Accumulation and fate of C_2-chlorocarbons and trichloroacetic acid in spruce needles from an Austrian mountain site

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The emission of volatile organic compounds (VOC) into the atmosphere proceeds predominantly in the industrialized countries of the northern hemisphere. In 1989, VOC emissions in the FRG were in the range of 2.5 M tons and thus equal to the amount of emitted NO_x in the same area. Single VOC species have been shown to have different atmospheric lifetimes; their photochemical degradation in the atmosphere is still subject to speculations. Special attention has been focused on short chain aliphatic halocarbons (SCHC) and their degradation products, for example trichloroacetic acid. The uptake of these compounds into the plant mesophyll may proceed via the stomates or after accumulation in the cuticle. Enormous accumulations of SCHC have been found in the leaves of evergreen plants, e.g. conifer needles. Data on stress or phytotoxicity caused by SCHC is scarce. Amongst the possible effects of SCHC on plant tissue membrane damage, inhibitory effects on enzymes and destruction of photosynthetic pigments are discussed. The spectrum of possible effects is even broadened when the substances are metabolized by plants because of the formation of reactive intermediates. Water soluble conjugates or metabolites (e.g. TCA) may thus be able to enter plant tissues via the transpiration stream and via the stomates. TCA for example, which has been used as a potent protein denaturing herbicide during recent years, can also cause chloroses, growth reductions and disturb the formation of cuticle structures.

In order to withstand attacks by VOC, it is essential for plants to possess the ability to detoxify xenobiotics that have already entered the cells. Detoxification can be achieved by enzymatic cleavage or conjugation of the xenobiotic. In principle, the required reaction chain consists of three distinct phases:

SCAH

Phase I: *Oxidation, Reduction, Hydrolysis*

Phase II: *Conjugation (Sugars; Glutathione)*

Phase III: *Metabolism / Transport*

TCA detected in the needles of various conifer needles may already be a product of a detoxification reaction against SCHC. In this respect the action of P-450 monooxygenases has been proposed from results obtained with animals and microorganisms. Whilst phase I reactions might lead to the formation of toxic intermediates, plants do also possess detoxification enzymes for example glutathione S-transferases. These enzymes are able to form water soluble compounds from xenobiotics by conjugation with the tripeptide glutathione. Conjugates like this can be transported in the plant and are subject to rapid metabolism.

The SCHC concentrations measured in spruce needles from an Austrian alpine site (Christlum-profile, close to Achenkirch) were in the same range with the SCHC contents of pine needles harvested in Berlin. The TCA-values, however, were significantly lower. SCHC concentrations were highest in the youngest needles, whereas TCA concentrations were highest in oldest needles. Highest accumulations for both, SCHC and TCA, were observed in spruce at sites 1050 m a.s.l. This indicates either a connection to the meteorological situation of the stand growing in the region of frequently observed inversion layers, or a difference in the metabolic activity of the trees. In this context, it might be noteworthy that inversion layers are connected with increasing temperatures in the respective altitude which could increase the uptake of SCHC because of a general increase in the general metabolic activity of the trees.

The protein contents of the needles exhibit an inverted pattern to the TCA accumulation. SCHC and TCA concentrations seem to be intercorrelated with GST activities in the needles; but statistical testing has to be performed with larger sample numbers.

These findings lead to the conclusions that

-TCA may be taken as an indicator of the overall SCHC pollution situation,
- concentration profiles may be similar for other pollutants
- SCHC or TCA leads to stress reactions in plants that may be overcome by detoxification reactions
- TCA or its metabolites are phytotoxic