Transfer of PCDD/PCDF from Contaminated Soils to Food and Fodder Crop Plants

Hülster, A. and H. Marschner
Universität Hohenheim, Institut für Pflanzenernährung, 7000 Stuttgart 70, Germany

Introduction

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) are lipophilic organic compounds and as such display a strong tendency to accumulate in terrestrial food chains. It is generally agreed that for humans the main intake route of PCDD/PCDF is their diet which is believed to account for over 90% of the total intake. To estimate potential human exposure to PCDD/PCDF through consumption of crops grown on contaminated soils, we need to know the mechanism of transfer of these substances into food products. PCDD/PCDF may accumulate in plants *via* different pathways: namely (1) adsorption to the root surface, (2) root uptake and transport to the shoot, (3) volatilization from the soil surface and subsequent foliar absorption, (4) contamination of foliage by soil particles, and (5) atmospheric deposition.

Measurement of the uptake of PCDD/PCDF by crop plants provides important information for the assessment of public health risks. Only few studies on this topic have been reported in the literature. They are mainly concerned with 2,3,7,8-TCDD, and have generally produced contradictory results[1].

Objectives

Using various crops yielding different organs of economic importance, the following aspects were examined in field experiments:
1. extent of PCDD/PCDF transfer into plants from soils with different levels of contamination
2. differences between plant species and organs in their ability to accumulate PCDD/PCDF
3. influence of post-harvest processing (*e.g.* cleaning and peeling) on the PCDD/PCDF content of the economically important plant parts, and
4. possible measures to reduce the soil - plant (- animal)-transfer

Experimental

The experiments were set up on a field in the vicinity of a former electric wire scrap incinerator for metal reclamation. The soil is a clayey-loam with pH 6.2, a cation exchange capacity of 450 mval kg^{-1} and an organic matter content of 8.1%. PCDD/PCDF concentrations declined gradually with increasing distance from the furnace from about 13000 to 300 ng I-TEq (NATO-CCMS)/kg soil. In order to establish five levels of contamination the field was devided into five

sections. Within each section the upper 10 cm of soil (representing 97% of the total PCDD/PCDF content) was homogenized. This resulted in PCDD/PCDF concentrations of 12800, 5752, 2390, 845, and 328 I-TEq/kg soil in each section respectively. A field some 2 km away from the furnace, with similar soil properties and a PCDD/PCDF concentration of 4.8 ng I-TEq/kg soil was used as control.

Main objective was to evaluate the transfer from soil to plants *via* pathways 2 and 3 mentioned above. To avoid soil-leaf contact and thus contamination of the foliage by soil particles (pathway 4) the soil was covered with a water permeable polypropylene fleece. In field experiments it is not possible to exclude atmospheric deposition (pathway 5). To evaluate PCDD/PCDF accumulation in food and fodder chains lettuce, potatoes and hay, were grown on the trial site.

PCDD/PCDF analyses in soil and plant materials were performed by "ERGO" laboratories, Hamburg, Germany.

Results and discussion

The I-TEq contents of the various crops are summarized in Fig. 1. In order to present all values in the same figure, the I-TEq contents of the hay were devided by a factor of 10. At soil concentrations of 5752 I-TEq/kg or lower there is little correlation between soil contaminations and plant contents (with the exception of unpeeled potato tubers). This is in good agreement with studies of Hembrock-Heger[2] and recent results published in the "NRW-Meßprogram: Chloraromaten - Herkunft und Transfer"[3]. Of the plant species examined the plant parts can be ranked according to their PCDD/PCDF contamination as follows: hay >> unpeeled potato tubers > lettuce > potato shoots >> peeled potato tubers.

Bioaccumulation factors (ng I-TEq/kg dm / ng I-TEq/kg soil) range from 0.1 to 7.8E-6 (Fig. 2). The factors decrease as soil contamination increases. Similar behaviour has been observed for HCB, PCP, and Atrazin[4]. The most likely explanation for this decrease is the dominance of air-plant transfer versus soil-plant transfer.

Compared with investigations on TCDD uptake in Seveso[5] in our study the contamination levels of potato samples are several orders of magnitude lower. The PCDD/PCDF

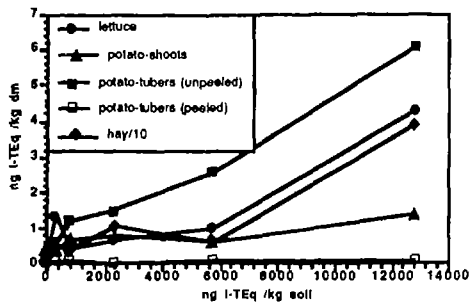

Fig. 1: PCDD/PCDF concentrations of the plant samples in relation to soil contamination

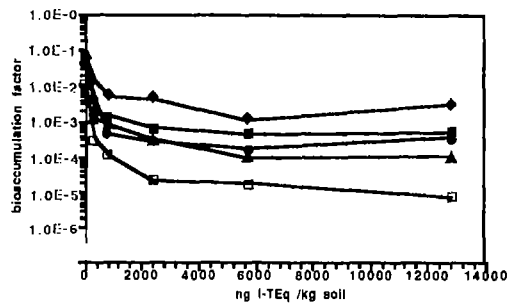

Fig. 2: Bioaccumulation factors of the plant samples in relation to soil contamination

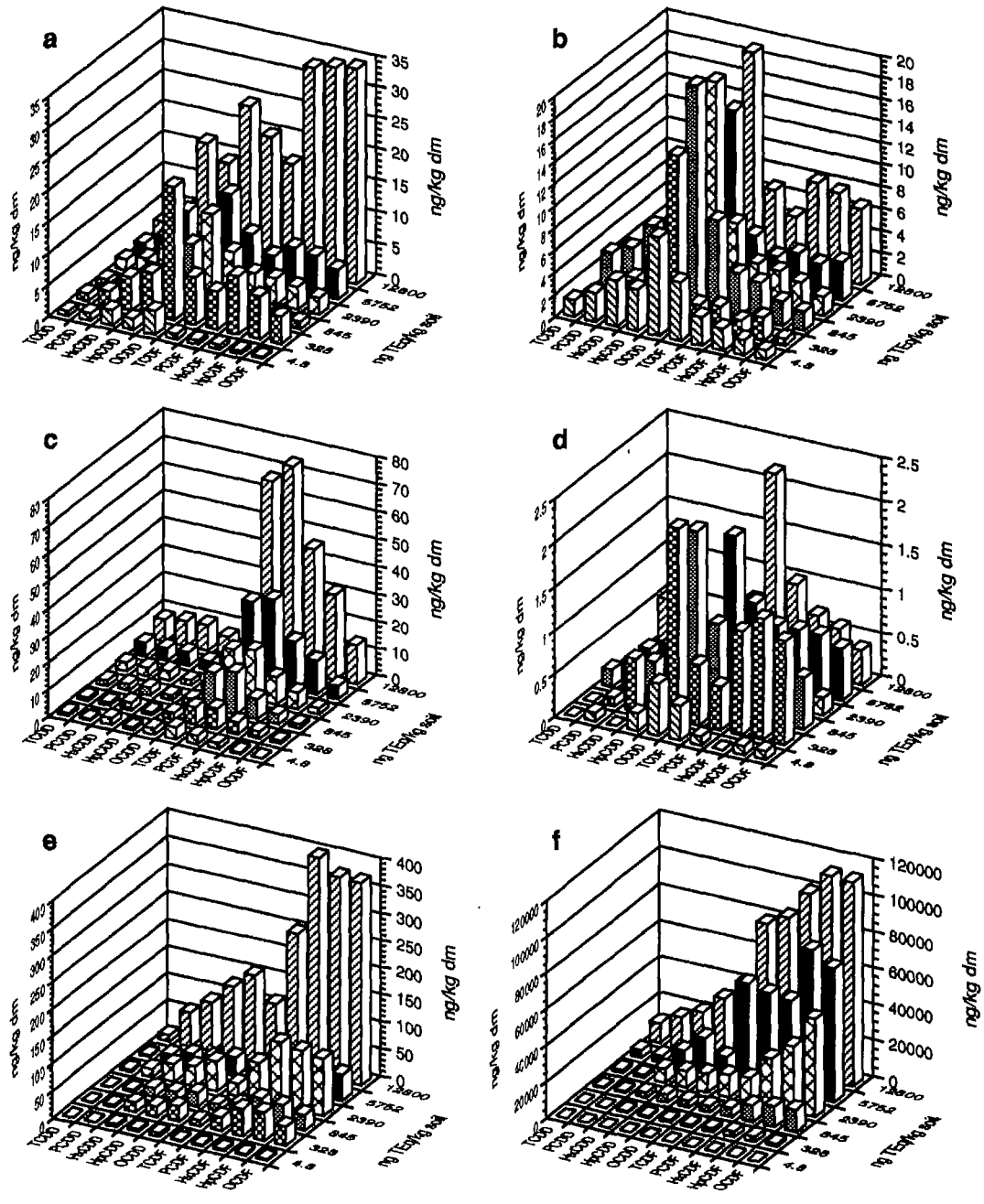

Fig. 2: Homologue distribution of PCDD/PCDF for lettuce (a), potato shoots (b), unpeeled (c) and peeled potato tubers (d), hay (e), and for soil (f)

concentrations of lettuce are only one hundredth of the concentrations measured in a study of Hagenmaier[6]. In our view this discrepancy reflects the importance of foliage contamination by soil particles. In our experiments we tried to exclude this pathway by soil covering and post-harvest cleaning.

The homologue distributions of the PCDD/PCDF in the soil and plant samples are presented in Fig. 3. All plant species and plant parts demonstrate distinct homologue patterns. With the exception of hay the patterns of homologue distribution for each plant studied were clearly different from the soil pattern. These results also indicate that for lettuce and potato pathway 4 was effectively minimised. In contrast, in hay the homologue distribution is quite similar to the soil pattern, indicating that in hay the main pathway for PCDD/PCDF accumulation was contamination of foliage by soil particles.

Conclusions

1. There is little correlation between soil and plant concentrations of PCDD/PCDF with the exception of plant parts growing in the soil (*e.g.* unpeeled potato tubers).
2. Contamination of crops by soil particles is an important pathway for PCDD/PCDF accumulation.
3. When contamination by soil particles is excluded (or the soil concentrations of PCDD/PCDF are low), "leafy" plants are mainly contaminated by atmospheric deposition and not by root uptake of PCDD/PCDF and subsequent transport to the shoot.
4. PCDD/PCDF levels in peeled potato tubers were not related to the level of soil contamination. Peeling may therefore be a practical method of minimising PCDD/PCDF levels in potato products for human consumption.

Acknowledgement

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