On the uptake and possible detoxification of short chain aliphatic halocarbons in conifers

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Emission control of classical air pollutants like SO_2 and NO_x has been achieved during recent years, but the emissions of organic xenobiotics from anthropogenic sources like traffic, industry and agriculture increase. Despite chemical reactions and scavenging by wet deposition, remarkably high amounts of VOC remain in the atmosphere and are transported to areas far remote from their sources (Müller, 1990). Because of the long atmospheric residence time of various xenobiotics and long range transport phenomena (Cunnold et al., 1983; Simmonds et al., 1983) even forests in clean air resorts and sparsely populated areas are not excluded from this threat. Conifers are evergreen, and the large leaf area index of coniferous forests leads to high scavenging ratios throughout the year. The cuticular properties of conifers are such that VOC may be easily solved in the leaf surfaces (Gaggi and Bacci 1985).

The present contribution reviews our studies focused on the fate of trichloroethene and tetrachloroethene in Norway spruce. Both substances are of solely anthropogenic origin and mostly used as cleansing agents and solvents. They are emitted into the atmosphere in amounts of several thousand tons per year and their atmospheric concentrations may vary from below 1 ppbv in pristine areas to 20 ppbv in the surroundings of industrialized areas. For a long time, they have been regarded as fairly stable and relatively non-toxic. During the last decade, however, data on animal and plant toxicity have been gained (cf. Materne 1989; Frank and Frank 1985, respectively).

The uptake of short chain aliphatic halocarbons into the spruce needles was monitored in field experiments with ambient concentrations of approximately 0.5 to 1 ppbv of the xenobiotics as well as in fumigation studies with considerably higher concentrations. In both cases, deposition velocities below 1 mm sec^{-1} were observed for both substances. However, despite of their physicochemical similarity, different uptake rates were observed for tri- and perchloroethene (see Fig.1). Whilst perchloroethene uptake into the needles proceeded at rates predicted from the stomatal conductance of water vapour, trichloroethene uptake was far below the values calculated from the leaf conductances of the gas.

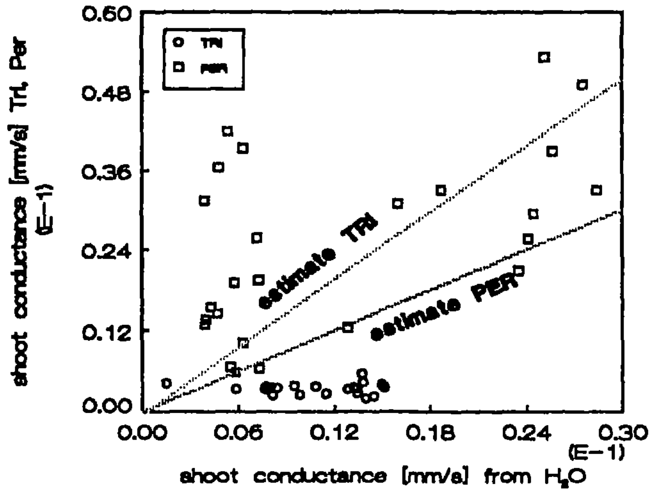

Figure 1: Measurement of tri- and perchloroethene leaf conductances as compared with estimates derived from water vapour fluxes calculated according to Graham's law of effusion. Line fits represent 1:1 lines of estimated shoot conductances of the respective gas. Data from Schröder and Weiß, 1991.

These results indicate that a significant amount of cuticular deposition is superimposed to stomatal uptake of perchloroethene, while trichloroethene uptake into the needles is limited due to some internal resistances. This could be explained by the observation of an equilibrium between the gas phase and leaf concentrations of trichloroethene in earlier fumigation experiments (Figge 1990).

When branches of cloned Norway spruce trees were fumigated with 25 ppbv of tri- or tetrachloroethene for 24 hrs, injurious effects of the fumigation on central metabolic functions of the spruce needles were observed. These effects included rapid changes in photosynthesis, respiration and transpiration of the trees as well as influences on the pigment pattern.

When the fumigation was terminated and the trees were allowed to readjust to clean air conditions, recouperation was observed within several days. This led to the conclusion that Norway spruce appears to be able to enzymatically detoxify halogenated hydrocarbons by conversion of the xenobiotics to non-toxic conjugates.

Information on the presence and properties of detoxification mechanisms in conifers is scanty and especially lacking for enzymes involved in the metabolism of organic xenobiotics. Recently activity of the detoxification enzyme glutathione S-transferase (GST) has been found in spruce (Schröder et al., 1990 a,b; 1992) and in dwarf pine needles (Schröder and Rennenberg 1992).

GST mediate the conjugation of lipophilic xenobiotics with glutathione (GSH) and form by this reaction a hydrophilic conjugate that is non toxic and might be further processed. GST activity has been isolated from human brain, liver and kidney as well as from several organs of rats and other mammals, from higher plants, fungi and even from some bacteria. An enhancement of GST-activity in several plant species after fumigation with halon-1211 (Debus and Schröder 1991; Schröder and Debus, 1991) and several other xenobiotics (Schröder et al. 1992) indicates a possible role of GST in the detoxification of halocarbons.

The present contribution provides data on the uptake of short chain aliphatic chlorocarbons in spruce and discusses the significance of the observed effects and detoxification pathways.

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