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Absorption of Atmospheric Trichloroethylene and Tetrachloroethylene by Oleander (*Nerium indicum*)

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Summary

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Foliar absorption of trichloroethylene and tetrachloroethylene were examined. Oleander was exposed to a mixture gas of trichloroethylene and tetrachloroethylene, and gas absorption and transpiration rate were measured simultaneously. A model analysis of gas exchange rates revealed that there was no substantial absorption of trichloroethylene and tetrachloroethylene by oleander, neither through the stomata nor through the cuticle. In the experiments on oleander, no visible foliar injury was observed during the 7 days exposure period.

Introduction

Trichloroethylene and tetrachloroethylene are ubiquitous air pollutants that have been of great concern because of their adverse effects on health. Trichloroethylene and tetrachloroethylene are widely used as solvents in metal or textile industries. Trichloroethylene and tetrachloroethylene are two of the most important hazardous volatile organic compounds, and both the environmental quality standards of their atmospheric concentration were legislated to be under 200 $\mu g\ m^{-3}$ in Japan (ENVIRONMENT AGENCY GOVERNMENT OF JAPAN 1996). Tree planting is one strategy for reducing the concentration of air pollutants in polluted

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urban and industrial areas (ENVIRONMENT AGENCY GOVERNMENT OF JAPAN 1989). Vegetation is known to act as an important sink for inorganic air pollutants, such as SO_2, NO_2, O_3 (HILL 1971, ELKIEY & al. 1982, OMASA & ABO 1978, OMASA & al. 1979). We have reported that atmospheric organic pollutants, such as formaldehyde (KONDO & al. 1995, 1996), C_2-C_5 aldehydes (KONDO & al. 1998), phenol (KONDO & al. 1999), acrolein and methyl ethyl keton (OMASA & al. 2000) are effectively absorbed by tree species at a rate similar to those of atmospheric SO_2, NO_2, O_3. However, it is not clear whether tree species have sufficient ability to absorb trichloroethylene and tetrachloroethylene. Therefore, measurements of trichloroethylene and tetrachloroethylene absorption by oleander (*Nerium indicum*), which is popular as a street tree or garden tree in Japan, were conducted.

Material and Methods

Seedling of oleander of height 0.7 m was used as plant materials. Oleander was grown in a sunny laboratory under ambient light and temperature, was watered daily to maintain pot moisture near to field capacity and was fertilized weekly with liquid fertilizer (Hyponex). The same apparatus and procedure as those used for measuring the absorption rate of formaldehyde by trees (KONDO & al. 1996) were used except for the method of gas sampling. Briefly, a potted plant was confined in a 120 L cylindrical transparent acrylic chamber equipped with 10 L buffer tanks at its inlet and outlet. The rate of the mixture gas (trichloroethylene and tetrachloroethylene) flow through the chamber was about 20 L min^{-1} and the chamber gas was mixed effectively by two internally mounted fans. The transpiration rate was determined from the decrease in the weight of the trees, which were planted in pots covered with plastic bags. The inlet concentrations of trichloroethylene and tetrachloroethylene were within the range of 370-420 $\mu g\ m^{-3}$ and 250-300 $\mu g\ m^{-3}$, respectively. The mean inlet temperature and the relative humidity were 27±2.0°C and 40±7%, respectively. Light intensity was maintained at 0 or 600 μmol photons $m^{-2} s^{-1}$. Gas samples from the inlet and outlet buffer tanks were drawn at a flow rate of 0.1 l min^{-1} for 3h through the sampling tube (ORBO91). The contents of the sampling tube were extracted by carbon disulfide, and analyzed by the GC-MS (Shimadzu QP5000, column: DB-WAX, 30m×0.25 mm×0.25μm) system.

Results and Discussion

Table 1 shows the outlet/inlet ratios of trichloroethylene and tetrachloroethylene concentration in the blank and absorption experiments. In the "blank" experiment performed with an empty chamber, the outlet/inlet ratios of trichloroethylene and tetrachloroethylene concentration were 101±0.7% (n=5) and 100±0.8% (n=5), respectively. This indicates that the adsorption of trichloroethylene and tetrachloroethylene to the walls of the chamber is very small. The outlet/inlet ratios of trichloroethylene and tetrachloroethylene concentration in the experiments using oleander both in the dark and in the light were nearly equal to those in the blank experiments.

The experimental data using oleander were analyzed with a simple gas-diffusion model (OMASA & al. 2002a, b), which was applied for the analysis of foliar absorption of formaldehyde (KONDO & al. 1995, 1996), C_2-C_5 aldehydes (KONDO & al. 1998), phenol (KONDO & al. 1999), acrolein and methyl ethyl keton

(OMASA & al. 2000), to investigate the foliar gas absorption mechanism in comparison with transpiration from stomata. Foliar gas-phase conductance of water vapor (g^W; mmol m^{-2} s^{-1}) was calculated from transpiration rate, leaf temperature,

Table 1. Outlet/inlet ratios of trichloroethylene and tetrachloroethylene concentration in the blank and absorption experiments.

Tree	PPFD (μmol photons m^{-2} s^{-1})	n	Outlet concentration / Inlet concentration (%)	
			trichloroethylene	tetrachloroethylene
Blank	0	5	101±0.7	100±0.8
Oleander	0	5	102±0.9	100±1.3
Oleander	600	5	102±1.3	100±0.5

humidity, and air temperature in the acrylic chamber. Foliar gas absorption rate on unit leaf area basis (Q) was determined from the difference in gas concentrations at the inlet and outlet of the chamber. Molar fraction of pollutant gas on the leaf-surface boundary layer (C_o) was assumed equal to the molar fraction of pollutant gas at the outlet of the chamber, and Q was normalized by dividing it by C_o to obtain q (mmol m^{-2} s^{-1}) (i.e., $q = Q/C_o$). The q is related to g^W by the following equation

$$q = k(1 - C_i/C_o)g^W + \alpha/C_o \qquad (1)$$

where C_i and α are the molar fraction of pollutant gas in the air space inside a leaf and nonstomatal pollutant-gas sorption/decomposition rate on unit leaf area basis (mmol m^{-2} s^{-1}), respectively, and k is a constant, of which the range is

$$k_s < k < k_b \qquad (2)$$

where k_s and k_b are constants calculated from molecular weights of water and the pollutant gas. For analysis of the experimental data, q was plotted against g^W, and α and C_i/C_o were evaluated from the y-intercept and slope of the regression line of this plot.

From the above measurements using oleander both in the dark and in the light, q was plotted against g^W for trichloroethylene and tetrachloroethylene (Fig. 1). The q was corrected for absorption to an empty chamber in the blank experiment. Fig. 1 shows relationships between g^W and q in oleander for trichloroethylene and tetrachloroethylene. For both pollutants, q was not increased with increasing g^W and the slope of the regression line of this plot almost equaled zero, and y-intercept was almost zero. These results suggest that there was no substantial absorption of trichloroethylene and tetrachloroethylene by oleander, neither through the stomata nor through the cuticle. In the experiments on oleander, no visible foliar injury was observed during the 7 days exposure period. It seems that that result was obtained because there was no substantial foliar absorption of trichloroethylene and tetrachloroethylene by oleander.

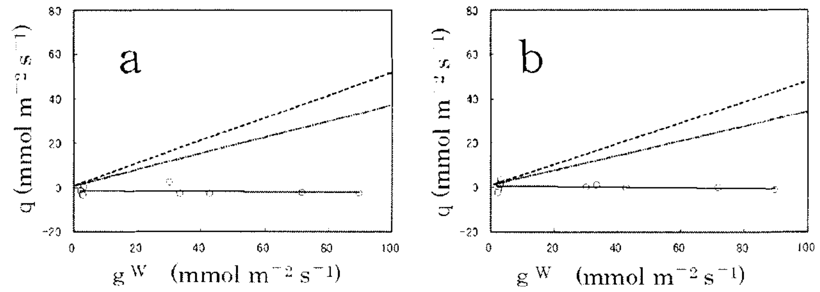

Fig. 1. Relationships between g^W and q in oleander. (a) trichloroethylene; (b) tetrachloroethylene. Regression lines are shown by solid lines, and line $q=k_b g^W$ and $q=k_c g^W$ are indicated by broken and dotted lines, respectively.

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