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Soil dioxins levels at agriculture sites and natural preserve areas of Taiwan

Jin-juh Jou [a,*], Kae-Long Lin [b], Jen-Chir Chung [a], Shu-Liang Liaw [c]

[a] *Environmental Analysis Laboratory, Environmental Protection Administration, Chung Li City, Taiwan 320, ROC*
[b] *Department of Environmental Engineering, National I-Lan University, I-Lan 260, Taiwan, ROC*
[c] *Department of Environmental Engineering, National Central University, Chung Li City, 320 Taiwan, ROC*

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Abstract

In this study, agriculture soil in Taiwan has been sampled and analyzed to determine the background level of polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/DF) in the agricultural and nature preserve areas. Another objective is to investigate relationship between soil characteristics and air deposition in Taiwan. The results indicate that in nature preserve areas the topsoil shows an extraordinary profile of PCDD/DF compared to that in the air deposition. The PCDD/DF levels of the low-contaminated agricultural soils are compatible with those of the nature preserves soils. However, in the highly-contaminated agricultural soils, there is an abrupt jump in their concentrations, 10–100 times higher. The overall I-TEQ values of the background topsoils range from 0.101 to 15.2 ng I-TEQ/kg. Near industrial/urban areas in Taiwan the PCDD/DF are slightly higher compared to those in the low concentration group. Typically, the PCDD/DF background values found in this survey fall in the 90% confidence interval and can thus, be deemed the background levels in Taiwan. Ninety-five percent of these data are below the European and American soil standard of 10 ng I-TEQ/kg d.w. The PCDD/DF profile with one neighborhood soil sample was shown no significant difference.

Keywords: Taiwan agriculture soil; PCDD/DF; Air deposition

1. Introduction

The territory of Taiwan covers an area of about 36,000 km^2, of which 73% is either mountainous or hilly. It is divided by the central mountain chain that stretches from north to south from Kee-Lung City to Heng-Chuen Town. On the east side of the island lies the Pacific Ocean while on the west side we find the Taiwan Strait [1]. Most parts of the island have a subtropical climate, with average temperatures between 21 and 24 °C. The annual average rainfall is about 2,510 mm. Eighty percent of precipitation is concentrated in the wet season from May to September. Crop patterns in Taiwan include 1st paddy, 2nd paddy, miscellaneous crops, sugarcane and others. The Irrigation Association of Taiwan is in charge of the irrigation of 865,723 ha area including 458,877 ha of paddy fields and 406,846 ha of dry farmland [2]. Water sources include reservoirs, rivers auxiliary pumping stations and groundwater. In contrast to the industrial and service sectors, the agricultural sectors in Taiwan have been shrinking drastically over the past few decades.

Due to the physicochemical properties of PCDD/DF, such as their high affinity to organic carbon, most PCDD/DF deposited in soils are localized in the top soil layer, from 0 to 15 cm [3,4]. In the current published database, there is very little survey data regarding the dioxin level in the environments [5–10]. Therefore, to remedy this deficiency, we have initiated a series of survey projects to investigate the dioxin levels in soil, compost material, percolates, deposited material, plants, air and water. Many of these projects are still in progress. They also cover the dioxin-like compounds Polychlorinated Biphenyls (DCL-PCBs) congener analyses. This paper is focusing on the investigation of agriculture soil to reach the following targets:

- to determine what are the current background level of PCDD/DF and DLC-PCBs in agricultural and nature preserve soils in Taiwan;

* Corresponding author. Tel. +886 3 4915818x2107; fax: +886 3 4912847.
E-mail address: jjjou@mail.niea.gov.tw (J.-j. Jou).

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- to study regional and geographical differences of PCDD/DF levels in the soil;
- to investigate the soil characteristics that affect adsorption from pollution sources.

2. Materials and methods

2.1. Sampling sites

Soil samples were collected from farmland in area irrigated by the Irrigation Association of Taiwan. Top soil samples were collected from 15 Irrigation Associations: I-Lan, Pei-Gi, Tao-Yuan, Shih-Men, Hsin-Chu, Miao-Li, Tai-Chung, Nan-Tou, Chang-Hua, Yun-Ling, Chia-Nan, Kao-Hsiung, Ping-Tung, Tai-Tung and Hua-Lien. Ninety-four agricultural soil samples were collected from newly ploughed crop fields, grassy fields and lawns in paddy farmland or other agricultural fields. Samples were also taken from the Kenting and Yangmingshan National Parks, the Fu-Shan Nature Preserve Area and the Alishan National Scenic Area for comparison.

2.2. Sample criteria and procedures

Samples were collected based on several criteria and procedures:

- samples chosen would reflect the typical agriculture soil and represent wetlands and national parks areas;
- the soil samples should not have direct contact with any polluted water or fly ash, sludge or chemical pollutants;
- soil samples were taken at the depth of 0–15 cm;
- five topsoil samples from different spots within 1 km^2 were combined into a 1 kg sample. All samples were preserved at 4 °C until they were analyzed.

2.3. Experimental methods

All samples were collected between January 2001 and August 2002. Sampling sites were spread out entire Taiwan, from north (Gin-San Village) to south (Ken-Ding National Park) and from west (Tai-Chung County) to east (Hua-Lien County). There were in total 96 agricultural soil samples collected from the irrigation area of the Irrigation Association of Taiwan. There were 11 reference samples collected from nature preserve areas and remote locations. A straw ash sample was also collected, in order to study the relationship to pollution sources. PCDD/DF concentrations were determined for all 108 samples. Among them 12 samples were analyzed for DLC-PCBs.

2.4. Analytical procedure

United States Environmental Protection Administration (USEPA) Method 1613B was adopted for the analysis of tetra-octa-chlorinated dioxins and furans using isotope dilution, high resolution gas chromatography and high resolution mass spectrometry (HRGC/HRMS). The USEPA Method 1668 draft version was used for the analysis of DLC-PCBs. After grasses, roots and gravels removed, the soil samples were freeze–dried. Dried soil sample was thoroughly ground to pass through a screen with #20 mesh and mixed thoroughly. A 20 g aliquot of the soil sample was then spiked with $^{13}C_{12}$-labelled internal standard solution prior to PCDD/DF and DLC-PCBs determi-

Table 1
Background dioxin (PCDD/DF) values in Taiwan

Taiwan area	Contract	Range	Irrigation association	Range	Average	No.
$\frac{0.101–15.2}{3.23}$ ($N=108$)	Agricultural soil	$\frac{0.254-15.2}{3.37}$ ($N=96$)	I-Lan	0.280–2.28	1.06	4
			Pei-Gi	1.82–3.22	2.52	2
			Tao-Yuan	2.81–11.6	5.76	12
			Shih-Men	3.35–11.5	8.05	3
			Hsin-Chu	1.31–2.92	2.28	3
			Nan-Tou	1.47–5.00	3.08	3
			Chang-Hua	1.00–15.2	3.88	9
			Tainan (ref. soil)	0.254–1.74	1.00	2
			Miao-Li	1.65–2.03	1.84	2
			Tai-Chung	1.47–12.0	5.88	12
			YunLin	0.494–4.38	2.15	12
			Chia-Nan	0.737–5.55	2.51	16
			Kaoh-Siung	1.01–7.04	2.95	5
			Ping-Tung	0.982–2.63	1.83	5
			Hua-Lien	0.520–0.828	0.670	3
			Taitung	0.643–0.834	0.740	3
	Nature Preserve	$\frac{0.101-8.48}{2.20}$ ($N=11$)	Fu Shan	1.21–8.48	3.25	4
	National Scenic Area		Alishan	0.975–2.27	1.62	2
	National Park		Yangmingshan	3.23		1
			Kenting	0.101–4.31	1.19	4
	Straw Ash		0.671			1

Unit in ng I-TEQ/kg.

nation. Samples were then extracted with toluene in Soxhlet extractors for 24 h. After spiked with the clean-up standard solution, the extracted solution. is purified by typical clean up procedures, including sulfuric acid wash, silica/H_2SO_4 column chromatograph, acidic alumina column chromatograph and active carbon (8% AX-21/Celite 545) column chromatograph. The elution solvents were benzene/dichloromethane (1:1) for the DLC-PCBs and toluene for the PCDD/DF. Final concentrated sample extracts were analyzed using HRGC/MRMS after spiked with a standard recovery solution (two $^{13}C_{12}$-labelled congeners in nonane). The mass spectometer used was the Micromass Utima with a resolution of 10,000 (10% valley), electron impact (EI) ionization mode and source temperature of: 280 °C. The gas chromatograph used was an Agilent 6890 with autosampler, equipped with a split/splitless injection port set at 300 °C and a 60 m long DB-5MS column (J&W Scientific). Helium was used as carrier gas at the flow rate of 1 mL/min. The temperature program for dioxin analysis was initial temperature 150 °C for 3 min, raise to 210 °C at 30 °C/min held for 15 min, raise to 230 °C at 1.5 °C/min held for 5 min then raise to final temperature 310 °C at 15 °C/min held for 12 min. The tempature program for DLPCB analysis was the initial temperature of 150 °C for 1.5 min, raise to 210 °C at 30 °C/min held for 15 min, raise to 230 °C at the rate of 1.5 °C/min held for 5 min and then raise to final temperature of 310 °C at 15 °C/min held 8 min.

3. Results and discussion

3.1. Agricultural soils

The average and the range of the background PCDD/DF values are listed in Table 1. The PCDD/DF concentrations are shown in the bar chart in Fig. 1. The overall modified concentration range is 0.101–15.2 ng I-TEQ/kg with average of 3.23 ($n = 108$). Among them, the average PCDD/DF concentration of agricultural soil is 3.37 ng I-TEQ/kg ($n = 96$), which is higher than that of soils from national parks on nature preserves, 2.20 ng I-TEQ/kg ($n = 11$).

We have used *t*-test to compare the average PCDD/DF concentration in agricultural soil (Sample 1) and the PCDD/DF concentration in national park (Sample 2). Assume the samples are not homogeneous. The equation we use is the following:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{S_1^2/n_1 + S_2^2/n_2}} \quad (1)$$

where $\bar{X}$ is average, S is standard deviation and n is the number of the value.

When,

$$\bar{X}_1 = 3.37, \quad \bar{X}_2 = 2.20, \quad n_1 = 96, \quad S_1 = 2.970,$$
$$n_2 = 11, \quad S_2 = 2.464$$

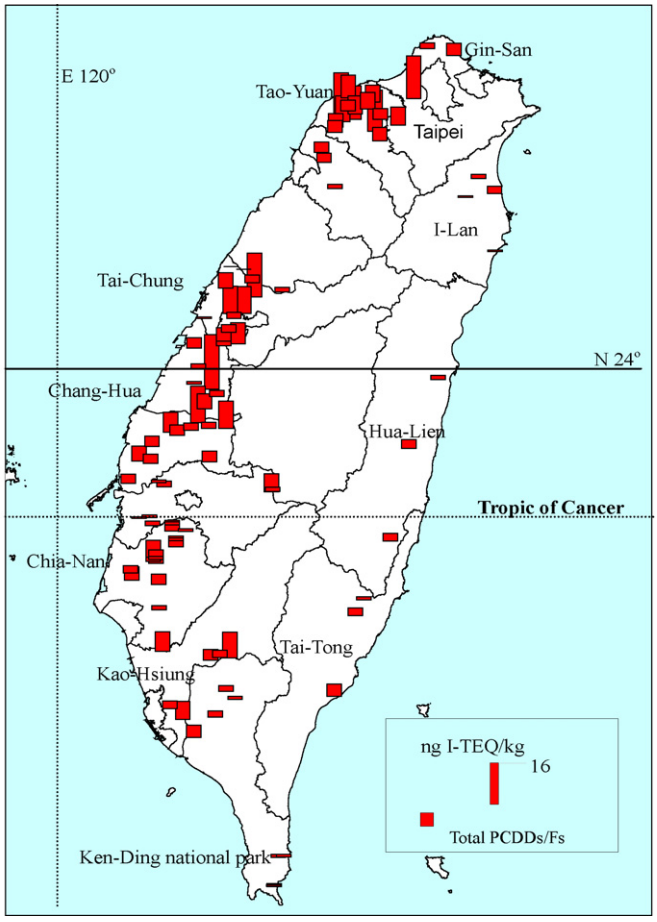

Fig. 1. Bar chart showing total dioxins concentration in Taiwan.

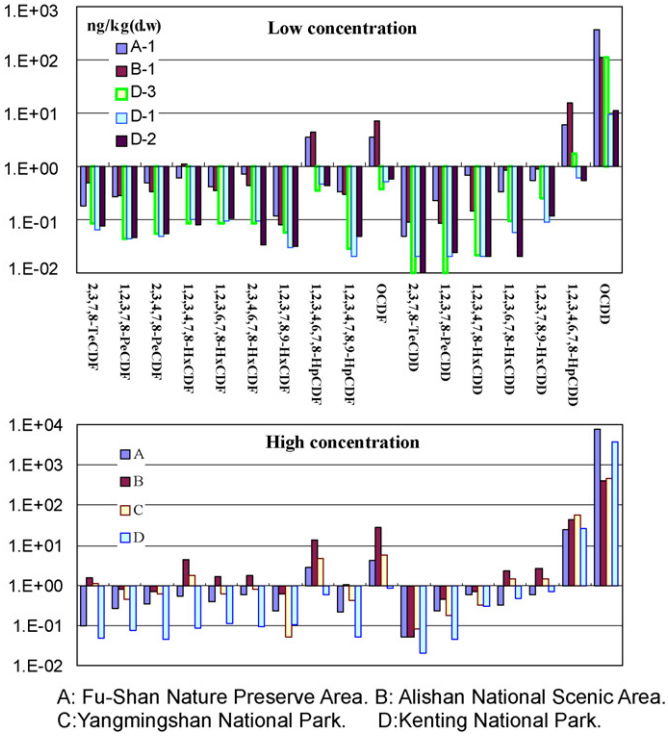

Fig. 2. The PCDD/DF profiles of national parks and natural preserve areas.

Table 2
Average dioxin (PCDD/DF) values of different soil group samples in this survey

Dioxin Series	Noncalcareous alluvial soils (23)	Eastern migmatite alluvial soils (2)	Schist alluvial soils (3)	Calcareous alluvial soils (28)	Colluvia l soils (2)	Red soils (15)	Low tableland alluvial soils (25)	Yellow soils (6)	Older alluvia l soils (2)	Alpine forest area (2)
2,3,7,8-TeCDF	2.80	0.110	0.270	1.09	0.310	2.85	1.49	1.08	0.850	0.800
1,2,3,7,8-PeCDF	1.05	0.110	0.180	0.630	0.630	1.07	0.840	0.320	0.570	0.370
2,3,4,7,8-PeCDF	1.19	0.160	0.260	0.760	0.430	1.02	0.480	0.420	0.680	0.480
1,2,3,4,7,8-HxCDF	1.70	0.140	0.250	0.8100	0.500	1.73	0.96	0.810	0.730	1.41
1,2,3,6,7,8-HxCDF	1.56	0.170	0.230	0.760	0.430	1.25	1.05	0.420	0.740	0.490
2,3,4,6,7,8-HxCDF	2.69	0.320	0.500	1.25	0.630	2.59	2.16	0.700	0.970	0.620
1,2,3,7,8,9-HxCDF	0.510	0.130	0.140	0.230	0.200	0.560	0.290	0.130	0.230	−0.13
1,2,3,4,6,7,8-HpCDF	19.1	0.780	1.58	7.56	1.18	19.4	11.8	2.74	3.66	4.67
1,2,3,4,7,8,9-HpCDF	1.32	0.140	0.280	0.330	0.330	1.15	0.630	0.250	0.260	0.350
OCDF	79.8	1.80	5.57	19.2	5.37	69.2	43.5	5.87	9.36	6.42
Total PCDFs	112	3.86	9.26	32.6	9.70	101	63.6	12.7	18.1	15.5
2,3,7,8-TeCDD	ND (<0.04)	0.150	0.120	0.22	0.030	0.060	0.100	$D < 0.04$	0.00	−0.170
1,2,3,7,8-PeCDD	1.79	0.260	0.330	1.05	0.250	1.63	1.80	0.330	0.720	0.130
1,2,3,4,7,8-HxCDD	0.800	0.110	0.120	0.270	1.47	0.710	0.460	0.360	0.260	0.230
1,2,3,6,7,8-HxCDD	3.92	0.320	0.380	1.01	0.620	2.79	2.39	0.530	0.910	1.15
1,2,3,7,8,9-HxCDD	2.75	0.370	0.320	0.690	0.960	3.45	2.12	0.730	0.660	1.17
1,2,3,4,6,7,8-HpCDD	61.6	2.17	3.06	7.92	15.9	40.6	23.2	13.0	3.95	36.4
OCDD	621	15.9	26.1	86.9	528	677	311	2033	41.4	286
Total PCDDs	692	19.3	30.4	98.1	547	726	341	2048	47.9	325
Total TEQ	4.80	0.580	0.740	2.05	1.65	4.44	3.31	3.09	1.61	1.62
$SD_{\text{Total TEQ}}$	4.24	0.080	0.090	1.37	0.19	3.14	2.24	3.11	0.39	0.91

( ): Number of samples, unit in ng/kg.

the degree of freedom (k),

$$k = \frac{(S_1^2/n_1 + S_2^2/n_2)^2}{\frac{(S_1^2/n_1)^2}{n_1-1} + \frac{(S_2^2/n_2)^2}{n_2-1}} \quad (2)$$

Calculate with the above equation, using the assigned value, the value of k, which is 13.57 (around 13). For the t distribution with 13 degrees of freedom, we find that $t_{13,0.1} = 1.3502$. The hypotheses are H_0: $\mu 1 = \mu 2$, H_1: $\mu 1$ is greater than $\mu 2$, with significance level (α) = 0.1. Since $t = 1.46$ greater than $t_{13,0.1} = 1.3502$, we reject the null hypothesis (H_0) in favor of the alternative hypothesis (H_1). Thus, this statistical test supports our conclusion that the average PCDD/DF concentration in agricultural soil (3.37 ng I-TEQ/kg, $n = 96$) is higher than the one in national park (2.20 ng I-TEQ/kg, $n = 11$).

As we can see in Fig. 1, the highest concentration (15.2 ng I-TEQ/kg) has been found in Chang-Hua County followed by Tao-Yuan and Tai-Chung. We have found samples taken in the nearby industrial zones/urban area with concentrations from 4 to 15.2 ng I-TEQ/kg, which is much higher than that of samples from the agricultural area. Concentrations of dioxins from the samples of Chia-Nan plain were in the middle range. The sample from Chia-Nan plain was collected at the farmland of first paddy, second paddy, miscellaneous crops, sugarcane and others, where the farmer often burn the straw as general farming practice. The lowest concentrations have found in the eastern Taiwan, I-Lan, Hua-Lien and Tai-Tung counties. The PCDD/DF concentrations in topsoil range from 0.280 to 2.28 ng I-TEQ/kg with average of 0.846 ($n = 10$). Of these, the octachloro dibenzo-*p*-dioxins (OCDD) concentrations exhibit the largest fluctuation, from 14.2 to 744 ng/kg with average of 99.9.

The PCDD/DF survey of the eastern Taiwan reveals that the values of most agricultural topsoils are below 1 ng I-TEQ/kg (Fig. 1). There are several possible reasons that may contribute to this fact:

- independent water supply is used in irrigation;
- much fewer high-pollution sources are in these areas;
- air pollution from industry zone in western Taiwan is blocked by the central mountain chain.

Table 3
The datas of dioxin (PCDD/DF) and DLPCB in Taoyuan Irrigation Association

Compound name	1	2	3	4	5	6	7	8	9	10	11	12
2,3,7,8-TeCDF	2.29	3.29	2.74	9.87	0.104	5.92	0.0	2.89	10.5	6.17	3.00	17.0
1,2,3,7,8-PeCDF	0.961	10.6	1.08	1.83	1.64	1.18	1.06	0.651	1.98	1.11	0.677	3.38
2,3,4,7,8-PeCDF	0.662	0.766	0.742	1.54	1.68	1.22	1.09	0.603	2.16	1.37	0.704	3.35
1,2,3,4,7,8-HxCDF	3.36	1.14	1.86	3.36	2.30	2.21	2.33	1.17	4.56	3.35	1.31	6.92
1,2,3,6,7,8-HxCDF	0.603	1.13	3.19	1.82	1.25	1.26	1.36	1.06	4.04	2.78	1.08	6.34
2,3,4,6,7,8-HxCDF	2.65	2.56	4.55	4.04	10.6	2.67	1.69	1.60	3.64	2.12	2.53	9.04
1,2,3,7,8,9-HxCDF	0.496	0.733	1.29	0.855	0.655	0.386	0.523	0.420	0.348	0.229	0.439	0.646
1,2,3,4,6,7,8-HpCDF	2.31	7.77	89.7	19.3	5.76	6.87	12.2	4.51	6.72	7.62	3.46	22.0
1,2,3,4,7,8,9-HpCDF	0.262	0.755	4.53	1.24	0.544	0.640	1.31	0.395	0.744	0.806	0.303	1.99
OCDF	3.99	21.1	414	60.0	10.7	12.4	48.1	9.66	6.06	16.4	6.09	35.9
2,3,7,8-TeCDD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1,2,3,7,8-PeCDD	2.13	2.27	1.67	2.36	10.0	2.22	0.655	1.34	2.21	0.935	2.46	3.16
1,2,3,4,7,8-HxCDD	0.312	0.752	1.26	0.759	0.883	0.768	0.511	0.457	0.505	0.505	0.290	0.965
1,2,3,6,7,8-HxCDD	2.44	4.70	4.43	3.65	11.0	3.66	2.01	2.25	2.70	1.31	3.37	6.86
1,2,3,7,8,9-HxCDD	2.02	5.65	6.58	4.42	8.86	4.72	2.84	3.60	2.08	2.03	4.11	4.32
1,2,3,4,6,7,8-HpCDD	6.77	72.4	83.5	49.4	31.4	36.8	37.0	25.3	10.2	15.3	19.7	121
OCDD	79.4	826	1048	784	441	376	514	283	98.0	416	245	1197
PCDD/DF (ng W-TEQ/kg)	3.82	5.60	6.60	6.88	14.9	5.53	2.94	3.35	6.42	3.80	4.72	11.8
3,3′,4,4′-TCB (PCB 77)	24.4	7.03	13.9	6.13	8.98	12.3	15.3	7.93	12.9	25.6	5.34	80.7
126)	5.84	1.63	2.50	1.02	2.32	3.00	4.31	1.18	4.17	3.32	1.58	9.35
3,3′,4,4′,5,5′-HCB (169)	1.04	0.354	0.451	0.334	0.528	0.815	0.638	0.427	1.13	0.725	0.486	1.45
3,4,4′,5-TCB (81)	3.09	1.05	1.56	0.772	1.14	1.95	2.38	1.10	2.31	2.53	1.00	7.76
2′,3,4,4′,5-PeCB (105)	39.0	12.9	26.3	7.42	15.0	22.0	37.5	15.8	20.4	31.1	8.75	145
2,3′,4,4′,5-PeCB (114)	2.48	0.638	1.29	0.511	1.25	1.13	1.78	1.36	1.76	2.16	0.603	6.00
2,3,4,4′,5-PeCB (118)	94.6	26.8	52.9	17.3	34.8	51.9	102	37.2	44.1	67.8	17.6	312
2,3,3′,4,4′-PeCB (123)	4.10	3.16	4.18	1.95	1.55	4.79	4.70	3.85	3.96	5.43	1.06	10.01
2,3,3′,4,4′,5′-HxCB (156)	19.7	6.69	9.62	4.48	9.68	12.5	19.3	8.84	11.9	13.9	5.08	57.5
2,3′,4,4′,5,5′-HxCB (157)	4.74	1.59	2.48	0.851	2.18	2.78	5.31	1.90	3.13	3.18	1.53	12.8
2,3,3′,4,4′,5-HxCB (167)	29.5	16.0	20.8	8.90	12.4	38.6	35.0	49.1	32.7	37.3	7.82	80.2
(189)	3.71	1.25	1.66	0.920	1.66	17.2	2.78	1.67	2.90	3.12	1.07	7.43
DLPCB (ngW-TEQ/kg)	0.626	0.177	0.2	0.112	0.250	0.328	0.467	0.135	0.446	0.363	0.170	1.04
$\sum$PCDD/DF + DLPCB (ngW-TEQ/kg)	4.44	5.78	6.88	6.99	15.2	5.86	3.41	3.49	6.87	4.17	4.89	12.8
% of DL-PCBs	14.1	3.06	3.95	1.60	1.65	5.59	13.7	3.88	6.49	8.72	3.48	8.14

Table 4
The dioxin (PCDD/DF) data of soil and straw ash at the same site of Taoyuan Irrigation Association

Compound name	Soil	Straw ash
2,3,7,8-TeCDF	2.38	3.83
1,2,3,7,8-PeCDF	1.59	0.520
2,3,4,7,8-PeCDF	1.97	0.384
1,2,3,4,7,8-HxCDF	1.97	0.262
1,2,3,7,8-HxCDF	1.66	0.100
1,2,3,7,8-HxCDF	7.15	0.306
1,2,3,7,8,9-HxCDF	0.53	0.200
1,2,3,4,7,8,9-HpCDF	18.8	0.200
1,2,3,4,7,8,9-HpCDF	1.88	0.350
OCDF	50.0	1.21
2,3,78-TeCDD	0.12	0.200
1,2,3,7,8-PeCDD	4.97	0.100
1,2,3,4,7,8-HxCDD	1.36	0.175
1,2,3,6,7,8-HxCDD	6.82	0.150
1,2,3,7,8,9-HxCDD	7.34	0.175
1,2,3,4,6,7,8-HcCDD	87.1	0.777
OCDD	1740	3.77

Unit in ng/kg.

3.2. Soils in the nature preserves

Nature Preserves areas in this study are Kenting, Yangmingshan National Park, Fu Shan Nature Preserve and Alishan National Scenic Area. The PCDD/DF values are from 0.101 to 8.48 ng I-TEQ/kg with an average of 2.20 ($n = 11$). The OCDD concentrations are from 9.59 to 7580 ng/kg with an average of 1427. Fig. 2 shows the comparison between the PCDD/DF profiles for the sites in the high and low concentrations groups. We have found that the OCDD concentration profiles in the high concentration group have a distinguished pattern compared to those in the low concentration group. These samples were either near incinerators or in wild-fire areas, as might contribute to the higher OCDD levels.

With taking away the four highest concentration samples, the PCDD/DF level range would be 0.101–1.21 ng I-TEQ/kg (on average: 0.527, $n = 5$), while the OCDD level will range from 9.59–372 ng/kg with average of 99.9. (Table 2)

The concentrations of the 12 composite samples from Taoyuan Irrigation Association are 0.112–1.04 ng WHO-TEQ/kg with an average of 0.366 for DL-PCB and 2.827–11.32 ng I-TEQ/kg with an average of 5.598 for PCDD/DF. The toxicity contribution from DL-PCB is only a small portion, ranging from 1.60 to 14.1% and averaging 7.26% (Table 3).

The average background PCDD/DF levels of the soils of various groups are listed in Table 2. The average background PCDD/DF values for the group consisting of Noncalcareous Alluvial Soils, Red Soils and Yellow Soils have higher concentrations of total I-TEQs and OCDDs than those of the Eastern Migmatite, Alluvial Soils, Schist Alluvial Soils, Calcareous Alluvial Soils, Colluvial Soils, Low Tableland Alluvial Soils, Older Alluvial Soils and Alpine Forest Area group. The dioxin data of soil and straw ash at the same site of Taoyuan Irrigation Association are listed in Table 4. The comparison of the PCDD/DF profile is shown in Fig. 3. No significant difference is observed. This is due to the limit number in each data set, which can demonstrate significant statistical difference.

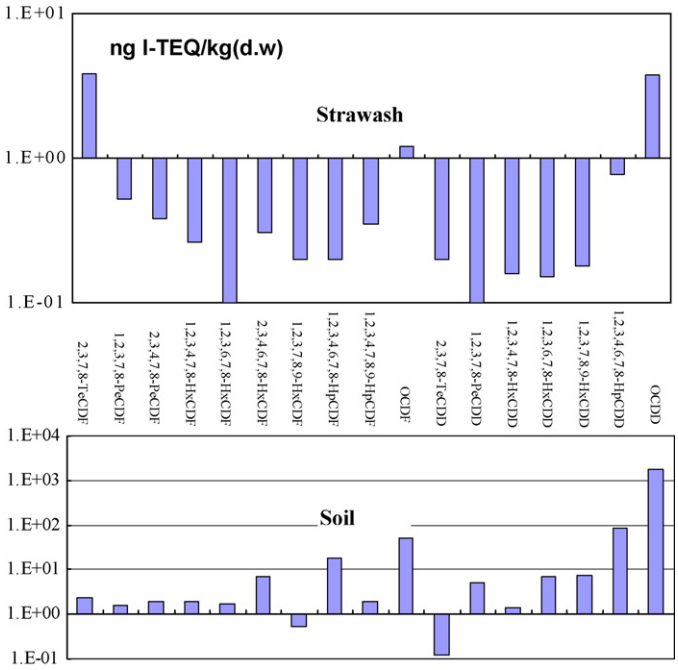

Fig. 3. Dioxins profiles in straw ash and soil samples.

4. Conclusions

1. The PCDD/DF profiles of the preserve area topsoil samples are extraordinary compared to those of the air deposition. The PCDD/DF levels of the low-concentration agricultural soils are compatible with those of the nature preserve soils. However, in the high concentration agricultural soils there is an abrupt jump in their concentrations, 10–100 times higher.
2. The overall I-TEQ of the background topsoils ranges from 0.101–15.2 ng I-TEQ/kg.
3. PCDD/DF levels of samples obtained near industrial/urban areas in Taiwan are slightly higher than those in the low concentration group, but there is not a significant difference.
4. Typically background PCDD/DF values in this survey fall in the 90% confidence interval, so this can be deemed the background level for Taiwan. 95% of the data are below the European and American soil standard of 10 ng I-TEQ /kg d.w.
5. The PCDD/DF profile with one neighborhood soil sample was shown no significant difference is observed.

References

[1] http://www.tjia.gov.tw, 2004.
[2] http://www.coa.gov.tw, 2003.
[3] G. Fries, D. Paustenbach, W. Luksemburg, M. Lorber, J. Ferrario, The formation of hepta- and octa-dioxins in feces of cows fed pentachlorophenol treated wood, Organohalogen Compd. 46 (2000) 1–3.
[4] E.J. Hoekstra, E. Weerd, W.B. Leer, U.A.T. Brinkman, Natural formation of chlorinated phenols, dibenzo-*p*-dioxins and dibenzzofuranss in soil of a douglas fir forest, Organohalogen Compd. 46 (2000) 5–8.

[5] P.B. Louis, A.H. Ronald, Estimating the atmospheric deposition of polychlorinated dibenzo-*p*-dioxins and dibenzofurans from soils, Environ. Sci. Technol. 29 (1995) 2090–2098.
[6] E.J. Kim, J.E. Oh, Y.S. Chang, Effects of forest fire on the level and distribution of PCDD/Fs and PAHs in soil, Sci. Total Environ. 311 (2003) 177–189.
[7] L.B. Sonnenberg, K.M. Nichols, Emissions of hydrochloric acid, PCDD and PCDF from the combustion of chlorine-containing kraft pulp mill bleach plant waste, Chemosphere 31 (10) (1995) 4207–4223.
[8] D. Cleverly, M. Mometti, L. Phillips, P. Cramer, M. Heit, S. McCarthy, K. O'Rourke, J. Stanley, D. Winters, A time-trend study of the occurrences and levels of PCDDs, PCDFs and dioxin-like PCBs in sediment cores from 11 geographically distributed lakes in the United States, Organohalogen Compd. 28 (1996) 77–82.
[9] L. Kjeller, K.C. Jones, A.E. Johnston, C. Rappe, Increases in the polychlorinated dibenzo-*p*-dioxin and furan content of soils and vegetation since the 1840's, Environ. Sci. Technol. 25 (1991) 1619–1627.
[10] D. Winters, S. Anderson, M. Lorber, C. Byrne, Trends in dioxin and PCB concentrations in meat samples from several decades of the 20th century, Organohalogen Compd. 38 (1998) 75–78.