PCDD/PCDF BALANCE OF DIFFERENT MUNICIPAL WASTE MANAGEMENT METHODS III: COMPOSTING

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Introduction

About 30 to 40 percent of municipal wastes consists of vegetable and other plant material. But up to now, less than 10 percent of all municipal wastes is collected separately and then composted in special plants. Degradation processes take place on waste disposals and are responsible for their biogas emissions (see part II: Waste disposals and disposal gas incineration).
The authors have analyzed several composts from different materials (green wastes, plant waste, mixed waste, bark) in regard to their contents of PCDD/PCDF. The results are presented in this paper.

Experimental

Screening analyses were prepared from the following stuff:
Mixed waste composts: A, B
Plant waste composts: C, D, E
Bark compost: F
Vegetable waste compost: G, H1 (n = 7), H 2, I1, I2 - I4 (detailled analyses),
compost not specified: K1 - K3 (detailled analyses).

Sample preparation and GC/MS-analysis followed VDI 3499. Detection limit was 0,01 ng/kg dry substance for each single isomer in the screening analyses and 0,05 resp. 0,001 in the detailled ones.

Results

The following table shows the results of compost analyses of different sources. The results are averages of double-samples.

Our analyses do not show great differences in either PCDD/PCDF burden or in the isomer patterns in composts. PCDD sums range from 0,276 to 19,1 ng/g, while the PCDF burden is always smaller (mainly < 1 ng/g). The toxicity equivalents range from 0,8 to 35,7 ng/kg (TE). Only four samples lie under the recommendend limit (5 ng/kg, TE) for soil for unrestricted agricultural use. As expected, octa- and hepta-CDD are chief constituents in the PCDD-pattern. Hexa-CDD were mainly detected in composts, which are suspected to be contaminated much higher because of their resources, especially mixed waste composts.

Tab. 1: PCDD/PCDF contents in different compost samples.

	A [ug/kg]	B [ug/kg]	C [ug/kg]	D [ug/kg]	E [ug/kg]	F [ug/kg]	G [ug/kg]
2378-TetraCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
12378-PentaCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123789-HexaCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123678-HexaCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123478-HexaCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
1234678-HeptaCDD	0,93	1,18	0,02	0,10	0,03	0,15	0,34
2378-TetraCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
12378+12348-PentaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
23478-PentaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123478+123479-HexaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123678-HexaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
123789-HexaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
234678-HexaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
1234678-HeptaCDF	0,01	0,01	< 0,01	0,10	< 0,01	< 0,01	0,01
1234789-HeptaCDF	< 0,01	< 0,01	< 0,01	0,01	< 0,01	< 0,01	< 0,01
Sum TetraCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum PentaCDD	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum HexaCDD	0,07	0,12	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum HeptaCDD	1,55	2,11	0,05	0,22	0,07	0,29	0,54
OctaCDD	10,71	16,67	1,57	2,72	1,81	1,86	15,37
Sum PCDD	12,53	19,10	1,62	2,94	1,88	2,15	15,91
Sum TetraCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum PentaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum HexaCDF	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01
Sum HeptaCDF	0,01	0,02	< 0,01	0,12	< 0,01	< 0,01	0,03
OctaCDF	0,03	0,02	< 0,01	0,04	< 0,01	< 0,01	0,02
Sum PCDF	0,04	0,04	< 0,01	0,16	< 0,01	0,05	0,05
Sum PCDD+PCDF	12,57	19,14	1,62	3,10	1,88	2,15	15,96
tox.Equi. (BGA) (ng/kg)	22,6	32,1	1,8	5,2	2,2	3,6	19,4

In two additional samples (L resp. M) we found 136 ng (TE)/kg in green and 186 ng (TE)/kg in mixed waste compost (unpublished). PCDD/PCDF contamination in different compost samples have not been published yet. We expect further analyses to lie in the same range as given here.

Tab. 1 cont.: PCDD/PCDF contents in different compost samples.

	H 1 (n= 7) [ug/kg]	H 2 [ug/kg]	I 1 [ug/kg]	I 2 [ug/kg]	I 3 [ug/kg]	I 4 [ug/kg]	K 1 [ug/kg]	K 2 [ug/kg]	K 3 [ug/kg]
2378-TetraCDD	< 0,01	< 0,01	< 0,01	< 0,005	< 0,005	< 0,005	< 0,001	0,001	0,001
12378-PentaCDD	< 0,01	< 0,01	< 0,01	< 0,005	< 0,005	< 0,005	0,002	0,003	0,002
123789-HexaCDD	< 0,01	< 0,01	< 0,01	< 0,005	0,006	< 0,005	0,018	0,006	0,016
123678-HexaCDD	< 0,01 - 0,01	< 0,01	< 0,01	< 0,005	0,008	< 0,005	0,019	0,006	0,006
123478-HexaCDD	< 0,01 - 0,01	< 0,01	< 0,01	< 0,005	0,006	< 0,005	0,005	0,004	0,018
1234678-HeptaCDD	0,09 - 0,36	0,22	0,34	0,025	0,056	0,030	0,846	0,400	0,408
2378-TetraCDF	< 0,01 - 0,02	< 0,01	< 0,01	< 0,005	0,024	< 0,005	0,008	0,006	0,009
12378+12348-PentaCDF	< 0,01 - 0,01	< 0,01	< 0,01	0,005	0,014	< 0,005	0,005	0,006	0,010
23478-PentaCDF	< 0,01 - 0,02	< 0,01	< 0,01	< 0,005	0,012	< 0,005	0,004	0,006	0,010
123478+123479-HexaCDF	< 0,01 - 0,02	< 0,01	< 0,01	0,016	0,006	< 0,005	0,019	0,009	0,010
123678-HexaCDF	< 0,01 - 0,01	< 0,01	< 0,01	0,021	0,020	< 0,005	0,008	0,007	0,009
123789-HexaCDF	< 0,01	< 0,01	< 0,01	< 0,005	< 0,005	< 0,005	0,001	< 0,001	< 0,001
234678-HexaCDF	< 0,01 - 0,01	< 0,01	< 0,01	0,010	0,010	< 0,005	0,004	0,010	0,003
1234678-HeptaCDF	0,02 - 0,28	0,01	0,02	0,041	0,019	0,008	0,095	0,041	0,047
1234789-HeptaCDF	< 0,01 - 0,01	< 0,01	< 0,01	0,005	< 0,005	< 0,005	0,003	0,004	0,004
Sum TetraCDD	< 0,01	< 0,01	< 0,01	< 0,005	< 0,005	< 0,005	0,010	0,023	0,022
Sum PentaCDD	< 0,01 - 0,05	< 0,01	< 0,01	< 0,005	< 0,005	< 0,005	0,050	0,062	0,038
Sum HexaCDD	< 0,01 - 0,12	< 0,01	< 0,01	0,015	0,071	0,005	0,124	0,115	0,188
Sum HeptaCDD	0,25 - 0,70	0,46	0,59	0,048	0,120	0,044	1,262	0,723	0,711
OctaCDD	4,71 - 20,63	10,60	17,33	0,213	0,543	0,288	7,097	3,859	4,434
Sum PCDD	4,68 - 21,28	11,06	17,92	0,276	0,734	0,338	8,543	4,782	5,394
Sum TetraCDF	< 0,01 - 0,54	< 0,01	< 0,01	0,032	0,173	0,006	0,107	0,081	0,130
Sum PentaCDF	< 0,01 - 0,44	< 0,01	< 0,01	0,055	0,124	< 0,005	0,103	0,070	0,116
Sum HexaCDF	< 0,01 - 0,32	< 0,01	0,02	0,104	0,084	< 0,005	0,177	0,093	0,080
Sum HeptaCDF	0,05 - 0,33	0,02	0,03	0,069	0,032	0,019	0,206	0,112	0,082
OctaCDF	0,02 - 0,34	0,02	0,06	0,025	0,030	0,031	0,352	0,167	0,127
Sum PCDF	0,14 - 1,76	0,04	0,11	0,285	0,443	0,056	0,884	0,523	0,534
Sum PCDD+PCDF	5,39 - 21,67	11,10	18,03	0,562	1,177	0,394	9,427	5,305	5,928
tox.Equi. (BGA) [ng/kg]	7,1 - 35,7	13,4	21,8	7,7	15,4	0,8	30,8	19,7	24,2

Discussion

What consequences will these results have for the agricultural use of compost? Compost is often used for melioration and as fertilizer for acricultural soils. PCDD/PCDF - contaminated compost could increase their toxic burden. For consumer's protection, the Federal Bureau of Health (Bundesgesundheitsamt) has proposed two limits for soils:

> 40 ng/kg PCDD/PCDF (TE): no agricultural use

> 5 ng/kg PCDD/PCDF (TE): restricted agricultural use.

Maximum soil burden by PCDD/PCDF in compost can be calculated as follows (1, varied):

$$Cmax = Ccomp \times \frac{Mcomp}{Msoil + Mcomp} : 1 - e^{-\frac{dt \times \ln 2}{hl}}$$

with

Cmax = maximum PCDD/PCDF - concentration in soil (in ug/t)
Ccomp = PCDD/PCDF concentration in compost (in ug/t) (see table 2)
Mcomp = mass of compost added to soil (here: 5, 10t or 100 t) (2)
dt = time between two spreading events (in years; here: 1 year)
hl = half-life of compounds of interest (in years; here: 12 years)
Msoil = mass of soil to which the compost is added, here:
Soil depth for dilution: 5 cm
Soil volume: 500 m^3 per hectar
Soil density: 1.5 t/m^3
Soil mass: 750 t

Tab. 2: PCDD/PCDF burden of uncontaminated soil due to compost spreading

	Compost H1	Compost L	Compost M
PCDD/PCDF (TE)	17,6 ng/kg	136 ng/kg	183 ng/kg
Cmax with an annual input of			
5 t/ha	2,1 ng/kg	16,1 ng/kg	21,6 ng/kg
10 t/ha	4,1 ng/kg	31,9 ng/kg	42,9 ng/kg
20 t/ha	8,2 ng/kg	63,0 ng/kg	84,7 ng/kg
100 t/ha	36,9 ng/kg	285,2 ng/kg	383,8 ng/kg

Under the assumption of a half-life of PCDD/PCDF of 12 years, even low contaminated compost (H1) leads to PCDD/PCDF contents in soil, that further agricultural use has to be restricted (5 - 40 ng/kg) after several years of intensive practice (see table 2). In addition, a pre-burden of about 1 ng (TE)/kg (3) has to be taken into account, reducing the maximum allowable amounts of compost in order to prevent reaching or exceeding the limits for agricultural use. As the mechanisms of degradation of PCDD/PCDF in compost-amended soils are not clear, we plead for establishing limits for agricultural use of compost depending on the PCDD/PCDF-content of compost and soil. Table 2 does not intend to doubt the usefulness of composting within municipal waste management programs. In consequence, it demonstrates the necessity of rapid and efficient countermeasures against the SOURCES of the problem.

References

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