Phytotoxicity of Sodium Fluoride and Uptake of Fluoride to Willow Trees

Clausen, Lauge Peter Westergaard; Gosewinkel Karlson, Ulrich; Trapp, Stefan

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Fluoride (F) is present in pristine air, soil and water. As exposure to F through food and beverages is unavoidable, the effects of F on human and mammalian health have been intensely investigated. Due to continued use of super phosphate fertilizers, F accumulates in agricultural soils. However, little is known about the phytotoxicity of sodium fluoride (NaF) and the uptake of F when exposed through roots. The aim of this study is to:

1) Assess the phytotoxicity of NaF to willows when taken up through the roots
2) Determine the uptake of F to willows when taken up through roots
3) Describe the uptake of F to willows with a non-linear mass balance model

**Intro and scope**

**Phytotoxicity of Sodium Fluoride and Uptake of Fluoride to Willow Trees**

Lauge Peter Westergaard Clausen¹, Ulrich Gosewinkel Karlson² and Stefan Trapp¹

¹Department of Environmental Engineering, Technical University of Denmark
²Department of Environmental Science, Aarhus University

*Email: lpwc@env.dtu.dk

Fluoride (F) is present in pristine air, soil and water. As exposure to F through food and beverages is unavoidable, the effects of F on human and mammalian health have been intensely investigated. Due to continued use of super phosphate fertilizers, F accumulates in agricultural soils. However, little is known about the phytotoxicity of sodium fluoride (NaF) and the uptake of F when exposed through roots. The aim of this study is to:

1) Assess the phytotoxicity of NaF to willows when taken up through the roots
2) Determine the uptake of F to willows when taken up through roots
3) Describe the uptake of F to willows with a non-linear mass balance model

**Phytotoxicity results**

- Toxic effects observed within 48 h for conc. >100 mg F L⁻¹
- Clear dose-response relationship
- No statistically significant difference between toxicity of 50 mg F L⁻¹ and 100 mg F L⁻¹
- Wilting of the trees exposed to 400 mg F L⁻¹

**Model description and output**

The model assumes:

- Steady state
- Passive uptake of F with the transpiration stream
- Enzymatic removal described by Michaelis-Menten kinetics

\[
\text{Enzymatic removal} = v_{\text{max}} \cdot \frac{C_R}{K_M + C_R}
\]

Where,

- C_R: Conc. ratio root/water
- K_M: Half saturation constant
- Q: Transpiration
- C_W: Conc. in external solution
- M_R: Mass of roots
- C_R: Conc. in roots

**Model parameterization**

- Maximal enzymatic removal rate, \( v_{\text{max}} \): 9 g F kg⁻¹ d⁻¹
- Breakthrough point (BTP): 210 mg F L⁻¹ – On a molar basis the same as obtained by Trapp et al. (2008)* for chloride (Cl)
- Uptake slope approx. 1 for C > BTP – unhindered transport with water

**Experimental setup – the willow tree test**

- 40 cm willow sticks (Salix viminalis) were pre-grown and transferred to Erlenmeyer flasks
- Trees were exposed to solutions of various NaF concentrations
- Test duration: 96 h
- Normalized Relative Transpiration (NRT) used as test parameter:
  - Toxic effects observed within 48 h for conc. >100 mg F L⁻¹
  - Clear dose-response relationship
  - No statistically significant difference between toxicity of 50 mg F L⁻¹ and 100 mg F L⁻¹
  - Wilting of the trees exposed to 400 mg F L⁻¹

**Parameter** | **Value** | **Unit** | **Origin**
--- | --- | --- | ---
Conc. in solution, C_W | 0-400 | mg L⁻¹ | Measured
Root mass, m_R | 0.001 | Kg | Estimated
Transpiration stream, Q | 0.04 | L d⁻¹ | Measured ave.
Half-saturation constant, K_M | 2 | g L⁻¹ | Fitted
Max. Enzymatic removal rate, v_{\text{max}} | 8.992 | g kg⁻¹ d⁻¹ | Fitted
Root growth rate, k_R | 0 | d⁻¹ | Estimated

**Conclusions**

- NaF is phytotoxic at levels of EC₁₀: 38.0±34.2; EC₂₀: 59.6±40.7 and EC₅₀: 128±51 (values in mg F L⁻¹±95% confidence interval)
- Uptake of F can be described by a non-linear mass balance model assuming enzymatic removal
- At external concentrations above 210 mg F L⁻¹ the willows can no longer pump out F from the plant cells and start to accumulate F
- Enzymatic removal of F and Cl from plant cells is likely to be managed by the same *pump*-system