Soil-Plant Transfer of PCDD/PCDF to Vegetables of the Cucumber Family (*Cucurbitaceae*)

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Introduction and Objectives

It is generally agreed that the human diet represents the main route of exposure to PCDD/PCDF. This route is believed to account for over 90% of the total PCDD/PCDF body burden[1], meat, milk and fish contributing 30% each, whereas the intake by consumption of vegetables and fruits is considered as negligible. However, as plants are the first link in the food chain, for risk assessment it is necessary to know by which pathways plants may become contaminated. Results published in the recent literature consistently show that the main uptake pathway of PCDD/PCDF for plant shoots is atmospheric deposition[2-5]. This is in agreement with models predicting negligible PCDD/PCDF uptake *via* plant roots due to the strong adsorption of these compounds to soil particles[6] and their low aqueous solubility. Furthermore, extremely hydrophobic substances (log K_{ow}>6) like PCDD/PCDF are believed not to be transported within plants[7,8].

In 1991 a field experiment was carried out with several fruits and vegetables on a soil contaminated with 148 ng I-TEq/kg[9]. Compared to the results of our studies[2,3] with other plant species, PCDD/PCDF concentrations in zucchini fruits of this experiment were exceptionally high and showed concentrations of about 30 ng I-TEq/kg dry matter in both peel and pulp which are approximately two orders of magnitude higher than in fruits of tomato plants grown in the same soil.

These results necessitated further systematic studies which we carried out in 1992. The main objective was to identify the principal pathway by which PCDD/PCDF enter zucchini plants. Theoretically, PCDD/PCDF may accumulate in zucchini fruits *via* different pathways, namely (1) root uptake and transport to the shoot (*via* the xylem), (2) absorption of volatilized PCDD/PCDF directly by the fruits, or by the

foliage with subsequent transport to the fruit (*via* the phloem), (3) contamination of the fruit surface by soil particles, and (4) atmospheric deposition. As the homologue profiles of soil and zucchini fruits were not identical, and as PCDD/PCDF contamination was not restricted to the peel, contamination of the fruit surface by soil particles can be considered of minor importance[9].

Experimental

To evaluate the influence of direct soil contact on contamination levels some zucchini fruits (*Cucurbita pepo* L., convar. *giromontiina* cv. Diamant F1) were cultivated in a conventional way (with soil contact), and some fruits were fixed to a wire frame to avoid soil contact. The contribution of atmospheric deposition was quantified by growing plants in pots of uncontaminated soil (0.4 ng I-TEq/kg soil) elevated approximately 1.5 m above the soil surface. To evaluate the proportion of root uptake and absorption of volatilized PCDD/PCDF, pots containing plants growing in uncontaminated soil were buried into the PCDD/PCDF contaminated ground, so that leaves and fruits were in contact with the conta-minated soil. Cucumber (*Cucumis sativus* L. cv. Delikateß) and pumpkin (*Cucurbita pepo* L. cv. Gelber Zentner) both, like zucchini, belonging to the family of Cucurbitaceae, were cultivated in the same plot. In addition to fruits, leaves from every treatment were harvested in order to estimate PCDD/PCDF distribution within the plants.

PCDD/PCDF concentrations in the soil and plant materials were determined by ERGO-Forschungsgesellschaft mbH, Hamburg.

Results and Discussion

In the table the PCDD/PCDF concentrations of the various plant samples are summarized. PCDD/PCDF concentrations in "conventional" fruits, in fruits grown without soil contact, as well as in leaves of these plants are about 20 ng I-TEq/kg dry matter. There seems to be a homogeneous distribution of PCDD/PCDF throughout the aerial parts of zucchini. The concentrations are in the same order of magnitude as those of 1991[9]. These results show furthermore that the usual soil contact of zucchini fruits is of no relevance for their elevated PCDD/PCDF concentrations.

Table: PCDD/PCDF concentrations (I-TEq and ΣPCDD/PCDF in ng/kg dry matter) in various samples of zucchini, pumpkin and cucumber (two replicates each)

Plant species	Plant part	Soil (I-TEq)	I-TEq	Σ PCDD/PCDF
Zucchini	fruits (conventional)	148	21.0 / 15.1	348.1 / 274.0
	fruits (no soil contact)		19.4 / 21.6	368.2 / 380.9
	leaves		21.4 / 22.6	440.6 / 490.9
	fruits	0.4/148	0.9 / 1.1	31.9 / 34.7
	leaves		4.4 / 10.2	196.2 / 348.4
	fruits	0.4	0.5 / 0.7	44.2 / 55.8
Pumpkin	fruits	148	7.6 / 7.5	163.8 / 95.4
	leaves		3.6 / 2.4	98.0 / 85.5
Cucumber	fruit	148	0.5 / 0.7	24.4 / 25.4
	leaves		3.4 / 2.0	322.7 / 135.2

In zucchini fruits cultivated in uncontaminated soil 1.5 m above the contaminated soil PCDD/PCDF concentrations are between 0.5 and 0.7 ng I-TEq/kg dm. Samples from zucchini grown in pots with uncontaminated soil surrounded by contaminated soil (treatment 0.4/148) show similarly low concentrations (0.9 / 1.1 ng I-TEq/kg dm). These results demonstrate that the high PCDD/PCDF concentrations found in conventionally cultivated zucchini fruits neither result from atmospheric deposition nor from absorption of volatilized PCDD/PCDF. The results rather prove that zucchini take up PCDD/PCDF with their roots and translocate them to the shoots.

Compared to other plant species of our earlier studies[2,3,9], the PCDD/PCDF concentrations of pumpkin fruits (7.5 ng I-TEq/kg dm) are high (Table). In contrast, the PCDD/PCDF concentrations of cucumber fruits (0.6 ng I-TEq/kg dm) are only slightly higher than in tomato fruits grown in the same soil[9]. Zucchini and pumpkin both belong to the genus *Cucurbita*, whereas cucumber belongs to the genus *Cucumis* . Therefore, it appears that plants of the genus *Cucurbita*, and particulary zucchini, show some propensity to take up and translocate PCDD/PCDF.

Conclusions

The relatively high PCDD/PCDF concentrations found in zucchini (and in pumpkin) can be attributed to an uptake of these substances *via* the roots and a subsequent translocation to the shoots. The nature of the mechanism responsible for this unexpectedly high transfer remains to be clarified.

References

1 Beck H, Eckhart K, Mathar W, Wittkowski R. PCDD and PCDF body burden from food intake in the Federal Republic of Germany. *Chemosphere* 1989;18:417-24.
2 Hülster A, Marschner H. Transfer of PCDD/PCDF from contaminated soils to food and fodder crop plants. *Chemosphere* 1993;27:439-46.
3 Müller JF, Hülster A, Päpke O, Ball M, Marschner H. Transfer pathways of PCDD/PCDF to fruits. *Chemosphere* 1993;27:195-201.
4 Prinz B, Krause GHM, Radermacher L. Criteria for the evaluation of dioxins in the environment. *Chemosphere* 1991;23:1743-61.
5 Kühn T, Steeg E. Lebensmitteluntersuchungsprogramm auf Dioxine im Bereich des Hamburger Südostens. Behörde für Arbeit, Gesundheit und Soziales der freien und Hansestadt Hamburg, Abschlußbericht, 1993; in press.
6 Karickoff SW, Brown DS, Scott TA. Sorption of hydrophobic pollutants on natural sediments. *Water Res* 1979;13:241-8.
7 Briggs GG, Bromilow RH, Evans AA. Relationships between lipophilicity and root uptake and translocation of non-ionised chemicals by barley. *Pestic Sci* 1982;13: 495-504.
8 McCrady J, McFarlane C, Gander LK. The transport and fate of 2.3.7.8-TCDD in soybean and corn. *Chemosphere* 1990;21:359-76.
9 Müller JF. Transferpfade von Dioxin (PCDD/PCDF) in verschiedene verzehrbare Pflanzenteile auf belasteten Böden in Maulach und Rheinfelden. Diplomarbeit, Universität Hohenheim, 1992.

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