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Immobilization of heavy metal in contaminated mine technosols using biochar: A phytomanagement strategy

Domenico Morabito
Manhattan Lebrun
Romain Nandillon
Florie Miard
Nour Hattab Hambli

See next page for additional authors

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Authors
Domenico Morabito, Manhattan Lebrun, Romain Nandillon, Florie Miard, Nour Hattab Hambli, Simon Chevolleau, Melissa Simiele, and Sylvain Bourgerie
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Domenico MORABITO
What is soil pollution?

A soil, is considered contaminated when:

- Its chemical state deviates from the normal composition (Kabata-Pendias 2011)

- When it has lost its function (JRC Technical Reports, 2016)

- And lastly when abnormal levels of contaminants become detrimental to human health (Rodriguez-Eugenio et al. 2018).
Detrimental effects caused by metal(loid)s depend mainly on their bioavailability?

Bioavailability is defined as the fraction of pollutant that, within a given time span, is available or will be made available for its uptake by plants and other organisms (Peijnenburg and Jager 2003).

Bioavailability depends on the physical, chemical and biological properties of the soil (Rodriguez-Eugenio et al. 2018).

In conclusion

- a soil can present very high levels of pollution but this pollution can be poorly available (Because bound to the residual fraction of the soil) low risk for the environment
- a soil having a low total metal(loid) concentrations with a high bioavailability will represent a high risk for the environment
What are the pathways of pollutant transfer to the environment?

- **Route of exposure**
- Wind erosion
- Land erosion
- **Polluted soil**
- Leaching to groundwater

**Sources:** concentration of metals and metalloids

**Vectors:**
- Direct transfer of substances (aerosols, soils, plants)
- Indirect transfer of substances (plants, meat, etc.)

**Target groups:** biosphere
How to limit the transfer of pollutants (metals and metalloids) to the environment?
Remediation techniques

- Physico-chemical and thermal techniques.

- Many constraints (difficult to set up on large surfaces, costly, disturb the balance of the soils, ...).
There is an environmentally-friendly technology to economically remediate mining soil containing important concentration of As and Pb.

The main point consist to stabilize the pollutants in the soil and to allow the growth of plants.

Using aided phytostabilization (using amendments - Biochar).

Considering that we produce a valuable biomass.

**PHYTOMANAGEMENT**
Addition of amendments to the soil → Stabilize pollutants: on the amendment and on the soil particles

- Biochar + Compost + iron

Before → After

No plant → Protected area

Limit leaching to the groundwater table

Limit the transfer of pollutants by wind and water erosion

Limit soil erosion

❖ When added to a soil it:
- Increase soil water holding capacity
- Provide nutrients
- Will decrease pollutant concentration in soil pore water
- Will make pollutant not phytoavailable
- Will increase soil microorganisms diversity and quantity
Mesocosm experiment
Preliminary mesocosm tests using an As and Pb polluted soil

➔ Which biochar feedstock modulates the availability of As and Pb in the soil pore water?

➔ Phytotoxicity test: using *Phaseolus vulgaris*.
  ➔ growth and final biomass
  ➔ Measured As and Pb concentration in the different plant organs
Preliminary mesocosm results

Biochar with fine grain size is the most efficient to stabilize Pb but not for As. For As addition of Iron sulfate
Field experiment
Field experiment: Pontgibaud (France) Pb and As polluted soil

- Average altitude of 700 m
- Rainfall 770 mm
- Temperatures ranging from +40°C to -20°C.
- Sandy texture.
Metal(loid)s mapping of the studied area

[As] (mg/kg) (300-2000mg/kg)

- High metal content
- Low pH (4)
- Very low OM
- Strong drainage
- No vegetation

[Pb] (mg/kg) (6000-16500 mg/kg)

Divided in 4 plots
Field experiment
Photos of the plots after 1 month (May 30, 2017) Salix + clover
Biochar II: Production, Characterization and Applications
Cetraro (Calabria), Italy

4 months
Biochar II: Production, Characterization and Applications
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After 6 months

After 18 months
Pb and As concentration in SPW

As SPW concentration at the time of incorporation of the amendments. B1c 1: biochar (2%), B2: organic amendment (5%), B3 biochar (2%) + organic amendment (5%) and B4: biochar (2%) + organic amendment (5%) + inorganic amendment (1.5%). P corresponds to unmodified technosol. The letters correspond to the comparison between each modality.

Pb SPW concentration at the time of incorporation of the amendments. B1c 1: biochar (2%), B2: organic amendment (5%), B3 biochar (2%) + organic amendment (5%) and B4: biochar (2%) + organic amendment (5%) + inorganic amendment (1.5%). P corresponds to unmodified technosol. The letters correspond to the comparison between each modality.
**Biochar II: Production, Characterization and Applications**

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**Biomasses sèches (kg)**

- *Salix alba*
  - PB: biochar 2%
  - PC: compost 5%
  - PBC: compost 5% + biochar 2%
  - PBCS: compost 5% + biochar 2% + sulfate de fer 0,15%

- *Salix viminalis*
  - PB: biochar 2%
  - PC: compost 5%
  - PBC: compost 5% + biochar 2%
  - PBCS: compost 5% + biochar 2% + sulfate de fer 0,15%

- *Salix purpurea*
  - PB: biochar 2%
  - PC: compost 5%
  - PBC: compost 5% + biochar 2%
  - PBCS: compost 5% + biochar 2% + sulfate de fer 0,15%

- *Salix triandra*
  - PB: biochar 2%
  - PC: compost 5%
  - PBC: compost 5% + biochar 2%
  - PBCS: compost 5% + biochar 2% + sulfate de fer 0,15%
Conclusion

Before field experiment it is necessary to proceed to :

- Mesocosm laboratory tests to define which are the best mixtures of amendments (Biochar + ........) according to the metal(loids) present in the soil.
- To verify that pollutant are immobilized:
  - Biochar alone is efficient to stabilize Pb 😊 but mobilize As 😞
- Efficient plant growth
- No metal(loid)s translocation to the aerial part of the plant (to found the good plant genotype)

Iron Biochar functionalization
- Improved As sorption in batch experiments
- No effect when incorporated into the soil

Good or bad surprise !!
Our HW biochar does not seem to be stable over time, because the use of a two-year old biochar allowed to stabilize Pb and As in the soil, which was not the case for As when we used the same biochar immediately after its production.
Biochar II: Production, Characterization and Applications
Cetraro (Calabria), Italy

S. Bourgerie  D. Morabito  F. Miard  R. Nandillon  M. Lebrun
Thèse
Phytostabilisation des éléments métalliques d'un technosol minier végétalisé par le genre Salix assistée par du biochar

Collaborations

« RESTOR »
(UO-INRA-ISTO-CNRS–NEODYME)
Projet de rechercher APR-IR
Région Centre Val de Loire

« EPHYPOP »
(UO-INRA-ISTO-CNRS–NEODYME)
CG 45

« PHYTOSELECT »
(ISTO-CNRS-BRGM-UO-IDDEA)
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Région Centre Val de Loire