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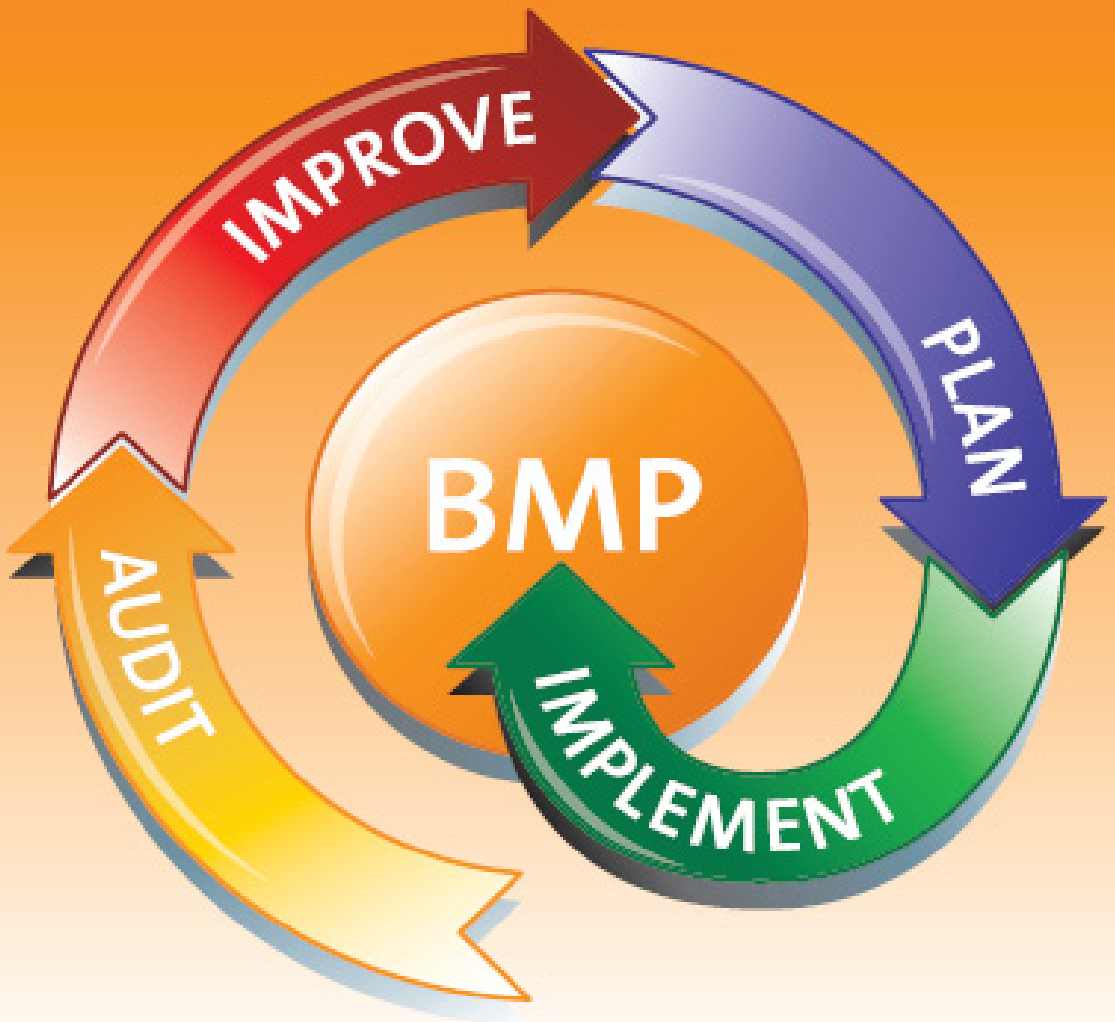

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Chances of uptake and fate of the explosives TNT and RDX in conifers

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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 a dwarf mutant of Canadian white spruce (*Picea glauca* 'Conica') were first cultivated in 8-cm pots in field soil. After one year of growth in field soil, the trees were transplanted into quartz sand. The 8-cm 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). 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 (Biological Oxidizer OX 500, Zinsser Analytik GmbH, Frankfurt/M, Germany). Extractability of radio-labelled explosives from plant tissues was calculated by radioactivity determination of plant extracts, using a Multipurpose Liquid Scintillation Counter (Beckman Instruments GmbH, Munich, Germany). Radio-labelled extracts were separated by radio thin layer chromatography (TLC). TLC plates were evaluated quantitatively using a Linear TLC Scanner (Bertholdt, Germany).

RESULTS AND DISCUSSION

Evaluating the mass distribution of radio-labelled compounds showned 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 explosive equivalents than unplanted variants.

Both TNT and RDX are accumulated in pines and spruces. For TNT, highest concentrations of 14[C]-TNT equivalents (eq) are found in roots. Concentrations up to 308 mg TNTeq kg-1 root

dry matter were determined for Pinus. Relative mass distribution shows that 96% of 14[C]-TNT equivalents taken up by both tree species remain in roots. Only a very small percentage is transported to above-ground tree compartments, i.e. wood (3%) and needles (2%). For RDX, however, highest concentrations of 14[C]-RDX equivalents are observed in above-ground tree compartments. Roots contain only 21–22 mg RDXeq kg-1 DM. In wood concentrations are 32 mg RDXeq kg-1 DM for Picea and 39 mg RDXeq kg-1 DM for Pinus. At the time of tree harvest after three weeks, highest concentrations were detected in needles of Pinus (94 mg RDXeq kg-1 DM). RDX is obviously translocated by the transpiration stream in conifers. This is supported by the finding that more than 60% of needle accumulated RDXeq are located in the youngest needles, where transpiration normally is most extensive.

For ultrasonic extraction procedures different extractants were tested. Extraction efficiency of is given by the following range: 50% (v/v) acetic acid > methanol > acetonitrile for both, TNTeq and RDXeq. Extractability of TNTeq was very low in roots (c. 10%) but higher in wood (25–30%) and highest in needles (30–40%). This leads to the conclusion that 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. This interpretation is confirmed by radio TLC analysis which indicates that extractable TNTeq residual portions contain neither TNT nor known metabolites (e.g. ADNTs, DANTs), but only very polar (unknown) compounds. In contrast to TNTeq, extractability of RDXeq is very high when applying acetic acid as extractant. It reaches 80% or more in almost every tree compartment. High extractability of RDXeq in Pinus and Picea obviously causes good mobility via the transpiration stream. Moreover, in all tissue extracts 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 they contribute as a remarkable sanitation potential. This dendroremediation potential opens a wide range of future sustainable sanitation possibilities for explosive-contaminated areas.

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