# Levels and Profiles of PCDDs and PCDFs in Soils and Plants

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## Introduction

Dietary intake of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) through food is considered to account for over 90% of the total PCDDs/DFs human body burden.[1-3] The intake by consumption of vegetables is small. However, plants are important as they come first in the food chain.[1] Several studies have demonstrated that the waxy outer surfaces of plants will accumulate lipophilic organic pollutants from the atmosphere.[4] Uptake pathways of PCDDs from soil by plants have been reported by several workers. [1,2,5,6] We examined the concentrations of PCDDs /DFs in different parts of the potato that had been grown in agricultural and urban fields, to evaluate the influence of the soil.

## Materials and methods

Five potatoes and cabbage heads (only from agricultural area) were collected from agricultural and urban areas. The soil samples collected from five points in each area was mixed together. Potatoes and cabbage were washed with water and then separated into different parts. Each potato was separated into root, tuber, stem and leaf. The cabbage was separated into inner and outer parts. Each part of the plants was extracted with acetone and the soil samples were extracted with methanol/benzene by using a Soxhlet extractor for 24 hrs. The extracts were fortified with ten kinds of $^{13}C$-label PCDDs/DFs as internal quantification standards. The extracts were purified on a $AgNO_3$-Silica gel and charcoal columns. PCDDs/DFs were analyzed by HRGC/HRMS in the EI mode with a Finnigan MAT 90 mass spectrometer (Finnigan MAT, Germany) directly interfaced to a Varian Model 3400 gas chromatograph. HpCDD/CDF and OCDD/CDF were measured with 50% methyl phenylsilicon, OV-17 (0.25mm × 60m; film thickness, 0.25$\mu$m) and for the analysis of PCDDs/DFs, a SP-2331 capillary column (0.32mm × 60m; film thickness, 0.2 $\mu$m) was used. The mass resolution (5 % valley) was 7000 to 8000. Two ions of a molecular cluster were recorded.

## Results and discussion

Table 1 shows the concentrations of PCDDs/DFs in each part of the potato cultured in agricultural and urban fields and that in the two soil specimens. The total PCDDs/DFs concentrations of the agricultural field soil were 4 times higher than those of the urban field soil. Nevertheless, the PCDDs/DFs concentrations of each part of the potato cultured in the agricultural field were the same as those in the urban field. Hüller *et al.* reported that the concentration of the cortex and the stele of carrot from the highly contaminated soil was much lower than that of the peel.[2] The PCDDs/DFs concentrations in the potatoes from

Table1 Concentrations of PCDDs/DFs in potatoes cultured in agricultural and urban fields as pg/g dry basis

| Field | Agricultural field | | | | | Urban field | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Congener | Soil | Root | Tuber | Stem | Leaf | Soil | Root | Tuber | Stem | Leaf |
| 1,3,6,8-TCDD | 49500 | 9640 | 194 | 246 | 1590 | 14700 | 10400 | 191 | 312 | 454 |
| TCDDs | 95700 | 13000 | 238 | 315 | 1840 | 22400 | 13100 | 223 | 366 | 583 |
| PnCDDs | 19200 | 3140 | 16.0 | 20.6 | 71.8 | 1840 | 909 | 11.2 | 19.2 | 58.5 |
| HxCDDs | 2260 | 59.7 | 0.6 | 4.8 | 21.8 | 237 | 108 | 0.9 | 6.2 | 15.5 |
| HpCDDs | 4160 | 93.2 | 0.9 | 4.1 | 11.8 | 1200 | 295 | 1.7 | 14.6 | 22.7 |
| OCDD | 88900 | 770 | 7.0 | 19.1 | 32.6 | 23200 | 1450 | 9.1 | 75.3 | 59.8 |
| Total PCDDs | 210000 | 17000 | 263 | 363 | 1980 | 48900 | 15900 | 246 | 481 | 740 |
| TCDFs | 3150 | 700 | 8.2 | 15.4 | 55.1 | 471 | 263 | 5.5 | 8.6 | 44.6 |
| PnCDFs | 483 | 103 | 2.2 | 7.4 | 25.0 | 115 | 82.3 | 1.5 | 3.6 | 21.8 |
| HxCDFs | 1070 | 39.0 | 1.0 | 2.2 | 8.3 | 126 | 71.3 | 1.2 | 3.0 | 10.9 |
| HpCDFs | 4330 | 53.3 | 0.7 | 0.8 | 3.5 | 285 | 82.7 | 0.6 | 2.4 | 4.8 |
| OCDF | 14100 | 50.9 | 0.6 | 1.6 | 1.4 | 621 | 63.9 | 0.7 | 2.6 | 2.3 |
| Total PCDFs | 23100 | 947 | 12.7 | 27.5 | 93.3 | 1620 | 563 | 9.5 | 20.1 | 84.4 |
| Total PCDDs/DFs | 233000 | 18000 | 275 | 391 | 2070 | 50500 | 16400 | 256 | 501 | 824 |
| Total PCDDs TEQ | 202 | 4.0 | 0.1 | 0.2 | 0.5 | 36.5 | 6.4 | 0.1 | 0.3 | 0.3 |
| Total PCDFs TEQ | 69.5 | 2.6 | 0.1 | 0.3 | 0.9 | 5.9 | 4.7 | 0.1 | 0.2 | 0.6 |
| Total PCDDs/DFs TEQ | 271 | 6.5 | 0.1 | 0.6 | 1.4 | 42.4 | 11.1 | 0.1 | 0.5 | 0.9 |

Table2 Concentrations of PCDDs/ DFs in cabbage cultured in agricultural field as pg/g dry basis

| Congener | Soil | Inner-leaf | Outer-leaf |
|---|---|---|---|
| 1,3,6,8-TCDD | 23300 | 12.9 | 1070 |
| TCDDs | 39900 | 17.3 | 1350 |
| PnCDDs | 9560 | 4.7 | 137 |
| HxCDDs | 471 | 1.3 | 31.0 |
| HpCDDs | 900 | 1.2 | 28.4 |
| OCDD | 12900 | 3.9 | 89.5 |
| Total PCDDs | 63800 | 28.4 | 1640 |
| TCDFs | 1500 | 4.1 | 127 |
| PnCDFs | 437 | 3.3 | 66.7 |
| HxCDFs | 262 | 2.1 | 19.1 |
| HpCDFs | 412 | 0.4 | 8.4 |
| OCDF | 388 | 0.0 | 4.3 |
| Total PCDFs | 3000 | 9.8 | 225 |
| Total PCDDs/DFs | 66800 | 38.2 | 1860 |
| Total PCDDs TEQ | 37.5 | 0.0 | 1.5 |
| Total PCDFs TEQ | 12.1 | 0.2 | 2.0 |
| Total PCDDs/DFs TEQ | 49.6 | 0.2 | 3.5 |

the two areas were the same. This suggests that the concentrations of the PCDDs/DFs detected in the roots and the tubers depend on the area of contact of each part with the soil. Moreover, the PCDDs/DFs concentrations of the tubers were extremely low as compared with those of the soils and the roots. This result suggested that PCDDs/DFs were hardly transferred from the root to the tuber. This consideration supported the conclusion made by Schroll *et al.* that OCDD was not translocated in the carrot plant from the root to other parts.[5] As shown in table 1, however, a significant difference existed between TCDDs concentrations of the leaves cultivated in the agricultural field and those cultivated in the urban field. A major component of the TCDDs in the leaf was 1,3,6,8-

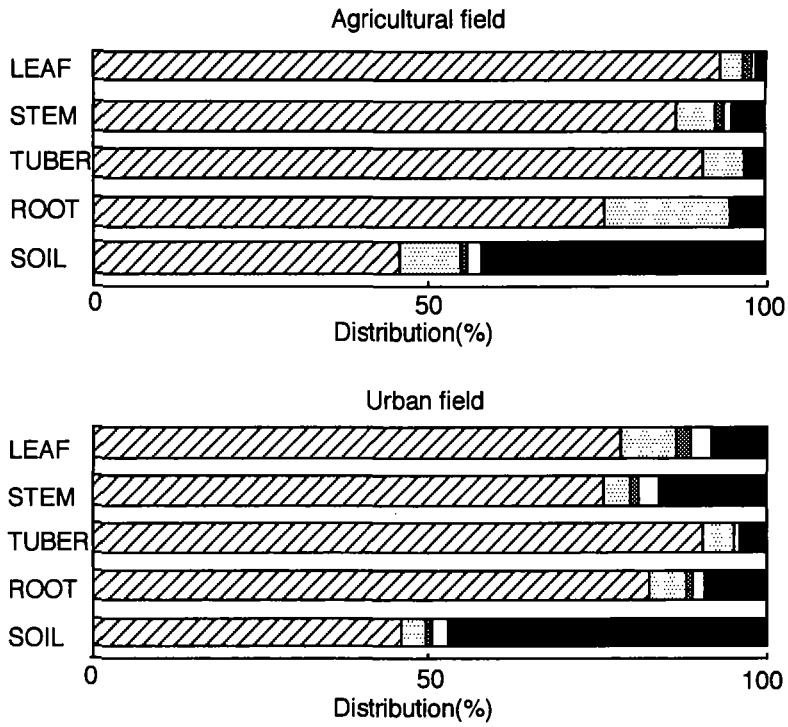


Fig. 1 Congener disributions of PCDDs in potatoes cultured in urban and agricultural field

▨ : TCDDs ▩ : PnCDDs ▩ : HxCDDs □ : HpCDDs ■ : OCDDs

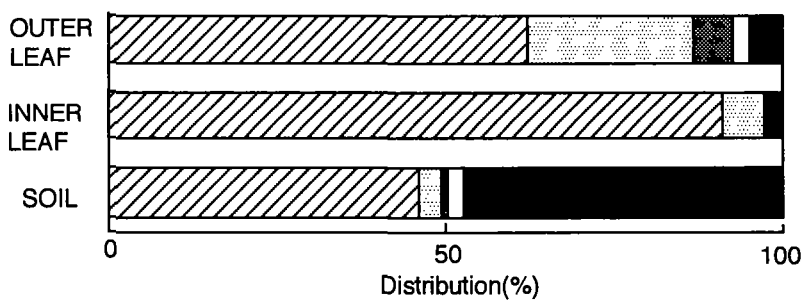


Fig. 2 Congener disribution of PCDDs in cabbage cultured in agricultural field

▨ : TCDDs ▩ : PnCDDs ▩ : HxCDDs □ : HpCDDs ■ : OCDDs

TCDD. The 1,3,6,8-TCDD which was the major congener in the soil was also the major congener in the leaf. It seemed a volatilization of 1,3,6,8-TCDD from the soil should have raised the concentration of the leaf. The PCDDs/DFs contamination of the leaf of the plant was derived from the air, and the PCDDs/DFs volatilization from highly contaminated soil raised the concentration of the leaf of the plant.[5] The relationship between the PCDDs/DFs concentration of the leaf and that of the soil was in agreement with the suggestions made by others. [5] The congener distributions of PCDDs in the two soil specimens were similar, but TCDDs and OCDD were more dominant than the other congeners. However, the distribution of OCDD in each part of the potatoes decreased more clearly than that in the soil (Fig.1). Table 2 shows the concentrations of PCDDs/DFs in the cabbage cultivated in an agricultural field and those in the soil specimens. The PCDDs/DFs concentrations of the outer leaf of the cabbage cultivated in the agricultural field were obviously different from those of the inner leaf of the same plant . The congener distribution of PCDDs in the inner leaf of the cabbage also differed from that in the outer leaf (Fig.2). This differed from the result for the lettuce in which there was no significant difference in PCDDs/DFs contamination pattern or level between inner and outer leaves. [2] The congener distribution of PCDDs in the outer leaf of the cabbage differed from that in the inner leaf. This is probably because the inner leaf of the cabbage is in less contact with the environmental air, because of the narrow gaps between the leaves. The differences between the leaf and other parts of the potato, and between the inner leaf and outer leaf of the cabbage suggested the obvious influence from the environmental air.

## Conclusions

1. PCDDs/DFs in the potato root were hardly transferred to the tuber.
2. The concentration of 1,3,6,8-TCDD in the potato leaf was related to the concentration of the soil that supplied gaseous 1,3,6,8-TCDD.
3. The PCDDs/DFs concentrations of the inner leaf and outer leaf of the cabbage grown in the agricultural field were markedly different.
4. The congener distribution of PCDDs in the outer leaf of the cabbage differed from that in the inner leaf probably because the inner leaf of the cabbage is in less contact with the environmental air .

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