Nonylphenol translocation in lettuce from contaminated soil amended with biochar

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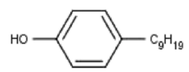
Emerging Contaminants (ECs): Synthetic or naturally occurring **chemicals** (personal care products, industrial additives, surfactants, etc.) **not commonly monitored**
Wide use and **environmental diffusion** → **Exposure pathways for humans** (ingestion of food grown on contaminated land or irrigated with reclaimed water, consumption of polluted water).

Overview

1 4-Nonylphenol (4-NP) is an ECs found in effluents and sludge from wastewater treatment plants.

4-Nonylphenol

- Lubricating oil additive, catalyst in epoxy resins curing, formulant in pesticides
- Waste water effluent: up to 50 µg/l
- Stabilized sludge for agriculture: up to 2000 µg/kg d.w
- Soils: 0.01 - 2720 µg/kg d.w.
- Food: 0.1-100 µg/kg f.w.
- Reference Dose for oral exposure: 5-100 µg/kg b.w./day



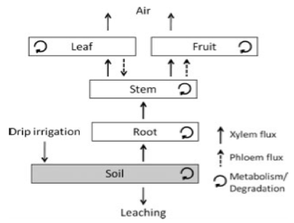
Degradation products:
✓ 4-hydroxybenzoic acid (p-HBA)
✓ p-cresol
✓ phenol

2 Biochar is a sorbent medium for many organic contaminants.

The biochar was produced by beech and chestnut pyrolysis (1000-1200 °C)				
Specific surface was about 250 m^2/g				
Material Characterization:	Organic carbon fraction	46±0,3 % (n=3)		
	Ashes	1,3±0,3 % (n=3)		
	pH	7,9±0,4 (n=6)		
		Biochar fraction:		
		<124 µm	*1000-2000 µm*	*Original*
	Moisture content	8,68±0,09 % (n=3)	6,73±0,05 % (n=3)	4,3±0,08 % (n=3)
	Apparent density	253±0,94 kg/m^3 (n=3)	132±1,35 kg/m^3 (n=3)	143±0,27 kg/m^3 (n=3)

Materials and methods

1.A Analytical model by **Legind et al. (2011)** was used to estimate 4-NP translocation from soil to lettuce



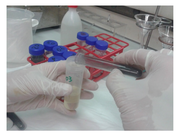
Model Eq.: 4-NP in soil and lettuce

$$\frac{dC_S}{dt} = -\left(\frac{Q_R K_{WS}}{M_S} + k_{deg}\right) C_S$$

$$\frac{dC_L}{dt} = \frac{Q_R}{M_L K_{RW}} C_R - (k_{g,L} + k_{m,L}) C_L$$

- C_S, C_L (mg/$kg_{w.w.}$) 4-NP concentration in soil and lettuce;
- Q_R (L/d) xylem flux;
- K_{WS} (kg $_{w.w.}$/L) water/soil distribution coefficient;
- K_{RW} (L/kg $_{w.w.}$) root/water distribution coefficient;
- M_S, M_L (kg $_{w.w.}$) lettuce and soil mass;
- k_{deg} (1/d) 4-NP degradation rate in soil;
- $K_{m,L}$ (1/d) 4-NP metabolic rate in lettuce;
- $K_{g,L}$ (1/d) 4-NP concentration decrease in lettuce over time due to lettuce growth.

1.B Model calibration: "k_{deg}" and "$k_{m,L}$" were estimated from experimental tests of lettuce cultivation on contaminated and uncontaminated soil without biochar.



Cultivation in pots filled with **agricultural soil**:

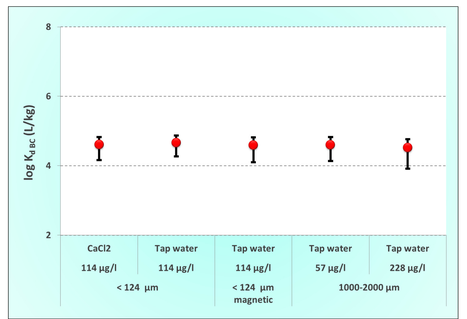
- artificially **contaminated with** 4-NP at 11 mg/kg
- **uncontaminated soil** (blank pots).

At the initial time (T0), pots were located in greenhouses, daily monitored and watered. After 50 d (T1), lettuce and soil samples from each pot were collected and analyzed for 4-NP and its degradation products

2 4-NP **"$K_{d\ BC}$" biochar-water partition coefficient** was estimated by batch tests → biochar for NP removal from wastewater during tertiary treatments.

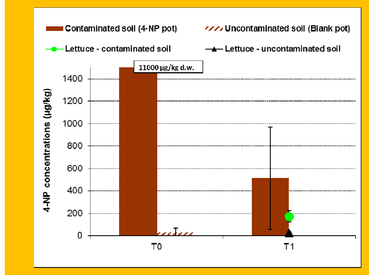
The following conditions were tested:

- 4-NP concentrations in the liquid phase: 50-200 µg/l.
- Bochar grain sizes: two different fractions (<124 µm and 1-2 mm);
- "Magnetized" biochar (<124 µm) to enhance its recovery at the end of water treatment.
- Different pH values (to assess whether 4-NP dissociation affects sorption on biochar): 6 and 8



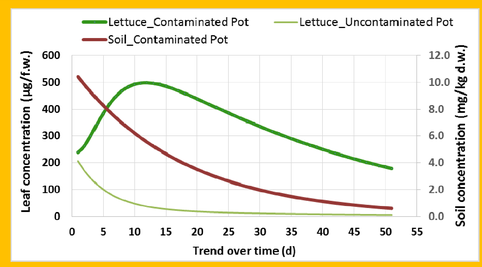
"$K_{d\ BC}$" for both grain sizes
≒ 40000 L/$kg_{BC\ d.w.}$

Results and discussion

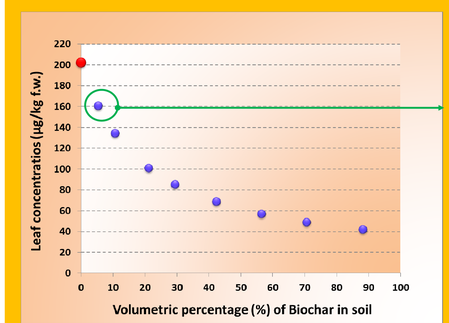


- Decrease of 4-NP (11 $mg/kg_{d.w}$ → 0.5 $mg/kg_{d.w.}$) in the contaminated soil.
- High 4-NP concentration (174±49 $\mu g/kg_{f.w.}$) and degradation product p-cresol in lettuce (100 ± 60 $\mu g/kg_{f.w.}$) grown on the contaminated soil.

Simulated concentrations vs. time



Once the model was available for predictive purposes, it was used to explore possible outcomes of biochar agronomic use in limiting 4-NP translocation to lettuce. **"$K_{d\ BC}$" values** from lab tests were used.



4-NP concentration in lettuce leaves vs. biochar concentration in soil **was simulated.**
According to the model outcome, **biochar** at the typical amount used for soil amendment in agriculture (**5% v/v**) would not be useful for significant 4-NP abatement in lettuce leaves.

However, variations in soil properties due to biochar mixing might promote 4-NP biodegradation and further investigation is required.

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