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Evaluating the environmental impact of an old municipal waste incinerator: PCDD/F levels in soil and vegetation samples

J.L. Domingo [a,*], M. Schuhmacher [a], L. Müller [b], J. Rivera [c], S. Granero [a], J.M. Llobet [d]

[a] *Laboratory of Toxicology and Environmental Health, Rovira i Virgili University, San Lorenzo 21, 43201 Reus, Spain*

[b] *MPU GmbH, Department of Analytical Laboratory, 10829 Berlin, Germany*

[c] *Mass Spectroscopy Laboratory, Ecotechnology Department, C.I.D., CSIC, 08034 Barcelona, Spain*

[d] *Toxicology Unit, School of Pharmacy, University of Barcelona, 08034 Barcelona, Spain*

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Abstract

In order to determine the temporal variation in the levels of polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in the vicinity of an old municipal solid waste incinerator (MSWI) (S. Adrià del Besòs, Barcelona, Spain), 24 soil and vegetation samples were collected at the same sampling points in which samples had been taken 1 year before. Each sample was analyzed for PCDDs and PCDFs by high-resolution gas chromatography/high-resolution mass spectrometry. While in the previous study PCDD/F concentrations in soil ranged from 1.22 to 34.28 ng I-TEQ/kg (median and mean values: 9.06 and 12.24 ng I-TEQ/kg), in the present study, PCDD/F levels ranged from 1.33 to 54.23 ng I-TEQ/kg (median and mean values: 11.85 and 14.41 ng I-TEQ/kg). On the other hand, in the previous study, PCDD/F levels in vegetation ranged from 0.33 to 1.98 ng I-TEQ/kg (median and mean values: 0.58 and 0.70 ng I-TEQ/kg), whereas in the present study, PCDD/F levels ranged from 0.32 to 2.52 ng I-TEQ/kg (median and mean values: 0.82 and 0.97 ng I-TEQ/kg). During the last 12 months, PCDD/F levels increased in 16 of the 24 soil samples and in 17 of the 24 vegetation samples analyzed.

* Corresponding author. Tel.: +34-977-759380; Fax: +34-977-759322.
E-mail address: jlldr@fmcs.urv.es (J.L. Domingo).

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However, no significant differences in the median I-TEQ concentrations of both studies were found either in soil or vegetation samples.

Keywords: Polychlorinated dibenzo-*p*-dioxins; Polychlorinated dibenzofurans; Soil; Vegetation; Municipal waste incinerator; Temporal variation

1. Introduction

Although municipal solid waste (MSW) incineration is a part of integrated waste management in many countries, the emission of trace amounts of metals and polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) has raised much concern about the environmental and health consequences of this process of treating MSW [1–7].

PCDD/Fs, which were discovered in the stack gas of MSW incinerator in 1977 [8], are among the most toxic environmental contaminants. Three main categories of environmental sources of PCDD/Fs can be identified: chemical–industrial processes, thermal or combustion sources, and reservoirs (secondary sources), which include sewage sludge, compost and contaminated soils [9–11]. However, the main pathway of PCDD/F to enter the environment is via combustion processes. Among these processes, stationary plants such as MSWI are of special relevance [2,12,13]. PCDD/Fs are present in all environmental compartments (air, soils, vegetation, sediments and water) and given their persistent nature and relative immobility, terrestrial and aquatic organisms are liable to exposure.

Since 1975, a MSWI has been operating in S. Adrià del Besòs (Barcelona, Spain). In March 1998, soil and vegetation samples were collected near the plant and analyzed for PCDD/F concentrations [14]. While soils reflect cumulative PCDD/F deposition during rather long periods of time, PCDD/F levels in vegetation can be a more suitable indicator of the atmospheric emissions of PCDD/Fs during short periods of time [15–18]. To establish the temporal variation in the environmental concentrations of PCDD/Fs in the area under potential influence of the plant, soil and herbage samples were collected at the same points in which samples were taken in a previous survey. The levels of PCDD/Fs in soil and vegetation are reported here and compared with those previously determined [14].

2. Materials and methods

The facility began operations in 1975 and handles about 300 000 tons of MSW per year. The height of the stack is 92 m and the stack gas flow is 240 Nm^3/h. Until recently, an electrostatic precipitator has been used as the emission control device. Therefore, it could be expected that in the last two decades, significant amounts of PCDD/Fs were released to the environment. In this plant, a scrubber to limit acid gas and metal emissions, which can complement the control of PCDD/F emissions, has been recently installed (March 1999). In order to assess the efficacy of the new

equipment, the knowledge of the previous levels of metals and PCDD/Fs in the area under potential influence of the plant is very important. In March 1999, 1 year after the first soil and vegetation sampling, 24 soil and 24 vegetation samples were collected in the surroundings of the MSWI in the same points in which samples had been taken in the 1998 survey [14]. Duplicate soil and vegetation samples were taken at 250, 500, 750, 1000, 1500, and 3000 m from the stack. Soil samples consisted of a minimum of 500 g. They were sieved through a 2-mm mesh screen to obtain a more homogenous grain distribution. Determination of dry matter content was achieved by drying subsamples (1–3 g) at 130°C overnight [14].

Herbage samples were obtained by cutting at a height of approximately 4 cm from the soil. They were immediately packed in aluminum foils. Subsequently, samples were dried at room temperature, kept in double aluminum foil, packed in labeled plastic bags and stored at room temperature until analysis. About 50 g (dry wt.) was used for analytical purposes. Samples were prepared by grinding them with a cutting mill to a fine powder, and placed in a Soxhlet thimble.

The clean-up procedure as well as the analytical determination of PCDD/Fs were carried out as recently reported [14]. Samples were analyzed for each of the five chlorinated dibenzo-*p*-dioxin and dibenzofuran congener groups (with four to eight chlorines) by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS). PCDD/F analysis in soil and vegetation samples was carried out using a Fisons 8060 GC and Fisons 8000 GC, respectively, both coupled with a VG Autospec Ultim system (emission impact and multiple ion determination mode, resolution 10 000). Quantitative determinations of PCDD/Fs were performed using internal standards. The analytical conditions were the same for the 1998 and 1999 surveys.

For comparison of the 1998 and 1999 data, statistical significance between groups was computed by one-way analysis of variance. In order to look for a possible linear dependence between the different PCDD/F homologues in soil and vegetation samples, Pearson correlation was applied. The 2,3,7,8-TeCDD toxic equivalents (I-TEQ) were calculated using the NATO/CCMS factors. In the case of results under the detection limit, I-TEQ calculations were carried out assuming that the congener was present at one-half of that value. A multivariate analysis of the results was done. Data matrices were evaluated through principal component analysis (PCA). Each soil and vegetation sample was assigned a score in each component allowing the summarized data to be further analyzed and plotted. The hierarchical cluster analysis (HCA), which identifies homogeneous groups of samples, was performed according to the average linkage between groups method on the squared euclidian distances matrix derived from the PCA scores. All calculations were performed using the SPSS-7.5 statistical software.

3. Results and discussion

The individual and total tetrachloro- to octachlorodibenzo-*p*-dioxins and dibenzofurans in soil and vegetation samples collected in the proximity of the MSWI in 1998 and 1999 are shown in Table 1. The percentages of temporal variation are also given. In the 1998 survey, PCDD/F concentrations in soil samples ranged from 1.22 to 34.28 ng

Table 1
Individual and total PCDD/Fs in soil and vegetation samples collected in the vicinity of an old municipal solid waste incinerator: temporal variation[a]

Congener	Soil			Vegetation		
	1998	1999	%	1998	1999	%
2,3,7,8-TeCDD	0.41	0.36	−12	0.08	0.11	36
Total TeCDDs	14.94	26.00	74	12.4	19.90	60*
1,2,3,7,8-PeCDD	1.31	1.58	21	0.16	0.21	30*
Total PeCDDs	30.13	33.00	10	8.08	8.86	10
1,2,3,4,7,8-HxCDD	1.48	2.08	40	0.09	0.14	52*
1,2,3,6,7,8-HxCDD	4.03	7.29	81	0.17	0.31	83*
1,2,3,7,8,9-HxCDD	4.23	4.56	8	0.12	0.20	69*
Total HxCDDs	54.14	94.20	74	4.11	6.30	53*
1,2,3,4,6,7,8-HpCDD	46.98	69.19	47	1.43	3.51	145**
Total HpCDDs	92.43	144.00	56	3.15	7.48	137**
OCDD	761.36	505.72	−34	5.49	15.75	187**
2,3,7,8-TeCDF	12.74	11.11	−13	1.14	1.30	14
Total TeCDFs	48.47	44.00	−9	22.65	31.10	37
1,2,3,7,8-PeCDF	2.23	3.18	43	0.34	0.39	14
2,3,4,7,8-PeCDF	4.73	5.16	9	0.31	0.33	8
Total PeCDFs	45.81	53.00	16	8.15	9.31	14
1,2,3,4,7,8-HxCDF	10.55	13.94	32	0.24	0.30	26
1,2,3,6,7,8-HxCDF	3.27	4.22	29	0.24	0.31	28*
1,2,3,7,8,9-HxCDF	0.23	0.29	24	< 0.05	< 0.05	–
2,3,4,6,7,8-HxCDF	4.47	5.57	25	0.18	0.27	49*
Total HxCDFs	34.14	53.83	58	2.64	3.49	32*
1,2,3,4,6,7,8-HpCDF	21.2	31.14	47	0.94	1.90	102**
1,2,3,4,7,8,9-HpCDF	2.44	3.54	45	0.09	0.18	103**
Total HpCDFs	35.47	55.20	56	1.41	3.06	117**
OCDF	21.54	32.23	50	0.81	2.11	160**
I-TEQ	9.06	11.85	31	0.58	0.82	41
Ratio PCDD/PCDF	6.60	4.22	−36	0.93	1.19	28

[a] Results are given as median values in nanogram per kilogram (dry matter).
* Significant difference at $p < 0.05$.
** Significant difference at $p < 0.001$.

I-TEQ/kg (dry matter) (median and mean values: 9.06 and 12.24 ng I-TEQ/kg) [14]. In the present study, PCDD/F levels ranged from 1.33 to 54.23 ng I-TEQ/kg (dry matter) (median and mean values: 11.85 and 14.41 ng I-TEQ/kg). The comparison of the data of both surveys indicates that PCDD/F concentrations increased in 16 of the 24 soil samples during the last 12 months. On the other hand, in the present study, PCDD/F

Table 2
Levels of PCDD/Fs in soil samples at increasing distances from the MSWI: temporal variation[a]

Distance (m)	250 ($n=6$)		%	500 ($n=5$)		%	750 ($n=4$)		%	1000 ($n=3$)		%	1500 ($n=3$)		%	3000 ($n=3$)		%
	1998	1999		1998	1999		1998	1999		1998	1999		1998	1999		1998	1999	
2,3,7,8-TeCDD	0.59	0.90	54	0.48	0.35	−27	0.59	0.36	−39	0.35	0.82	134	0.17	0.11	−35	0.13	0.11	−15
1,2,3,7,8-PeCDD	1.38	2.13	55	1.05	1.61	53	1.61	2.45	52	2.59	3.48	34	1.29	0.42	−67	0.77	1.12	45
1,2,3,4,7,8-HxCDD	2.54	3.04	20	1.24	1.89	52	2.85	3.00	5	4.04	3.33	−18	1.07	0.47	−56	1.45	1.43	−1
1,2,3,6,7,8-HxCDD	5.71	10.16	78	5.30	7.06	33	4.73	8.70	84	11.37	9.78	−14	2.68	1.97	−26	4.37	3.84	−12
1,2,3,7,8,9-HxCDD	4.23	8.54	102	5.58	4.38	−22	4.64	6.20	34	12.47	7.89	−37	3.22	0.82	−75	4.55	1.50	−67
1,2,3,4,6,7,8-HpCDD	60.76	98.84	63	56.75	58.09	2	43.73	97.15	122	93.66	111.8	19	34.49	62.54	81	65.56	35.94	−45
OCDD	438.2	505.7	15	343.9	308.0	−10	273.8	584.6	114	534.5	605.9	13	414.8	715.6	73	426.1	177.2	−58
2,3,7,8-TeCDF	8.67	16.52	91	13.56	10.21	−25	12.31	19.06	55	21.01	16.70	−21	21.63	3.82	−82	3.98	4.30	8
1,2,3,7,8-PeCDF	3.05	2.69	−12	2.73	4.13	51	2.52	5.44	116	7.85	4.73	−40	2.21	1.05	−52	1.00	1.00	0
2,3,4,7,8-PeCDF	6.29	9.27	47	4.63	5.03	9	7.40	8.13	10	9.89	8.12	−18	4.83	2.03	−58	2.09	3.29	57
1,2,3,4,7,8-HxCDF	12.42	18.96	53	14.34	14.95	4	13.94	21.23	52	24.84	18.32	−26	9.29	3.76	−60	11.81	8.68	−27
1,2,3,6,7,8-HxCDF	3.93	6.28	60	5.10	6.21	22	5.53	6.92	25	8.89	8.16	−8	3.27	1.27	−61	2.62	3.41	30
1,2,3,7,8,9-HxCDF	0.31	0.45	46	0.29	0.35	21	0.35	0.41	17	0.70	0.49	−30	0.16	0.10	−38	0.18	0.26	44
2,3,4,6,7,8-HxCDF	5.78	7.57	31	6.34	5.64	−11	7.96	9.40	18	8.78	11.97	36	4.36	1.65	−62	4.43	5.13	16
1,2,3,4,6,7,8-HpCDF	32.90	50.49	53	16.67	25.63	54	29.66	48.33	63	61.73	68.78	11	21.20	10.06	−53	20.90	22.31	7
1,2,3,4,7,8,9-HpCDF	2.91	5.53	90	2.22	2.59	17	2.88	5.28	83	7.74	6.71	−13	2.00	1.54	−23	1.91	2.33	22
OCDF	32.09	56.57	76	28.79	21.41	−26	20.99	43.37	107	61.10	60.19	−1	16.40	14.35	−13	14.71	17.91	22
I-TEQ	11.90	15.82	33	10.46	11.49	10	11.90	15.82	33	20.43	17.08	−16	8.94	4.32	−52	6.28	6.01	−4

[a]Results are given as median values in nanogram per kilogram (dry matter); n = number of samples.

Table 3
Levels of PCDD/Fs in vegetation samples at increasing distances from the MSWI: temporal variation[a]

Distance (m)	250 ($n=6$)		%	500 ($n=5$)		%	750 ($n=4$)		%	1000 ($n=3$)		%	1500 ($n=3$)		%	3000 ($n=3$)		%
	1998	1999		1998	1999		1998	1999		1998	1999		1998	1999		1998	1999	
2,3,7,8-TeCDD	0.06	0.09	46	0.12	0.11	−11	0.08	0.10	29	0.05	0.12	142	0.07	0.11	57	0.09	0.14	54
1,2,3,7,8-PeCDD	0.12	0.18	52	0.18	0.20	12	0.16	0.16	3	0.13	0.26	103	0.22	0.22	−2	0.25	0.29	16
1,2,3,4,7,8-HxCDD	0.07	0.19	178	0.1	0.15	47	0.12	0.08	−33	0.07	0.14	93	0.10	0.15	46	0.11	0.11	−3
1,2,3,6,7,8-HxCDD	0.16	0.45	183	0.25	0.43	73	0.24	0.29	21	0.13	0.26	98	0.16	0.26	60	0.30	0.26	−14
1,2,3,7,8,9-HxCDD	0.11	0.31	182	0.17	0.28	62	0.16	0.18	12	0.08	0.17	111	0.12	0.22	87	0.19	0.17	−11
1,2,3,4,6,7,8-HpCDD	1.54	6.73	337	1.63	3.72	128	1.22	2.87	135	0.71	2.79	293	1.46	4.30	195	1.91	2.56	34
OCDD	5.69	33.40	487	6.38	22.40	251	4.73	13.60	188	3.41	13.00	281	5.33	23.30	337	7.21	11.50	60
2,3,7,8-TeCDF	0.85	0.96	13	1.45	1.41	−3	0.88	1.13	29	1.14	1.28	12	1.16	1.46	26	2.11	1.53	−27
1,2,3,7,8-PeCDF	0.28	0.30	8	0.48	0.47	−2	0.34	0.35	2	0.33	0.36	9	0.34	0.40	17	0.68	0.49	−28
2,3,4,7,8-PeCDF	0.29	0.26	−10	0.41	0.42	3	0.34	0.26	−23	0.30	0.30	−1	0.32	0.34	7	0.67	0.40	−40
1,2,3,4,7,8-HxCDF	0.22	0.27	23	0.26	0.50	93	0.25	0.26	3	0.22	0.32	44	0.25	0.34	34	0.34	0.29	−15
1,2,3,6,7,8-HxCDF	0.23	0.31	34	0.26	0.44	69	0.22	0.27	22	0.17	0.28	64	0.26	0.23	−11	0.38	0.38	0
1,2,3,7,8,9-HxCDF	< 0.05	< 0.05	–	< 0.05	< 0.05	–	< 0.05	0.02	–	< 0.05	< 0.05	–	< 0.05	< 0.05	–	< 0.05	< 0.05	–
2,3,4,6,7,8-HxCDF	0.18	0.32	77	0.19	0.44	134	0.19	0.23	21	0.15	0.24	57	0.19	0.20	7	0.32	0.26	−20
1,2,3,4,6,7,8-HpCDF	0.92	2.22	141	1.04	2.68	158	0.97	1.64	69	0.65	1.85	185	0.92	1.63	77	1.40	1.60	14
1,2,3,4,7,8,9-HpCDF	0.08	0.18	129	0.11	0.19	74	0.08	0.16	98	0.07	0.14	100	0.07	0.10	39	0.09	0.24	167
OCDF	0.77	2.75	256	0.95	2.29	141	0.57	1.65	189	0.60	1.96	227	0.82	1.56	90	0.93	1.47	58
I-TEQ	0.53	0.73	37	0.77	0.91	18	0.60	0.63	5	0.46	0.86	87	0.56	0.82	46	1.02	0.86	−15

[a]Results are given as median values in nanogram per kilogram (dry matter); n = number of samples.

concentrations in herbage samples ranged from 0.32 to 2.52 ng I-TEQ/kg (dry matter) (median and mean values: 0.82 and 0.97 ng I-TEQ/kg), whereas in the 1998 survey, the levels of PCDD/Fs ranged from 0.33 to 1.98 ng I-TEQ/kg (dry matter) (median and mean values: 0.58 and 0.70 ng I-TEQ/kg) [14]. The comparison of the data indicates that PCDD/F levels in vegetation increased in 17 of the 24 samples.

In herbage samples, statistically significant differences between both surveys were found for the levels of a number of homologues and congeners, especially for the most substituted. In contrast, significant differences were not observed in soil samples. Moreover, neither in soils nor in vegetation, the median I-TEQ concentrations of both surveys were significantly different (Table 1). Pearson correlation was applied for the different homologues in soil and vegetation samples. Only PeCDF in soils was significantly correlated ($p < 0.01$) with the PCDD/F homologues in vegetation (with the exceptions of OCDD and OCDF), whereas I-TEQ values in soil and vegetation samples were not significantly correlated.

Bruzy and Hites [19] showed that soil acts as a conservative matrix for the collection of atmospheric deposition of PCDD/Fs, while Trapp and Mathies [20] investigating volatilization of PCDD/Fs from soils with a mathematical model concluded that for background conditions, air and soil are close to equilibrium and desorption from soil plays a minor role even when soil concentrations are above chemical equilibrium to air. However, when soils are highly polluted, volatilization can be important.

Tables 2 and 3 show the concentrations of PCDD/Fs in soil and vegetation samples, respectively, according to different distances from the plant. In turn, Figs. 1 and 2 show a summary of I-TEQ values at increasing distances from the plant for soil and herbage samples, respectively. While PCDD/F concentrations in vegetation did not show remarkable changes with the distance to the plant, the maximum PCDD/F levels in soil samples were observed at 250–1000 m of the MSWI. The highest PCDD/F level was found at 1000 m from the plant (54.23 ng I-TEQ/kg, 1999). The finding of higher PCDD/F levels near the stack can be attributed to fugitive emissions during storage, handling, and transport of ashes. Also, wet deposition might play an important role in increasing the concentrations of PCDD/Fs near the stack.

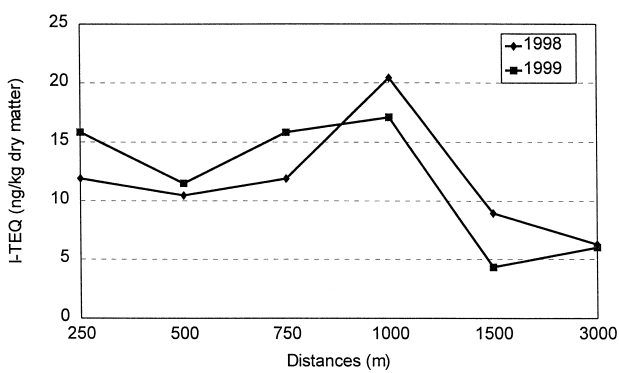

Fig. 1. PCDD/F levels in soil samples at increasing distances from the MSWI.

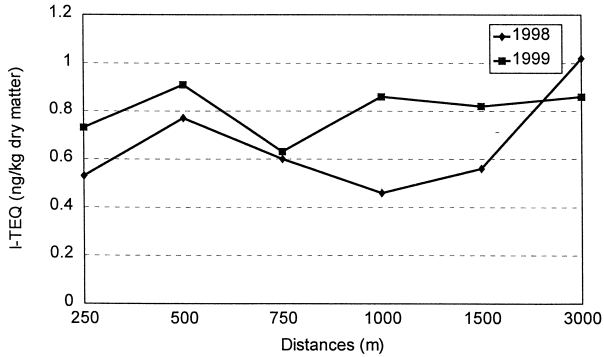

Fig. 2. PCDD/F levels in vegetation samples at increasing distances from the MSWI.

In a recent study carried out to determine the baseline PCDD/F levels in an area from Catalonia, in which a new hazardous waste incinerator (HWI) was being constructed, we determined the PCDD/Fs concentrations in soil and herbage samples in a rural and an urban area not directly affected by PCDD/F emissions from MSWIs [21,22]. Since in the current study the MSWI is located in an urban area, we compared the results obtained in the present study with those corresponding to the urban area of that recent survey [21,22].

Figs. 3 and 4 show the percentage contribution of the homologue profile to the total PCDD/Fs in soil and vegetation samples (1999 survey), respectively, corresponding to the current area of study and the area in which a new HWI was constructed [21,22]. As it can be seen, the percentages of contribution of the PCDD/F homologues in soil samples collected in both areas are quite similar. By contrast, the percentages of contribution of the PCDD/F homologues in vegetation show some important differences, especially in the higher contribution of the TeCDD and TeCDF for samples

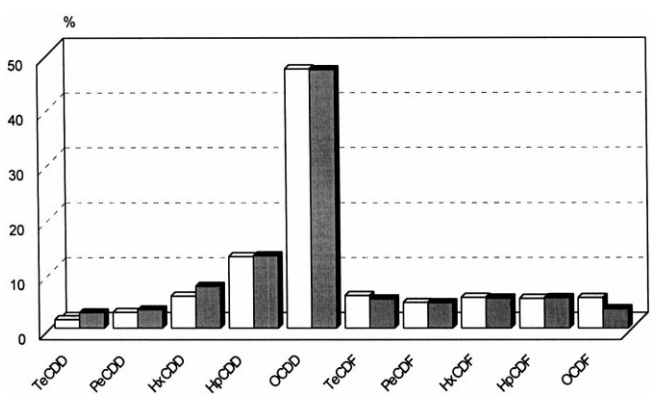

Fig. 3. Percentage contribution of the homogue profile to the total PCDD/Fs in soil samples. □ Data correspond to an area not directly affected by PCDD/F emissions from MSWls. ■ Data correspond to the area of the current study.

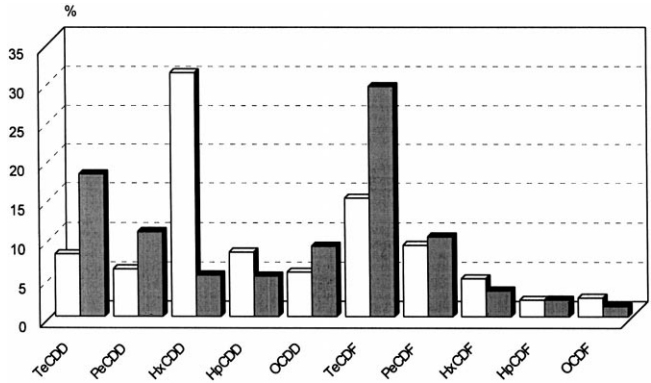

Fig. 4. Percentage contribution of the homologue profile to the total PCDD/Fs in vegetation samples. □ Data correspond to an area not directly affected by PCDD/F emissions from MSWIs. ■ Data correspond to the area of the current study.

collected in the proximity of the MSWI. The differences between soil and vegetation samples can be explained taking into account that soils reflect cumulative PCDD/F deposition during long periods of time, while vegetation is a better indicator for short periods of deposition [19]. Consequently, congener profiles of vegetation samples are more affected than those of soils by local emissions of PCDD/Fs such as some fires that occurred in the area of the MSWI in the last 12 months. Moreover, it should be taken into account that the emission of PCDD/Fs to air may be transported over long distances and could affect the environment far from the source itself [23]. In turn, homologue profiles in vegetation samples are determined by the deposition of different proportions of gas phase PCDD/Fs and particle-bound PCDD/Fs from air [24].

PCDD/Fs are introduced in the atmosphere by a number of combustion sources. As the air mass moves away from the sources, it is diluted with cleaner air. During transport, wet and dry deposition as well as chemical transformation and degradation processes may alter the PCDD/F composition. Lower chlorinated PCDD/Fs are to a larger extent found in vapor phase, and thus, they can undergo transformation reactions such as photolytic degradation in gas phase [25]. Photolytic reactions are a possible transformation process that may occur fairly rapidly [26]. Gas phase reactions with the hydroxyl radical are another possibility [27]. All these reactions of transformation would enhance the relative concentration of higher chlorinated congeners on the particles. The remaining fraction of PCDD/Fs would be deposited by dry or wet processes, efficiently removing the particulate fraction from the atmosphere. Each process favours a profile enriched in the higher chlorinated congeners. On the other hand, studies developed by Tysklind and co-workers [28] showed that photodechlorination of the highest substituted chlorinated congeners (OCDD and OCDF) in soil samples can occur after sunlight irradiation. This process supposes an increase of the lower chlorinated congeners in soil.

The large number of data obtained in this study makes exact interpretation of trends difficult. Multivariate projection methods, such as PCA, combine a large number of variables into a few underlying descriptive dimensions, which summarize the systematic

information and give an overview of the dominant patterns or major trends in the results. In order to evaluate possible similarities and/or differences in the congener profiles of PCDD/Fs in soil and vegetation samples during the 1998 and 1999 surveys, a multivariate analysis (PCA) of the data was applied. The scatterplots of the component scores for soil and herbage samples are presented in Figs. 5 and 6, respectively. Two principal components accounted for 78.4% (54.0% + 24.4%) and 86.7% (46.7% + 40.0%) of the variance for soil and vegetation, respectively. In soils, the first main component was strongly and positively correlated with the higher PCDD/Fs, while the second was correlated with the TeCDFs and PeCDFs. With the exceptions of sample 14 (collected at 1000 m from the plant during the 1999 survey), which showed a higher relative concentration of the highest PCDD/Fs congeners substituted, and sample 9 (collected at 500 m from the plant during the 1998 survey), which showed a higher relative concentration of TeCDFs and PeCDFs, no great variations in the congener profiles of both surveys could be observed. Samples 9 and 14 could be influenced by other local sources different from the MSWI here examined.

With regard to vegetation samples, the first component correlated positively with the lower-substituted congeners (TeCDD/F and PeCDD/F), and the second with the higher-substituted congeners (OCDD, OCDF, HpCDD and HpCDF). Samples 5 and 6 collected in 1999 at 250 m from the plant showed a relative high content of the higher-substituted congeners. However, although sample 5 collected during the 1998 survey did not show a high relative content in OCDD and OCDF, a relative high level of TeCDD/F was found. Sample 24 collected in 1998 and again in 1999 at 750 m from the plant showed a relative high content in TeCDD and TeCDF. This sample showed also a high relative content of TeCDD and TeCDF in soils.

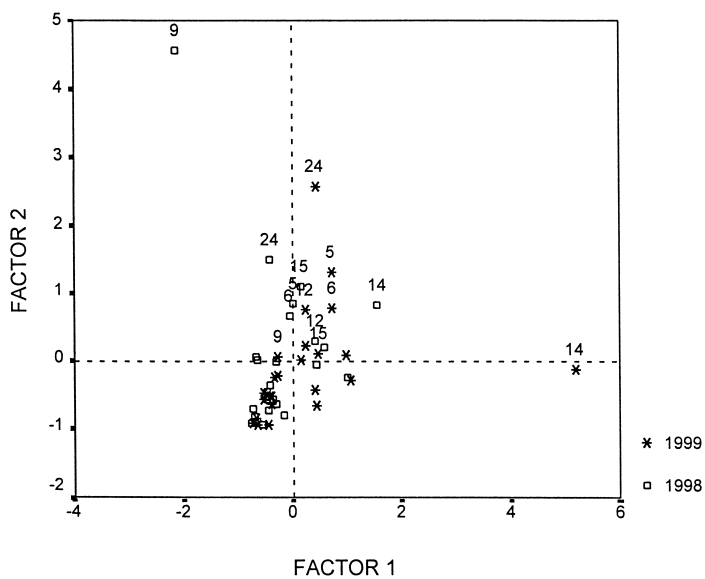

Fig. 5. Principal component plot of soil samples collected near the MSWI.

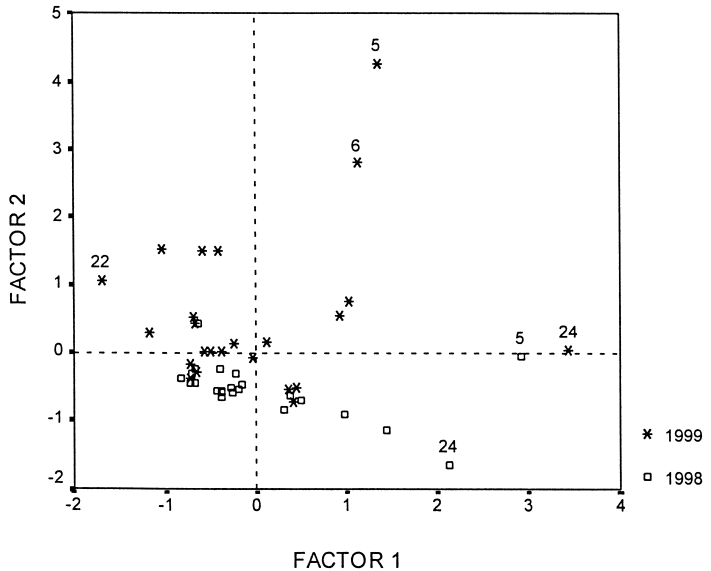

Fig. 6. Principle component plot of vegetation samples collected near the MSWI.

Although Figs. 5 and 6 clearly indicate that there is a main group of soil and vegetation samples that can be considered to be under the direct influence of the PCDD/F emissions from the MSWI, it is also evident that other local sources (traffic, industrial activities, etc.) have also a notable influence on some sampling points under study. Therefore, it seems evident that a reduction in PCDD/F emissions of the MSWI could decrease only in part the environmental levels of these organic pollutants in the area.

After collection of soil and vegetation samples in March 1999, a dry scrubber to limit acid gas and metal emissions, which can also complement with charcoal the control of PCDD/F emissions from the stack, was installed in the plant. Taking into account the current temporal variation in PCDD/F concentrations, the potential reduction in PCDD/F levels in soil and vegetation samples collected in the vicinity of the MSWI, which can be found in future surveys could not be as great as it could be, in principle, expected.

The present results show that although in general terms, PCDD/F levels in soil and herbage samples collected near the MSWI increased slightly during the last 12 months, the differences in the median I-TEQ values did not reach the level of statistical significance. On the other hand, although the present mean levels of PCDD/Fs in soils are of the same order of magnitude than those reported in previous studies [29,30], the risks to the human health posed by contaminated soil should not be underated. Considering I-TEQ values < 5 ng/kg (dry matter) as a concentration of reference for PCDD/F levels in soils [10], in the present study, PCDD/F concentrations exceeded this level in 20 of the 24 soil samples analyzed. Twelve of these levels were > 10 ng/kg, and six of them were > 20 ng/kg. Although soil is a conservative medium for

PCDD/Fs, it is expected that the implementation of the new equipment to reduce air emissions will improve air quality, and consequently, a decline in the levels of PCDD/Fs in air and vegetation is expected in the near future.

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