Polychlorinated dibenzo-*p*-dioxins, dibenzofurans and non-*ortho* PCBs in household organic-waste compost and mature garden waste compost

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1. Introduction

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) can be enzymatically formed from chlorophenols[1]. Pentachlorophenol in activated sewage sludge is transformed to OCDD [2]. Compared to activated sewage sludge, compost usually contains less organohalogen environmental pollutants. Nevertheless, PCDD/Fs in compost have been of some concern, especially in Germany[3–18]. Recent studies of grass and garden field compost show *de novo* formation[2, 19–24] of all PCDD/Fs – particularly of HpCDD/Fs and OCDD/F – and occasionally degradation[21], particularly of TCDD/Fs. Similar results have been obtained in a laboratory compost reactor[25]. In this paper we present results from composting of household organic waste. Additionally, data from mature garden compost are presented.

2. Materials & Methods

Two garden-composts and two household organic-waste composts have been studied. The construction of compost and experimental set-up has been described in detail elsewhere[20, 21]. The garden compost was covered on top but was open to the sides and the bottom. In contrast, the household organic-waste compost was insulated. The compost core was enclosed in a netted bag. The garden waste consisted of grass, twigs, leaves, and finely chopped bushes and small trees. The household organic-waste consisted of garden waste mixed with food refuse. The cold climate in Umeå (64°N, 20°E) leads to a short composting season. We followed a GLP-protocol[26] for extraction, clean-up and isomer-specific analysis of PCDD/Fs by HRGC-HRMS (Hewlett Packard 5890 A, J&W DB5 columns, VG Analytical 70-250S). PCDD/F standards were from CIL. Planar non-*ortho* PCBs (3,3',4,4'-TeCB; 3,3',4,4',5-PeCB; and 3,3',4,4',5,5'-HxCB) that elute in the PCDD/F fraction were also analysed. Data are presented as pg/g dry matter (d.m.) corrected for CO_2-loss.

3. Results & Discussion

The total loss of organic matter (released as CO_2) is listed in Table 1; in Fig. 1 the decrease of organic matter over time is shown for the household organic-waste compost. Obviously, similar composts may progress differently over time. During composting the levels of PCDD/Fs often increase[21], which is reflected in the homologue profiles that change from U-shape to saw-toothed shape (Fig. 2 top row, garden compost) [21]. In contrast to grass and garden compost, little formation occurred in the household organic-waste compost; the general trend is a slight decrease of PCDD/Fs (Fig. 3) and non-*ortho* PCBs (Fig. 5). Others have reported formation of PCDD/Fs in household waste compost[25].

Table 1. Loss of organic matter (dry matter, d.m.) during composting.

	Garden compost #1	Garden compost #2	Garden compost #1	Garden compost #2	Household compost #1	Household compost #2
Time span	0 – 39 w	0 – 40 w	39 – 60 w	40 – 61 w	0 – 12 w	0 – 12 w
Loss d.m.	18%	32%	26%	21%	48%	30%

Even though the household compost contained substantial composting activity (Fig. 1), only minor changes of PCDD/F-levels were seen (Fig. 3, Fig. 7). This is also reflected in the homologue profiles (Fig. 2 middle and bottom rows) that hardly differ from the original U-shape. However, examining the homologue profiles carefully hints at some decrease of lower chlorinated dibenzofurans (*e.g.* single TCDF congeners) and possible increase of higher chlorinated dibenzodioxins. This is in accord with earlier findings[21], and could imply that there may be a residual PCDD/F *de novo* formation to be seen in the household compost at later stages. The decrease of TCDFs and increase of OCDD (Fig. 2, Fig. 7) has also been seen in mature grass compost[19–21]. Homologue profiles may be used to describe the potential for PCDD/F *de novo* formation in compost ("PCDD/F maturation").

The concentration of non-*ortho* PCBs in the household organic-waste compost (Fig. 5) is slightly higher than that of total PCDD/Fs (Fig. 3), and contribute two thirds of the total dioxin-like toxicity (I-TEq). The decrease in PCB concentration over time is moderate (Fig. 5).

The garden compost shows some increase in PCDD/Fs over the winter (Fig. 4, Fig. 6). This has been seen for mature grass compost as well[19–21], but was then a dramatic event. The mature garden compost shows a trend of decreasing PCDFs and increasing PCDDs (Fig. 8). The *de novo* formation of PCDD/Fs in mature garden compost was weak (second summer; Fig. 4, Fig. 6, Fig. 8) although organic matter continued to degrade (Table 1). The garden compost that lost less CO_2 the first year, now showed higher biological activity and also more pronounced formation of PCDD/Fs. On the other hand, TCDD/Fs decrease slightly, which may also be the case for PeCDD/Fs (Fig. 8). In the few samples from garden-waste compost that we have analysed for PCBs, the ratio of PCBs to PCDD/Fs stays constant.

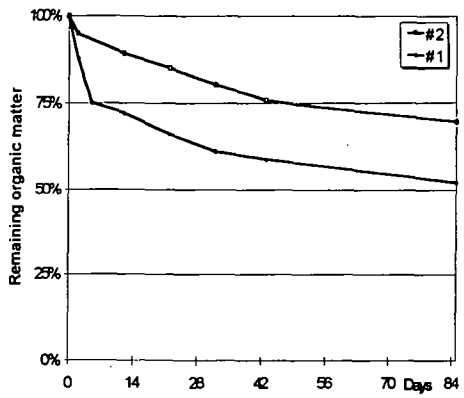

Fig. 1. Loss of organic matter in household compost (#1, #2).

The household organic-waste compost we studied is a new compost situation with no PCDD/F or PCB formation, while still being biologically active. Nevertheless, there are some weak signs of processes similar to other studied composts. We hypothesise that precursors and particular bioprocesses are responsible for the observed differences between grass, garden and household compost.

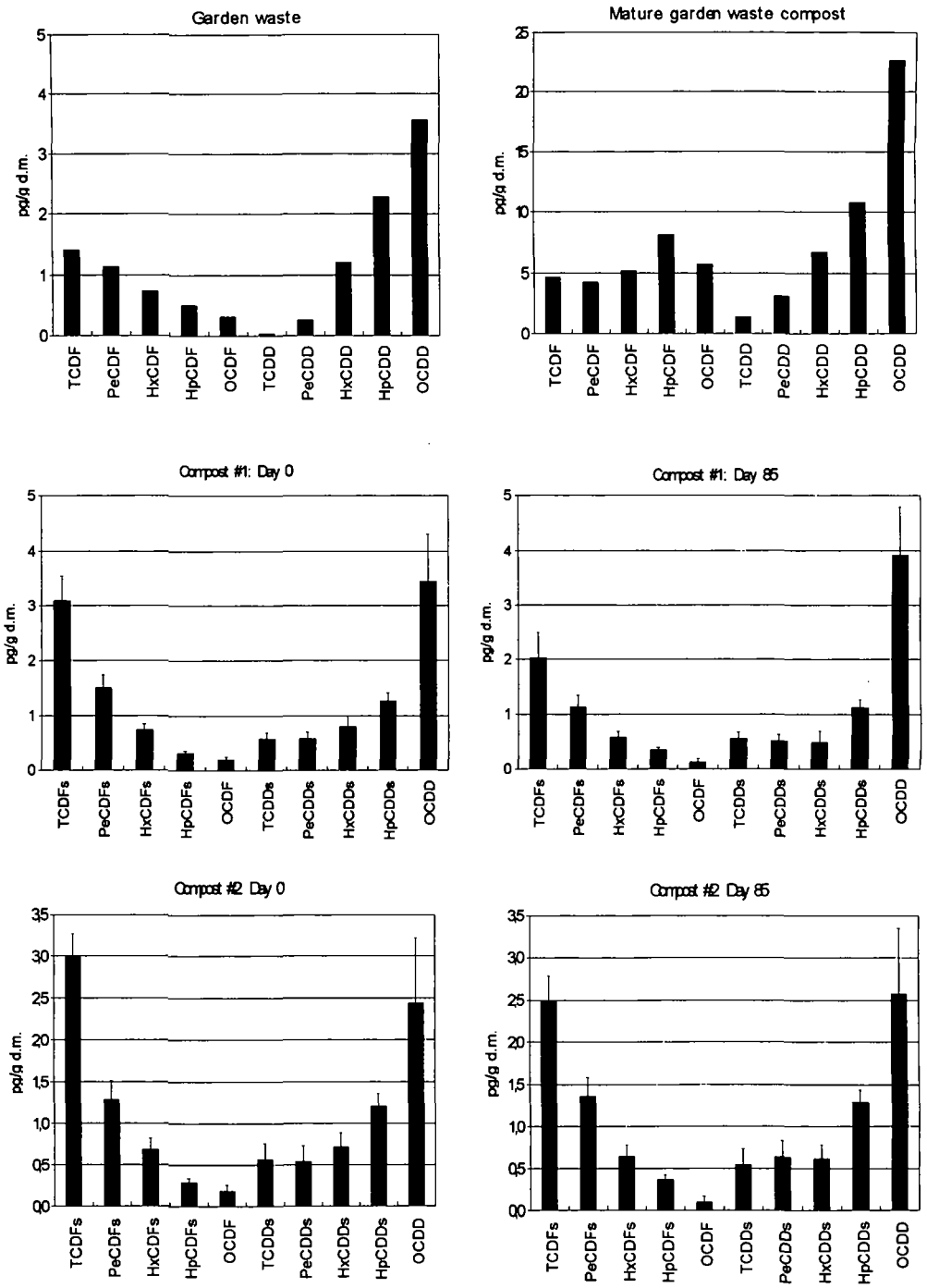

Fig. 2. Homologue profiles for PCDD/Fs: garden waste and mature garden compost (top row); *household compost* (middle and bottom row) at Day 0 and at Day 85.

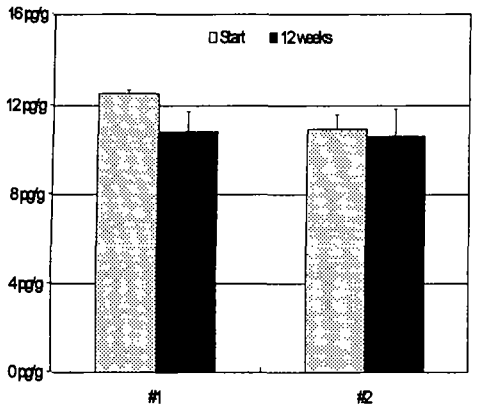

Fig. 3. Sum of PCDD/Fs in household organic-waste compost (#1, #2).

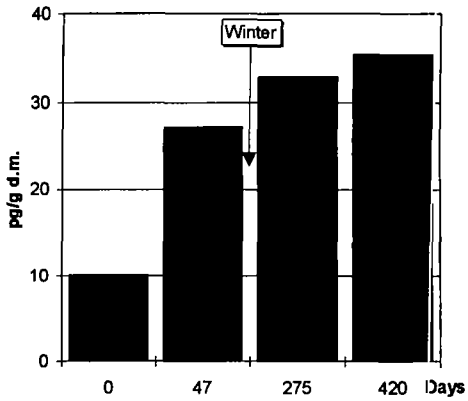

Fig. 4. Sum of PCDD/Fs in maturing garden compost (#1).

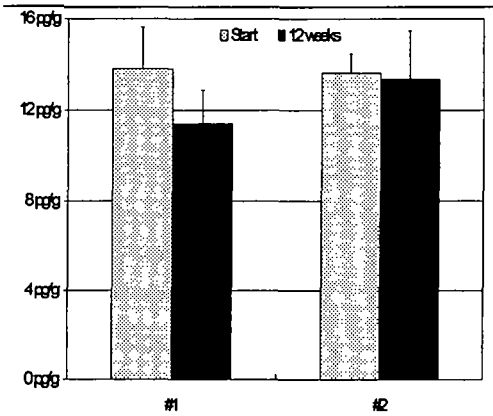

Fig. 5. Sum of non-*ortho* PCBs in household waste compost (#1, #2).

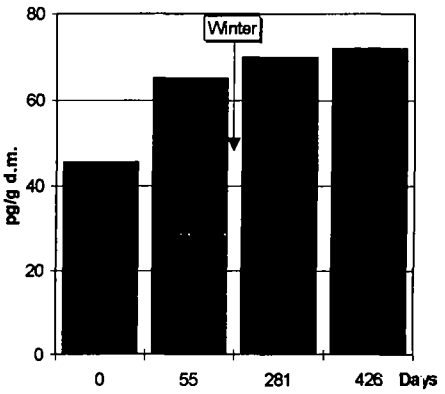

Fig. 6. Sum of PCDD/Fs in maturing garden compost (#2).

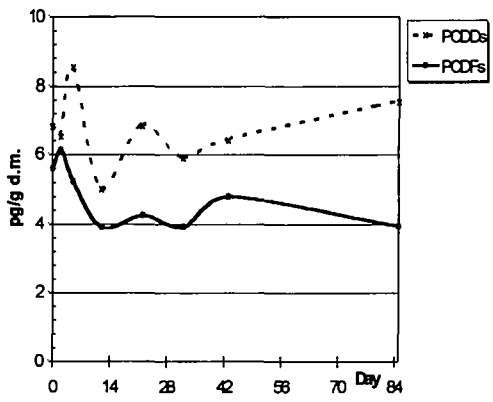

Fig. 7. Time trend for PCDDs and PCDFs in household organic-waste compost.

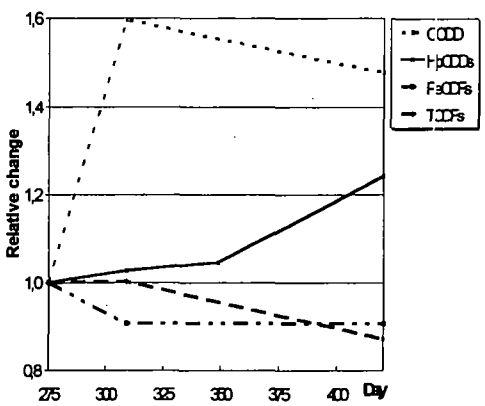

Fig. 8. Small relative changes of PCDD/Fs in mature garden compost.

4. Conclusions

The background samples and the household compost have U-shaped homologue profiles, while the mature garden compost has saw-toothed homologue profiles. Mature garden waste compost shows an increase of PCDD/Fs when compared to the last sample before the winter, thus confirming earlier results from grass compost[20, 21]. The mature garden compost continues to degrade organic matter, but the changes in PCDD/Fs are moderate. Higher chlorinated PCDDs tend to increase, and lower chlorinated PCDFs tend to decrease. In household organic-waste compost the changes are minor. Total PCDD/Fs decline slightly, mainly because TCDFs decrease more than OCDD increases. The concentration of planar non-*ortho* PCBs decreases slightly. Thus, findings in garden and household compost agree with what was found for TCDFs in mature grass compost[21]. We suggest that the difference between the garden and household compost reflects differences in precursors (type and level) and in bioprocesses (microbial activity and capacity). The differences are not attributed to garden waste *vs.* household organic-waste, nor to "cold" *vs.* "warm" composting. It remains to be explained why *de novo* formation of PCDD/Fs occurs in a certain situation. This question is important to answer if large-scale composting is introduced as a general means of reducing the enormous organic waste problem.

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