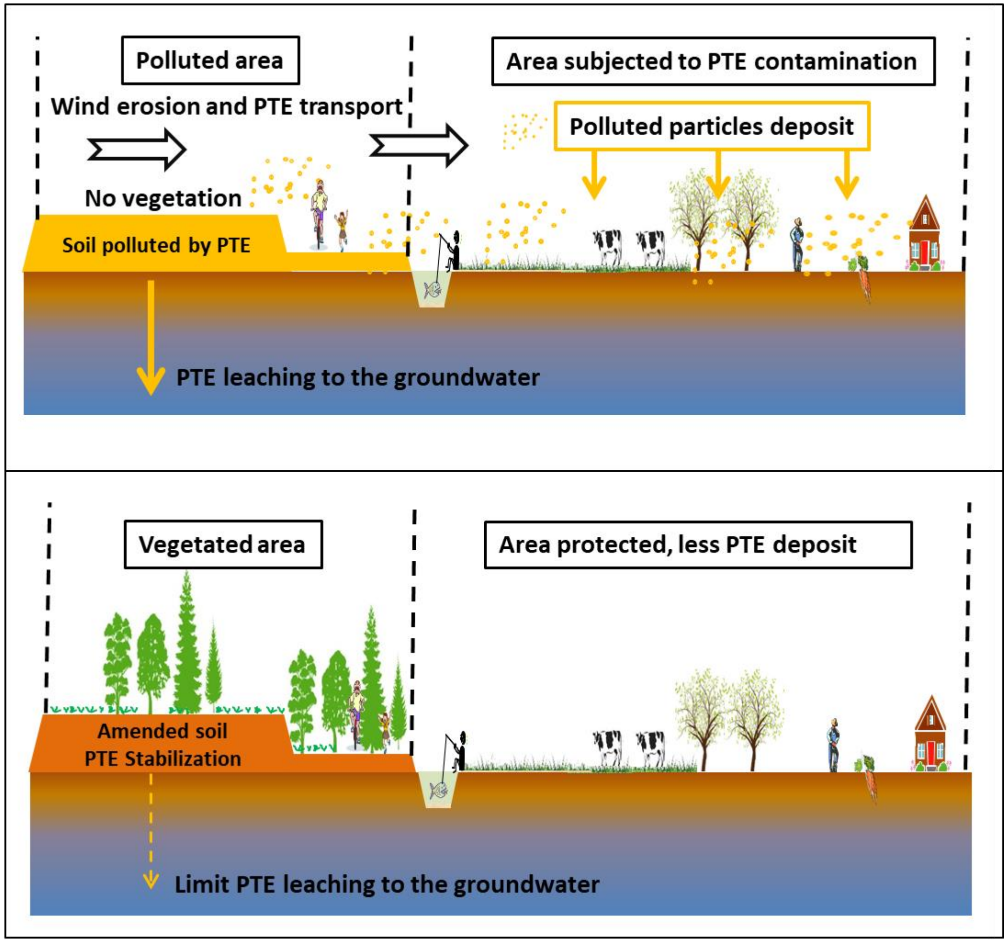


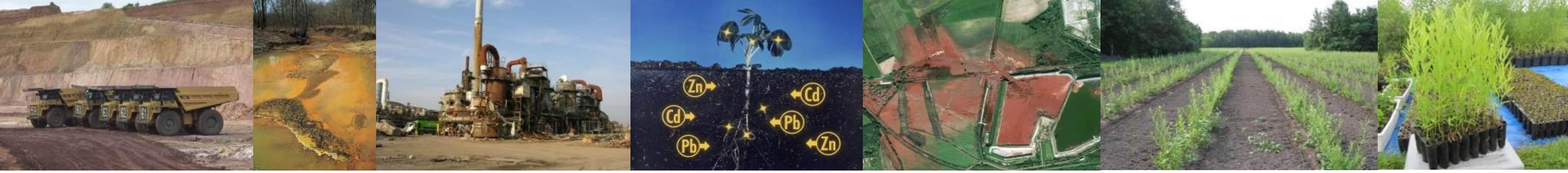
The contaminated site of Pontgibaud

Need to reduce erosion and leaching risks
= Protect the surrounding area

→ Implementation of a vegetation cover
→ Requires amendments



Lebrun et al. 2022, Assisted phytoremediation (pp. 101-130)



The use of amendments to ameliorate the soil

Bichar

- ❖ Source of stable carbon
- ❖ Shelter for microorganisms
- ❖ Cation immobilization

Biochar used:
- ✓ Hardwood biomass
- ✓ 500 °C

La Carbonerie
L'innovation dans la Chimie du Végétal

Compost

- ❖ Source of nutrients
- ❖ Source of microorganisms
- ❖ Cation immobilization

Compost used:
- ✓ Commercial product
- ✓ Peat moss, softwood bark, green compost, seaweed

Iron sulfate

- ❖ Source of iron
- ❖ Arsenic immobilization

Iron sulfate used:
- ✓ Commercial product

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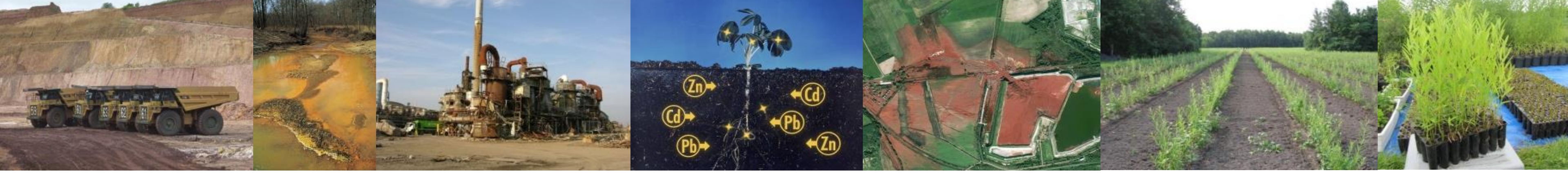
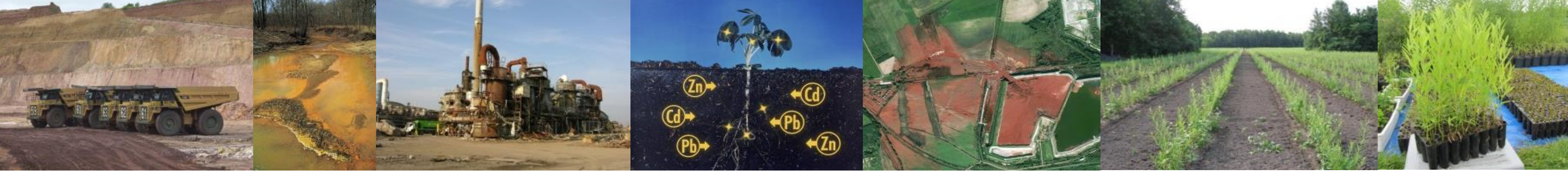


The use of amendments to ameliorate the soil

	Biochar	Compost	Iron sulfate
pH	8.46 ± 0.01	7.40 ± 0.02	2.58 ± 0.00
Electrical Conductivity (μS.cm^{-1})	302 ± 1	801 ± 24	ND
Water Holding Capacity (%)	212 ± 4	312 ± 9	ND
NH_4N0_3 [As] (mg.kg^{-1})	0.9 ± 0.1	0.7 ± 0.3	16.5 ± 0.5
NH_4N0_3 [Pb] (mg.kg^{-1})	1.6 ± 0.1	0.4 ± 0.0	22.2 ± 0.9
NH_4N0_3 [Fe] (mg.kg^{-1})	18 ± 5	1 ± 0	23265 ± 299

→ Selection based on previous lab experiments



The field experiment

Objectives

➢Evaluate the effect of three amendments, alone or combined, to ameliorate soil fertility, lower metal(loid) toxicity, and improve willow growth.

➢Determine which combination of amendment-willow species allows the valorization of the produced biomass for industrial purposes, based on the regulations.

Field established by **Romain Nandillon** during his PhD
Monitoring took over by M. Lebrun, S. Bourgerie, D. Morabito, F. Miard and Y. Chafik

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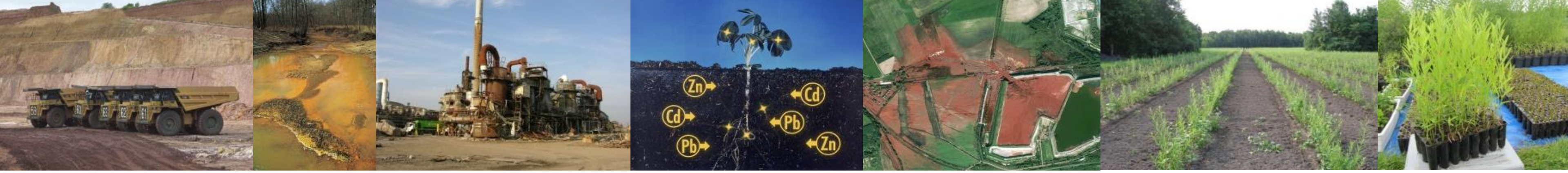

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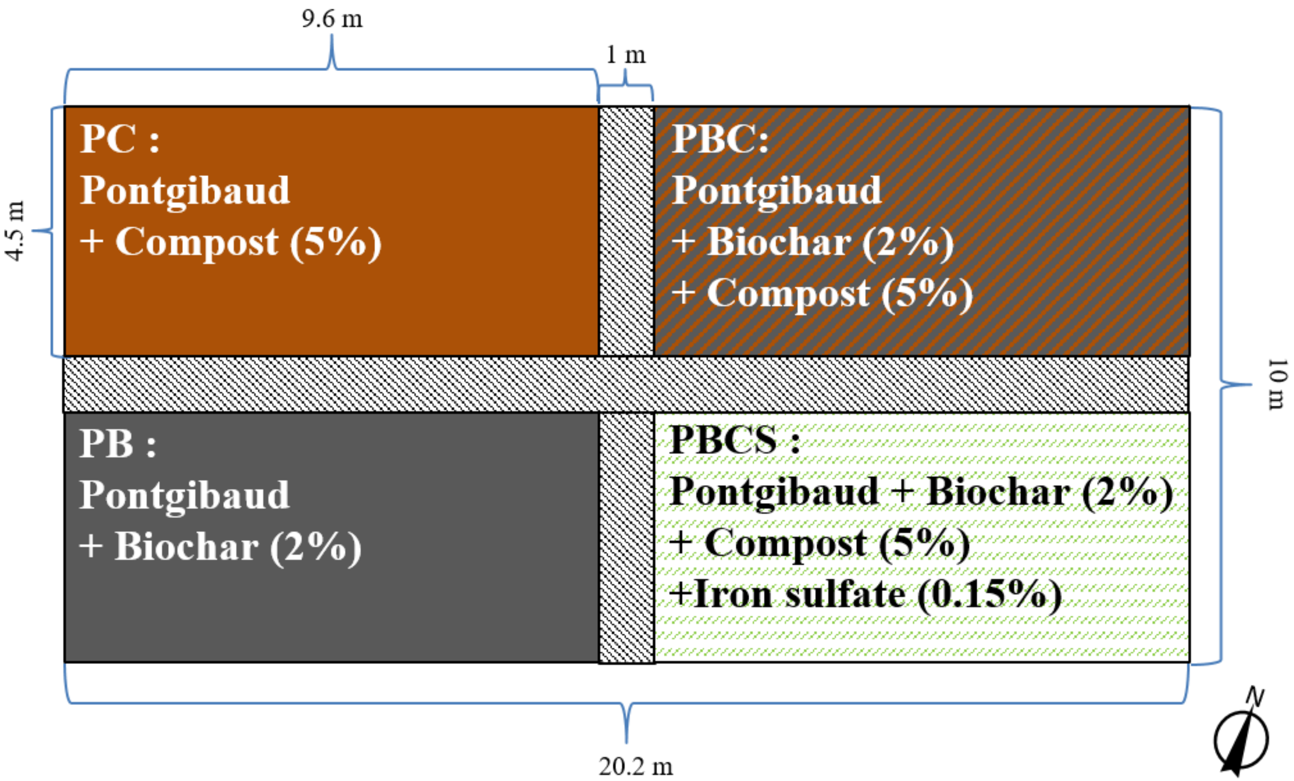

4 willow species:

- ✓ *Salix purpurea*,
- ✓ *Salix alba*,
- ✓ *Salix triandra*, and
- ✓ *Salix viminalis*.

5-year monitoring

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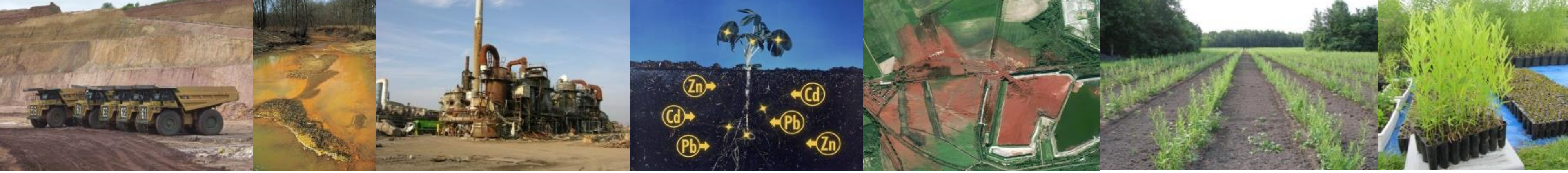
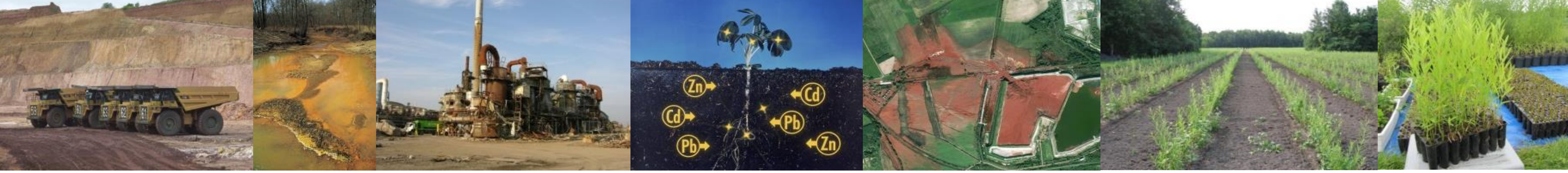


The soil 6 months after amendment application

Treatments	pH	CEC (cmol.kg^{-1})	C_{org} (%)	OM (%)	N_{tot} (%)	C_{org}/N_{tot}	[P] (mg.kg^{-1})	[K] (mg.kg^{-1})
Pg (initial)	4.8 ± 0.0	0.7 ± 0.0	0.3 ± 0.0	0.5	< QL	-	1.1 ± 0.1	15.8 ± 0.2
	+	+	+	+			+	+
PB T6	5.7 ± 0.2 B	0.9 ± 0.0 B	2.8 ± 0.0 C	4.8	< QL C	-	1.7 ± 0.1 C	41.4 ± 0.3 C
PC T6	5.6 ± 0.1 B	1.6 ± 0.0 A	2.9 ± 0.0 C	5.0	0.1 ± 0.0 B	21	3.3 ± 0.1 B	59.4 ± 1.0 B
PBC T6	7.1 ± 0.2 A	1.6 ± 0.1 A	6.5 ± 0.1 A	11.2	0.2 ± 0.0 A	39	5.4 ± 0.6 A	98.1 ± 3.2 A
PBCS T6	5.1 ± 0.4 B	1.5 ± 0.0 A	4.8 ± 0.1 B	8.3	0.1 ± 0.0 B	36	2.3 ± 0.1 B	51.6 ± 4.0 C

- All the parameters were increased by the amendments

- pH
  - ✓ Biochar and/or compost increased pH → liming effect due to high pH of biochar and compost
  - ✓ Best increase with combined BC → higher total amendment
  - ✓ S reduced pH (until P level) → acidic pH of the iron sulfate



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- ❖ All the parameters were increased by the amendments
- ❖ <u>CEC</u>
  - ✓ Biochar and/or compost increased CEC → high CEC of the amendments (especially compost)
  - ✓ Best increase with compost → low CEC of biochar compared to compost

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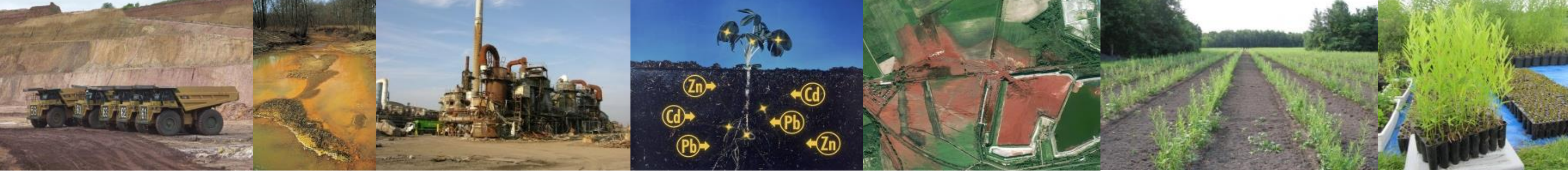

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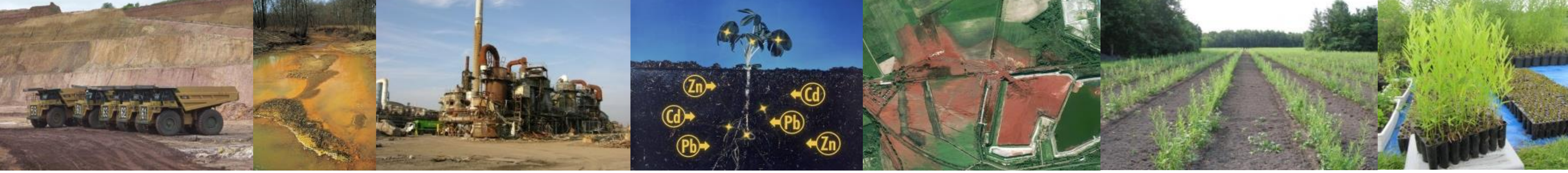
- All the parameters were increased by the amendments

- C_{org} / OM
  - ✓ All treatments increased C_{org} & OM → both compost and biochar are a source of C and OM + improvement of microbial activity
  - ✓ Best increase with combined BC → higher total amendment
  - ✓ S reduced C_{org} & OM → acidic pH reduced microbial activity



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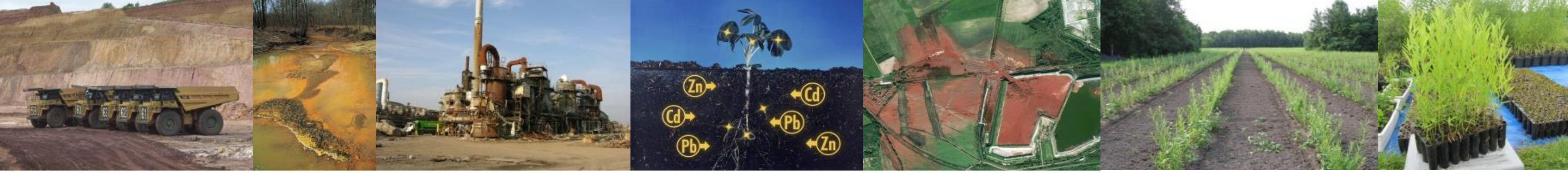
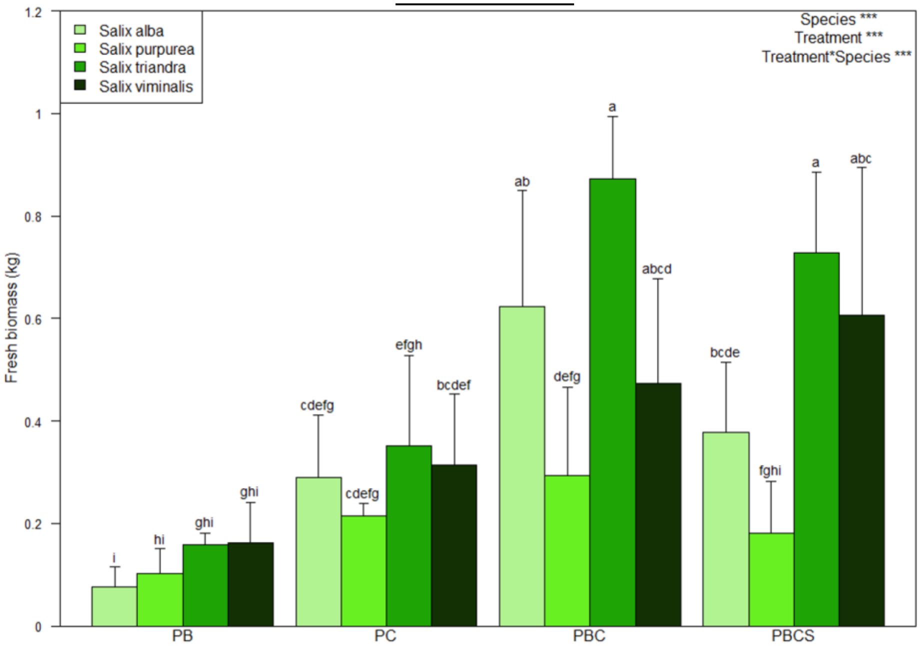
- All the parameters were increased by the amendments
- <u>Phosphorus and Potassium</u>
  - ✓ All treatments increased P & K contents → both compost and biochar are a source of nutrients + improvement of microbial activity (nutrient cycling)
  - ✓ Highest increase with C (± B) → compost contains more nutrients than biochar
  - ✓ S reduced P & K → acidic pH reduced microbial activity

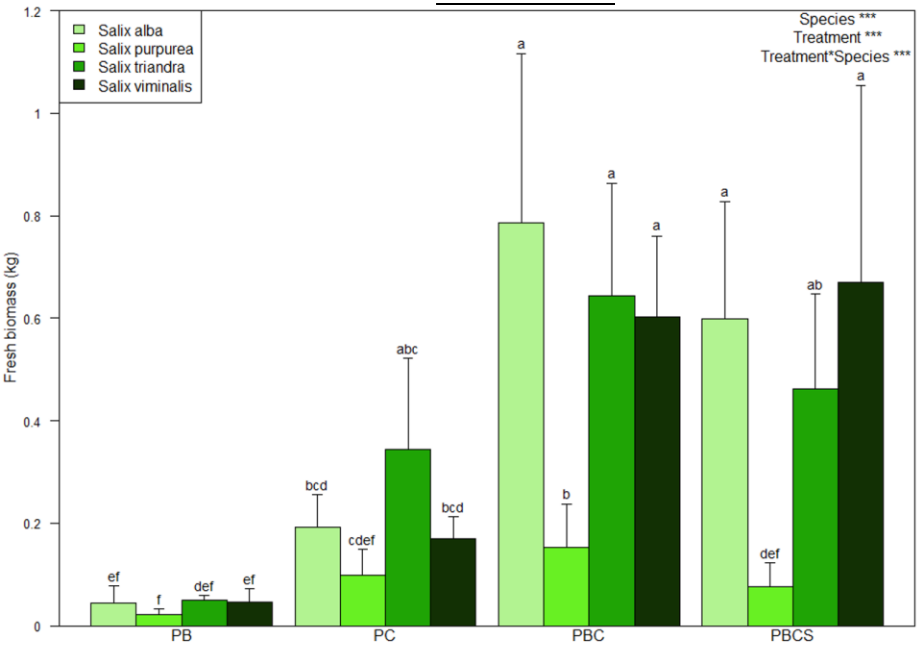


The plant biomass production

<u>22 months</u>



<u>55 months</u>



- <u>Treatment effect</u>
  - ✓ Highest biomass on PBC → amelioration of soil conditions best with biochar + compost

- <u>Species effect</u>
  - ✓ 22 months: *Salix triandra* best
  - ✓ 55 months: *Salix alba* – *Salix triandra* – *Salix vimalis* > *Salix purpurea*

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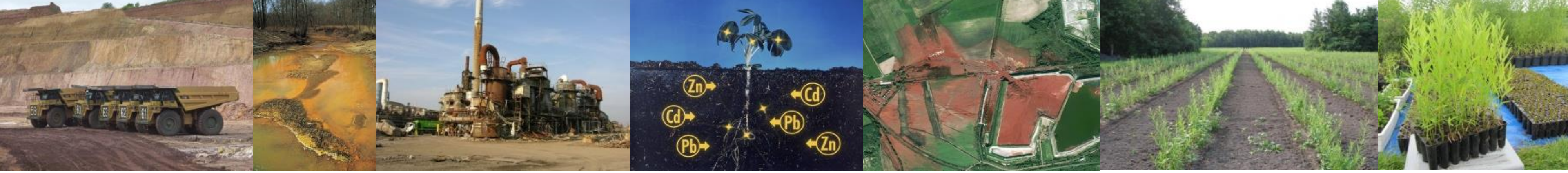
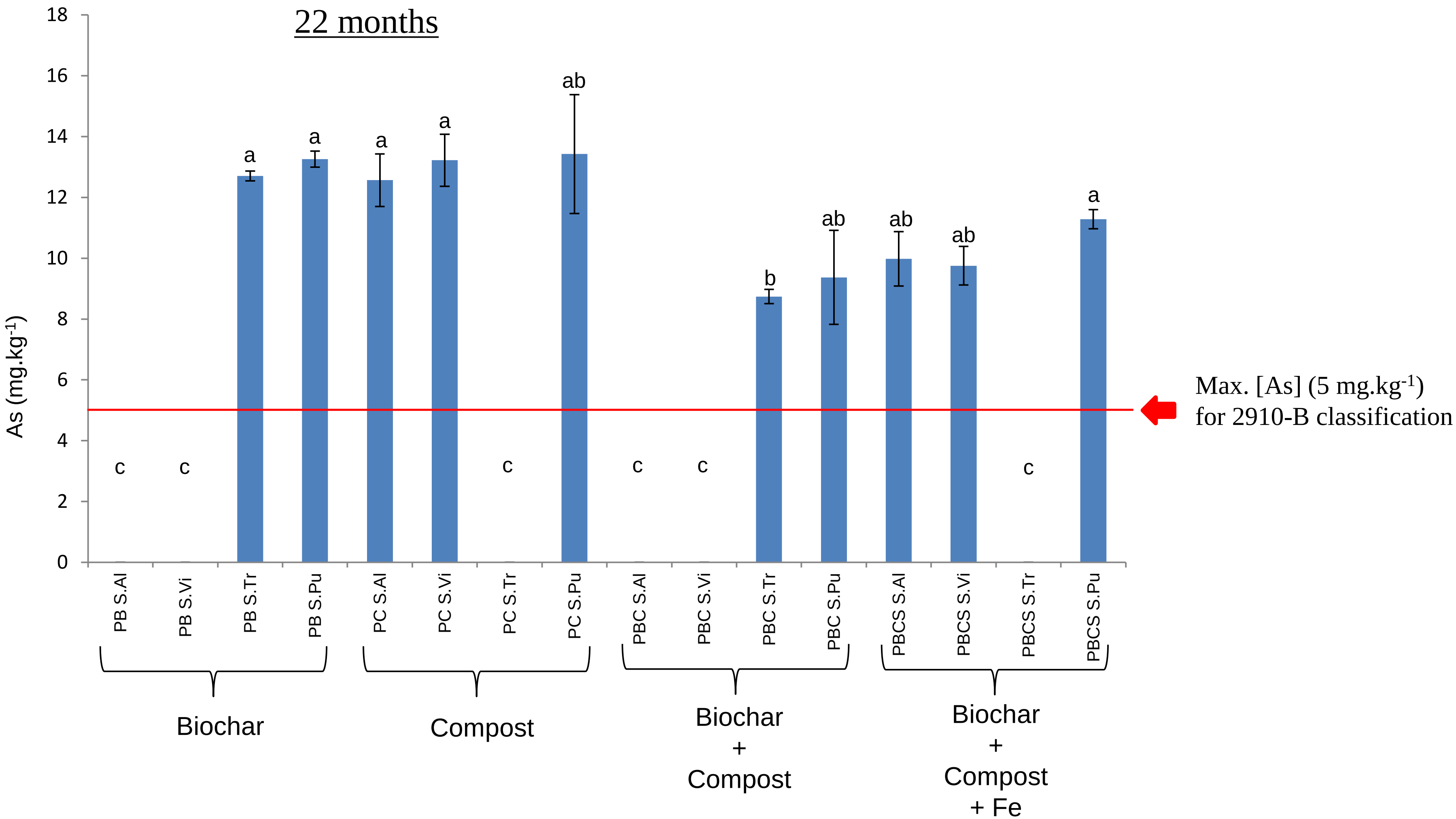


The As accumulation in the plants



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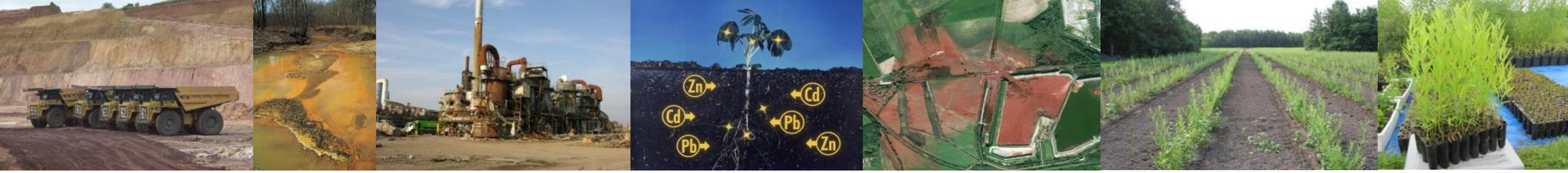
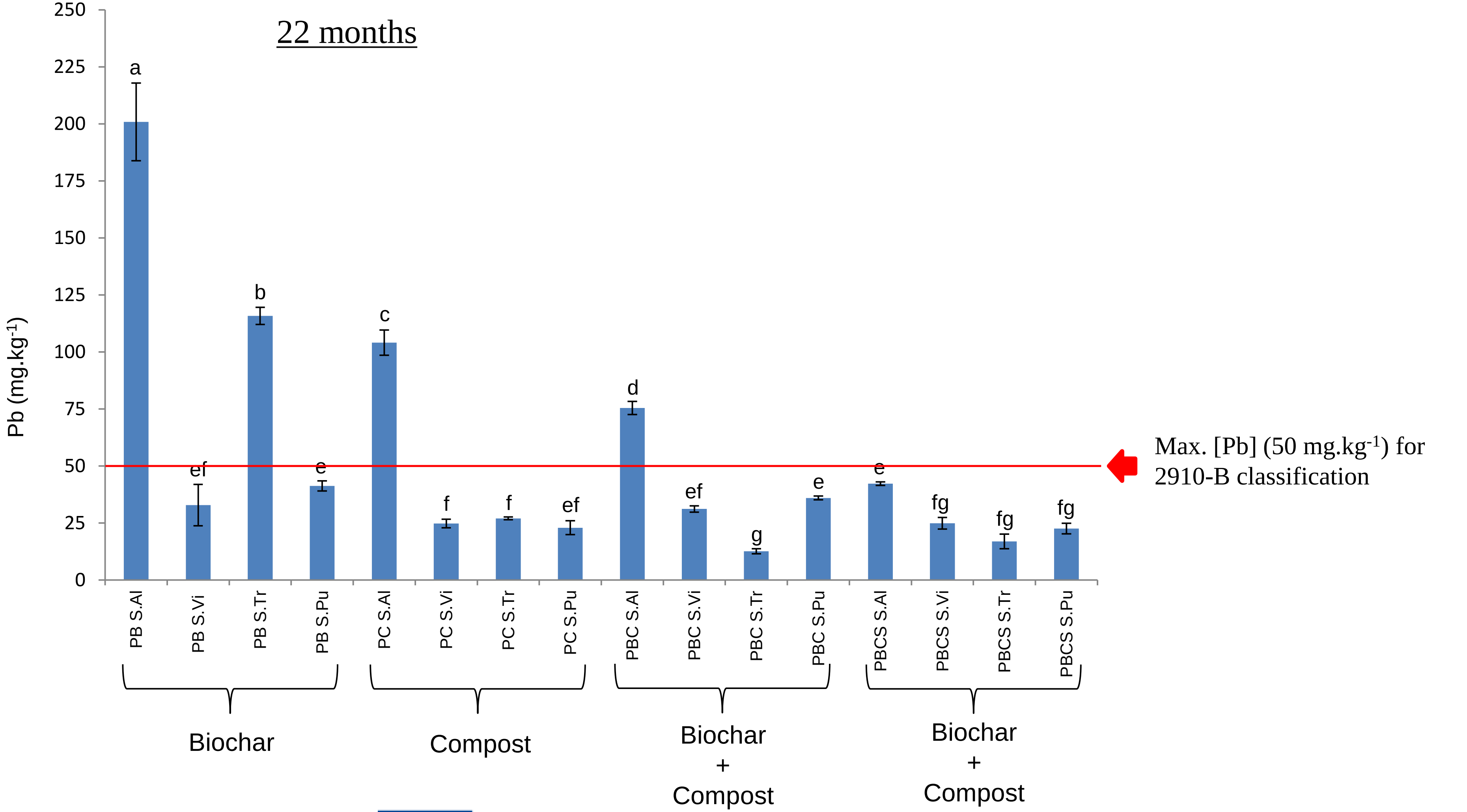


The Pb accumulation in the plants



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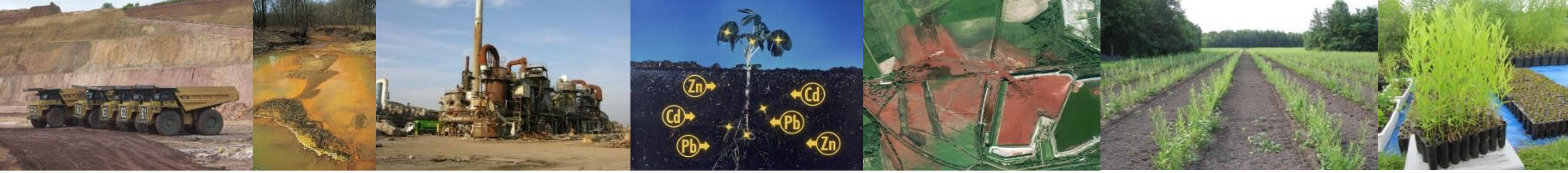

Take home message

- ❖ <u>Soil</u>
  - ✓ Amelioration of fertility: pH, nutrients, OM
  - ✓ As and Pb immobilization

    BEST: PBC

- ❖ <u>Plants</u>
  - ✓ Success to implement a vegetation cover (+ natural revegetation on the amended plots)
  - ✓ Accumulation of As and Pb in stems makes it possible to use this biomass for industrial purposes

    BEST: *Salix purpurea*

Associations biochar + compost with *Salix purpurea* BEST

Recommendations: use multiple species (those useable for industrial purposes)

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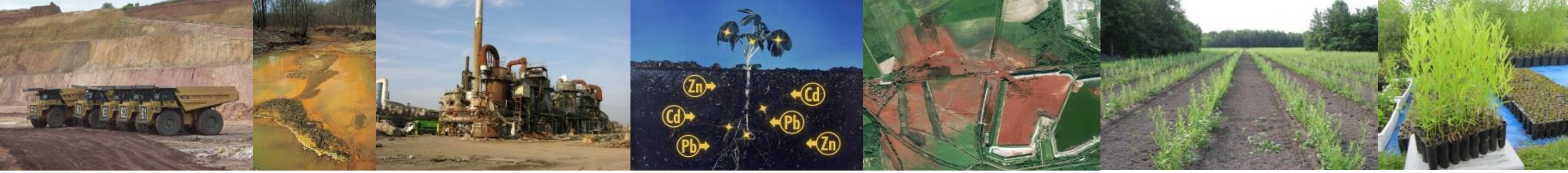

Thank you for your attention


June 2017


October 2017


PBC October 2018


1 year old *Salix triandra* tree


July 2022

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