Evidence for uptake and fate of the explosives TNT and RDX in conifers

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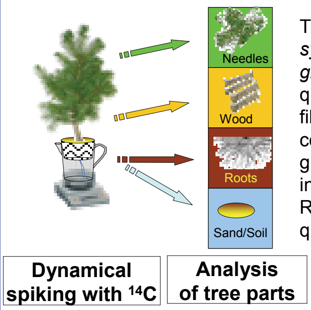
Introduction

Former military sites (ammunition plants and military training areas) represent 2.8% (9,997 km²) of the entire German territory (Schröder *et al.*, 2003). Many of these areas are contaminated with residues of explosive specific compounds. Main contaminants are TNT (2,4,6-trinitrotoluene) and RDX (Royal Demolition eXplosive, hexahydro-1,3,5-trinitro-1,3,5-triazine). The hazardous potential, mammalian toxicity, mutagenic and carcinogenic features of explosives are reviewed by Talmage *et al.* (1999).
Most of German former military sites are covered by woodlands dominated by conifers. This causes our hypothesis, if conifer trees may contribute to natural decontamination processes in explosive-polluted soils. Besides tolerance features of conifers to explosives, uptake of explosives by coniferous species are the focus of our investigations.

Methods



Three-years-old plants of Scots pine (*Pinus sylvestris*) and of Canadian white spruce (*Picea glauca* 'Conica') were cultivated in 8-cm pots in quartz sand. The pots were supplied with glass fibre wicks and placed on 500-ml-glass vessels containing 200 ml of application solution. Using glass fibre application systems the time course of input of water-solved, bioavailable pollutants (TNT, RDX) to the soil/tree system is precisely quantifiable (Schoenmuth & Pestemer, 2004).

Fig. 1: Experimental design

For uptake studies, uniform ring-labelled [^{14}C]-TNT and [^{14}C]-RDX were permanently applied via glass fibre wicks. After exposition to [^{14}C]-TNT and [^{14}C]-RDX overall radioactivity of tree compartments was determined. Extractability of radio-labelled explosives from plant tissues was estimated by Liquid Scintillation Counting. Radio-labelled extracts were separated by radio thin layer chromatography (TLC).

Results & Discussion

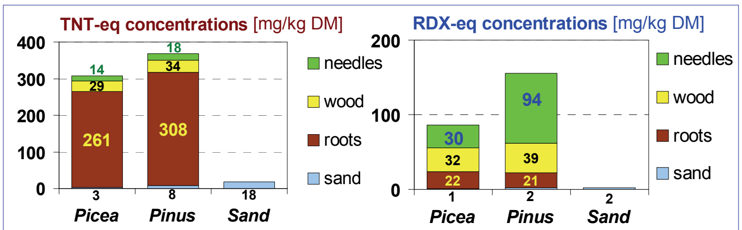


Fig. 2: Morphological compartimentalisation of ^{14}C-uptake.

Both, TNT and RDX are accumulated in pines and in spruces. For TNT, highest concentrations of [^{14}C]-TNT equivalents (eq) are found in roots (Fig. 2). Only a very small percentage is transported to above-ground tree compartments, i.e. wood (3%) and needles (2%).
For RDX, however, higher concentrations of [^{14}C]-RDX equivalents are observed in above-ground tree compartments (wood and needles). Highest concentrations were detected in needles of *Pinus* (94 mg RDXeq kg^{-1} DM). RDX is obviously translocated by the transpiration stream in conifers.

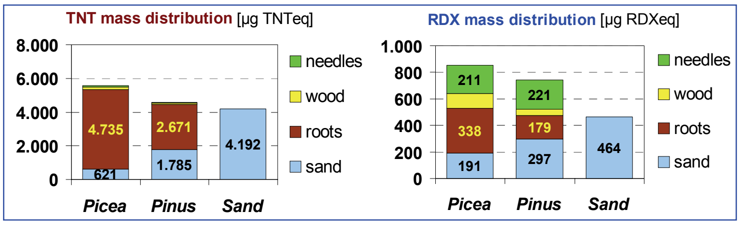


Fig. 3: Reduction of soil explosives by conifers.

The mass distribution of radio-labelled compounds shows that pines as well as spruces are able to reduce the content of [^{14}C]-TNT and [^{14}C]-RDX in soil. Substrates containing conifer plants clearly indicate less contents of explosive equivalents than unplanted variants.

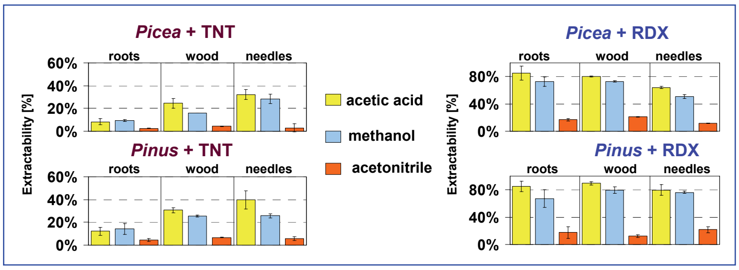


Fig. 4: Extractability is low for [^{14}C]-TNT and high for [^{14}C]-RDX

Extractability of TNTeq was very low in roots (10%) but higher in wood (25–30%) and highest in needles (30–40%). The bulk of TNTeq is non-extractable bound in root tissue and only very low amounts of metabolites are translocated to above-ground tree parts. In contrast to TNTeq, high extractability of RDXeq in *Pinus* and *Picea* obviously causes good mobility via the transpiration stream.

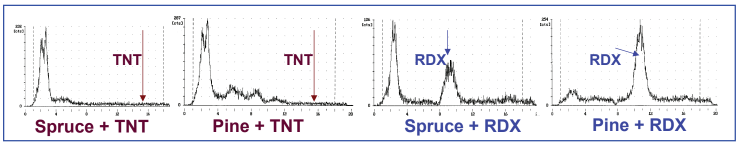


Fig. 5: Radio TLC analysis of ^{14}C extracts from conifer roots

TLC analysis indicates that extractable TNTeq residual portions contain neither TNT nor known metabolites (e.g. ADNTs, DANTs), but TNT is metabolised to polar metabolites. In RDX extracts however, RDX itself is the predominating compound. This low degree of RDX metabolisation seems to be a prerequisite for mobility and accumulation of RDXeq in above-ground tree compartments.

Conclusions

Conifers are excellent helper components to reduce the content of TNT and RDX in soils, and so they may contribute remarkably to soil decontamination. Their "dendroremediation" potential opens a wide range of future sustainable sanitation possibilities for explosive-contaminated areas.

References

Schoenmuth B W; Pestemer W (2004). Dendroremediation of trinitrotoluene (TNT). Part 2: Fate of radio-labelled TNT in trees. *Environmental Science & Pollution Research* **11**, 331-339.
Schröder P; Fischer C; Debus R; Wenzel A (2003). Reaction of detoxification mechanisms in suspension cultured spruce cells (*Picea abies* L. KARST.) to heavy metals in pure mixture and in soil eluates. *Environmental Science & Pollution Research* **10**, 225-234.
Talmage S S; Opresko D M; Maxwell C J; Welsh C J E; Cretalla M F; Reno P H; Daniel F B (1999). Nitroaromatic munition compounds: Environmental effects and screening values. *Review of Environmental Contamination & Toxicology* **161**, 1-156.

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