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Approaches adopted to assess environmental impacts of PCDD/F emissions from a municipal solid waste incinerator

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Abstract

Different approaches were carried out in this work to assess environmental impacts of a municipal solid waste incinerator. A total of seven sites in the vicinity of the facility were chosen to collect air, banyan leaf and soil samples for analyses of PCDD/Fs by high-resolution gas chromatography/high-resolution mass spectrometry. Based on the PCDD/F concentrations of the three matrices determined at sites upwind, downwind and area of maximum ground concentration, it was found that the environmental impact of the MSWI was not obvious. PCDD/F concentration isopleths of the three environmental compartments coupled with wind rose of the region proved that the influence of the MSWI on the environment was also rather limited. It clarified emission sources by confirming that the PCDD/F concentrations originated mostly from the existing stationary emission sources in the vicinity. Through principal component and cluster analyses on congener profiles, the influence of metallurgical facilities and medical waste incinerators on the ambient air was assessed. Moreover, the modeling of ISCST3 demonstrated also that the contribution of the MSWI to ambient atmospheric PCDD/Fs was minimal. The approaches studied have led to identical conclusions, and thus are useful to cross-evaluate the environmental impact of an MSWI.

Keywords: PCDD/PCDF; Atmosphere; Vegetation; Soil; Municipal solid waste incinerator; Concentration isopleth; Principal component analysis; Cluster analysis; ISCST3

1. Introduction

Since polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were discovered in the flue gases and fly ash of municipal solid waste incinerators (MSWIs) in 1977 [1], PCDD/F emissions from various sources have raised serious concerns globally because of their toxicological effects and associated adverse health implications. PCDD/Fs released to the surroundings are mainly from anthropogenic activities, including waste incineration, power/energy generation, high temperature sources, metallurgical processes and many other chemical–industrial sources. These pollutants are transported and diffused through the atmosphere, resulting in subsequent aerial deposition onto soil and vegetation [2].

Among various PCDD/F emission sources, MSWIs remain as a significant source of PCDD/Fs to the environment. In the United Kingdom, MSWIs contributed about 30–50% of the total PCDD/F I-TEQ emissions (460–580 g I-TEQ) in 1999 despite source reduction measures [3]. Quass et al. [4] revealed that on the European scale the largest annual PCDD/F emission is released from MSWIs. It was also reported that MSWIs are the leading PCDD/F source in the highly industrialized Lombardy Region of northern Italy, emitting about 32% of the total PCDD/Fs [5].

Incineration has been widely employed in Taiwan for treating municipal solid wastes because of its high population density and rapidly increasing per-capita waste generation. Compared with other countries, MSWIs in Taiwan are larger in size and newer in control technologies, with only six of the existing MSWIs hav-

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ing started operations before 1999. The PCDD/F emission limit of large scale MSWIs is regulated as 0.1 ng I-TEQ N m^{-3} by the EPA of Taiwan. Although this emission limit is among the most stringent in the world and the levels of PCDD/Fs in the stack flue gases of MSWIs have been quite low, the emission of these environmental pollutants have become one of the most controversial issues associated with MSW incineration in Taiwan.

Because of the public concern over potential adverse health effects of PCDD/Fs from stack emissions, this work reports approaches adopted to assess environmental impacts of MSWIs and to clarify emission sources in the neighborhood. In this regard, field sampling and concentration isopleth analyses were conducted on a municipal solid waste incinerator located in northern Taiwan (referred to as 'the MSWI', hereafter) by taking air, soil and vegetative samples from seven sites in the vicinity of the facility based on the modeling of ISCST3. Finally, the significance of the stationary emission sources near the MSWI to the PCDD/F concentrations of the ambient air was evaluated through the use of statistical analyses.

2. Experimental

2.1. Industrial source complex short-term modeling (ISCST3)

The ISCST3 is the current regulatory model employed by US EPA for many New Source Review (NSR) and other air permitting applications applicable for estimating ambient impacts from point, area and volume sources out to a distance of about 50 km. In this study, the ISCST3 model was used to evaluate contributions of the MSWI to the ambient atmospheric PCDD/F concentrations. We first defined the areas of 3 km × 3 km around the MSWI as our potential MSWI impact areas, which were divided into 90 sectors. We modeled mean PCDD/F concentrations of the stack flue gases in vapor and particle phases separately in each sector within the impact areas, which was 100 m × 100 m. Information on the stack parameters such as height, diameter, temperature, flow rate, and elevation was required to run the model. In addition, the dispersion parameters adopted in ISCST3, such as atmospheric stability and mixing height were chosen based on the hourly meteorological data of the area. The basic information of the MSWI is listed in Table 1. The sampling sites of maximum ground concentration were determined by the ISCST3 model. The sampling sites upwind and downwind the MSWI were established by the year-round prevailing wind directions. Those sampling areas took the MSWI as the center of a circle within a radius of 3 to 5 km.

Table 1
Basic details of the MSWI

Capacity (t/day)	1350
Capacity of furnace, three sets (t/h/set)	18.75
Stack emission flow rate (N m^3/min)	1600
Stack emission velocity (m/s)	160
Stack emission temperature (°C)	150
Height of stack (m)	120
Stack diameter (m)	2

2.2. PCDD/F sampling

The stack flue gas from the MSWI and all ambient air samples were collected simultaneously in August 2004 on three consecutive days. The soil and vegetative samples were taken on the second day of this period.

Each ambient air sample was collected using a PS-1 sampler (Graseby Andersen, GA, USA) according to the revised EPA Reference Method T09A, and collected continuously for three consecutive days (sampling volume ∼972 m^3). The sampling flow rate was specified at ∼0.225 m^3 min^{-1}. The PS-1 sampler was equipped with a quartz-fiber filter for sampling particle-phase PCDD/Fs, followed by a glass cartridge for sampling gas-phase PCDD/Fs. A known amount of surrogate standard was spiked to the glass cartridge in the laboratory prior to the field sampling. Details are similar to those given in the previous work of Wang et al. [6].

For taking ambient soil samples, nine points were chosen within an area of approximately 36 m^2 at each sampling site and at each point about 500 g of surface soil (at depths from 0 to 5 cm) was collected. All these soils were mixed to be considered as one representative sample, following the standard soil sampling procedure in Taiwan (NIEA S102.60B). After it was naturally weathered indoors to dryness, 10 g of soil was used for analytical purposes.

Because banyan is widely grown in the neighborhood of the MSWI and in Taiwan generally, the levels of PCDD/Fs in its leaves can serve as an indicator of the atmospheric emissions of PCDD/Fs. The banyan leaves were collected at the same locations as the soil samples. The leaf sample was collected from 3 to 5 banyans and about 500 g of leaves was sampled from each tree by cutting at a height of approximately 1–2 m from the ground. All these leaves were mixed and immediately packed in aluminum foils to be considered as one representative sample. Subsequently, the sample was naturally weathered to dryness in room conditions. The sample was pretreated by grinding with a cutting mill to fine powders, out of which 20 g was taken for further analytical work.

2.3. Analyses of PCDD/Fs

Analyses of the ambient air samples followed the US EPA Reference Method T09A, while the Taiwan Method NIEA M801.10B for PCDD/Fs was followed for analyses of the soil and banyan leaf samples. All the chemical analyses were conducted in the Super Micro Mass Research and Technology Center of Cheng Shiu University, which is accredited for PCDD/F analyses in Taiwan. Standard procedures were strictly followed for the analyses. A high-resolution gas chromatograph coupled with a high-resolution mass spectrometer (HRGC/HRMS) was used for PCDD/F measurements. The HRGC (Hewlett Packard 6970 Series gas, CA, USA) was equipped with a DB-5MS fused silica capillary column (60 m, 0.25 mm i.d., 0.25 μm film thickness) (J&W Scientific, CA, USA), and with a splitless injection. Helium was used as the carrier gas. The HRMS (Micromass Autospec Ultima, Manchester, UK) was equipped with a positive electron impact (EI+) source.

Table 2
Ambient atmospheric PCDD/F concentrations of the MSWI

Ambient atmospheres	Area of maximum ground concentration					Upwind site	Downwind site
PCDD/PCDFs	E	C	D	F	G	A	B
PCDDs	0.746	1.17	3.23	0.853	0.752	0.760	0.684
PCDFs	1.14	1.98	5.25	1.19	0.936	0.990	0.798
PCDDs/PCDFs ratio	0.657	0.591	0.616	0.717	0.803	0.768	0.858
Total PCDD/Fs	1.88	3.15	8.48	2.04	1.69	1.75	1.48
Total I-TEQ (pg I-TEQ/N m^3)	0.118	0.229	0.630	0.121	0.0882	0.0865	0.0747
Mean PCDD/Fs (pg/N m^3)	3.37 (RSD = 83.8%, $n = 5$)					1.75	1.48
Mean I-TEQ (pg I-TEQ/N m^3)	0.237 (RSD = 95.4%, $n = 5$)					0.0865	0.0747

The analyzer mode of the selected ion monitoring (SIM) was used with a resolving power of 10,000. The electron energy and source temperature were specified at 35 eV and 250 °C, respectively. The method detection limits of PCDD/Fs for ambient air, soil and banyan leaf samples were found to be between 0.202 and 1.09 pg, 0.014 and 0.242 ng/kg, and 0.174 and 1.169 pg, respectively. The recoveries of PCDD/Fs ranged from 50% to 115%.

2.4. Principal component analysis (PCA)

PCA allows a multi-dimensional data set to be projected onto two or three dimensions in such a way that much of the information of the original data is retained. The data is divided into cases (in this study; PCDD/F emission sources and atmosphere receptors) and variables (in this study; the fractions of seventeen 2,3,7,8-congeners). The variables are used to characterize the cases. The cases are classified according to the position of their corresponding coordinates with respect to the factor axis. For the score plot, the cases with similar patterns will be located close to each other, while those which have divergent patterns will be located further apart. Details of PCA are given in Jambu [7].

3. Results and discussion

3.1. Upwind and downwind PCDD/F concentrations

The ambient atmospheric PCDD/F concentrations of the MSWI are displayed in Table 2. The mean atmospheric PCDD/F concentration of the upwind (A) and downwind (B) sites at the time of sampling, as well as area of maximum ground concentration (C–G) were determined as 1.75, 1.48 and 3.37 (relative standard deviation, RSD: 83.8%) pg N m^{-3}, respectively, while the corresponding I-TEQ concentrations were 0.0865, 0.0747 and 0.237 (RSD: 95.4%) pg I-TEQ N m^{-3}, respectively. The closeness of the atmospheric PCDD/Fs and I-TEQ concentrations at the upwind and downwind sites indicates that the influence of this MSWI on the ambient atmospheric PCDD/F concentrations is not obvious.

It is worth assessing the effect of the MSWI by also studying the PCDD/F concentrations in the banyan leaves collected near the facility. As a result, Table 3 shows that the mean PCDD/F contents in banyan leaves sampled at the sites of year-round prevailing upwind (E) and downwind (A) locations, as well as in the area of maximum ground concentration (B–D, F, G) were measured as 34.6, 16.8 and 46.0 ng kg^{-1} (RSD: 48.6%), respectively. The corresponding I-TEQ contents in banyan leaves were 3.23, 1.29 and 4.92 ng I-TEQ kg^{-1} (RSD: 64.0%), respectively. The results indicate that the mean PCDD/F content in banyan leaves at the year-round prevailing upwind site was higher than that of the downwind one. Thus, it suggests that the impact of this MSWI on the ambient vegetative PCDD/F contents is rather limited. The mean I-TEQ content of 3.81 ng I-TEQ kg^{-1} in the banyan leaves studied in this work was comparable to that of pine needles in the industrial city of Changwon (4.50 ng I-TEQ kg^{-1}) or black pine needles of urban areas (5.5 ng I-TEQ kg^{-1}) in Korea [8], reflecting the similarity of the social activities.

To further evaluate the environmental impact of the MSWI and to verify the atmospheric and vegetative findings, the

Table 3
PCDD/F concentrations in the ambient banyan leaves of the MSWI

Ambient banyan leaves	Area of maximum ground concentration					Upwind site	Downwind site
PCDD/PCDFs	B	C	D	F	G	E	A
PCDDs	18.8	27.6	22.5	7.35	14.0	12.1	7.46
PCDFs	26.1	42.5	42.9	8.96	19.4	22.4	9.32
PCDDs/PCDFs ratio	0.719	0.650	0.525	0.820	0.720	0.539	0.800
Total PCDD/Fs	44.9	70.2	65.4	16.3	33.3	34.4	16.8
Total I-TEQ (ng I-TEQ/kg)	3.82	7.25	9.06	1.37	3.10	3.23	1.29
Mean PCDD/Fs (ng/kg)	46.0 (RSD = 48.6%, $n = 5$)					34.4	16.8
Mean I-TEQ (ng I-TEQ/kg)	4.92 (RSD = 64.0%, $n = 5$)					3.23	1.29

Table 4
PCDD/F concentrations in the ambient soils of the MSWI

Ambient soils	Area of maximum ground concentration					Upwind site	Downwind site
PCDD/PCDFs	B	C	D	F	G	E	A
PCDDs	192	591	132	281	64.8	51.6	52.2
PCDFs	2.78	119	15.4	10.9	13.6	66.4	21.2
PCDDs/PCDFs ratio	69.162	4.97	8.61	25.749	4.75	0.778	2.46
Total PCDD/Fs	195	711	148	292	78.5	118	73.4
Total I-TEQ (ng I-TEQ/kg)	0.592	11.8	1.64	1.35	1.58	8.72	2.52
Mean PCDD/Fs (ng/kg)	285 (RSD = 87.9%, $n = 5$)					118	73.4
Mean I-TEQ (ng I-TEQ/kg)	3.40 (RSD = 139%, $n = 5$)					8.72	2.52

PCDD/F concentrations were determined in soils taken in the vicinity of the plant. Thus, the mean PCDD/F contents in the soils sampled at the year-round prevailing upwind (E) and downwind (A) locations surrounding the MSWI, as well as in the area of maximum ground concentration (B–D, F, G) are shown in Table 4 as 118, 73.4 and 285 ng kg^{-1} (RSD: 87.9%), respectively, whereas the corresponding I-TEQ contents in the soil were 8.72, 2.52 and 3.40 ng I-TEQ kg^{-1} (RSD: 139%), respectively. × the soil at the year-round prevailing upwind site was higher than that of the downwind one, implying limited influence of the MSWI on the PCDD/F contents in the ambient soil. The mean I-TEQ content of 4.00 ng I-TEQ kg^{-1} in the soil samples under investigation in this work was relatively low, compared with those found from soil samples near other operating MSWIs and PCDD/F sources [9,10].

From the congener profiles of seventeen 2,3,7,8-PCDD/Fs, we found that the 1,2,3,4,6,7,8-HpCDD, OCDD, 1,2,3,4,6,7,8-HpCDF, and OCDF were predominant in the ambient atmospheric, vegetative, and soil samples. These findings for the soil samples were rather consistent with those reported above for the ambient atmospheric and vegetative PCDD/F analyses, and were in accordance with the dominant PCDD/F contaminants found from the soil samples taken in the proximity of an MSWI reported by Schuhmacher et al. [11].

3.2. Ambient PCDD/F concentration isopleths

PCDD/F concentration isopleth analyses were conducted to verify its validity to assess the impact of PCDD/F emissions from the MSWI on its environment. The atmospheric PCDD/F concentration isopleths of the seven sampling sites are depicted in Fig. 1, utilizing the Arcview GIS software (Environmental Systems Research Institute). It shows the relationship between the atmospheric PCDD/F concentration isopleths and wind rose at the time of sampling. The points in the figure represent the EPA-regulated stationary emission sources around the MSWI. It is clearly observable from the figure that the prevailing winds at the time of sampling were from the north and west, and the high PCDD/F concentration isopleths were located to the southwest of the MSWI. It reveals that the areas having high PCDD/F concentration isopleths do not match with the wind rose and the upwind and downwind geographic locations of sampling. Rather, the denseness of the PCDD/F concentration isopleths correlated with the locations of stationary emission sources in the neighborhood. In fact, the ambient atmospheric PCDD/F concentrations of sites C and D, south of the stationary emission sources of brick kilns and foundries, were 0.630 and 0.229 pg I-TEQ N m^{-3}, respectively, the former of which even exceeds the PCDD/F emission limit of 0.6 pg I-TEQ N m^{-3} of Japan.

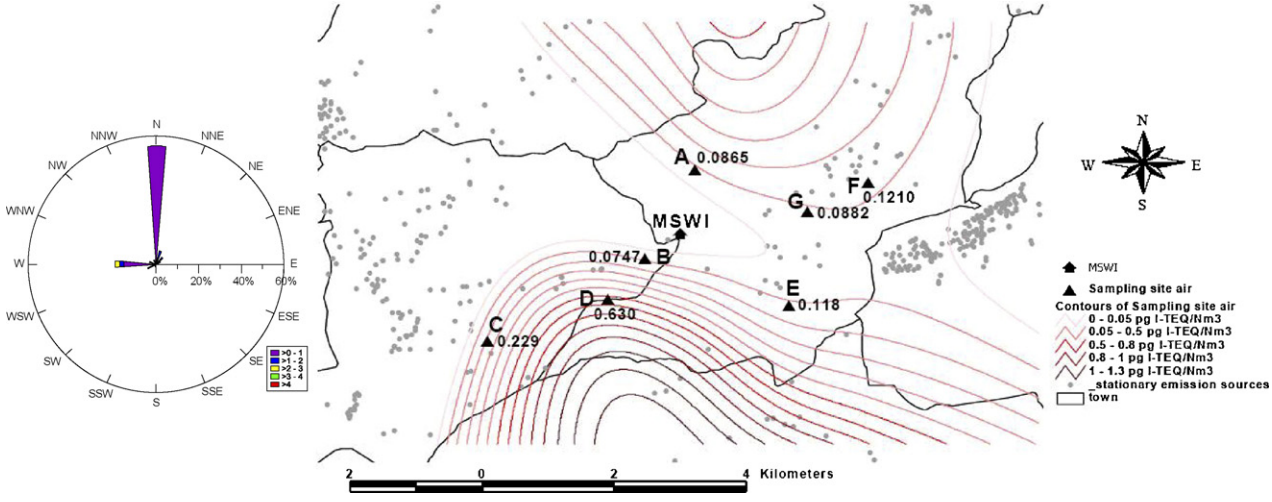


Fig. 1. The atmospheric PCDD/F concentration isopleths in the ambient air of the MSWI and the regional wind rose at the time of sampling.

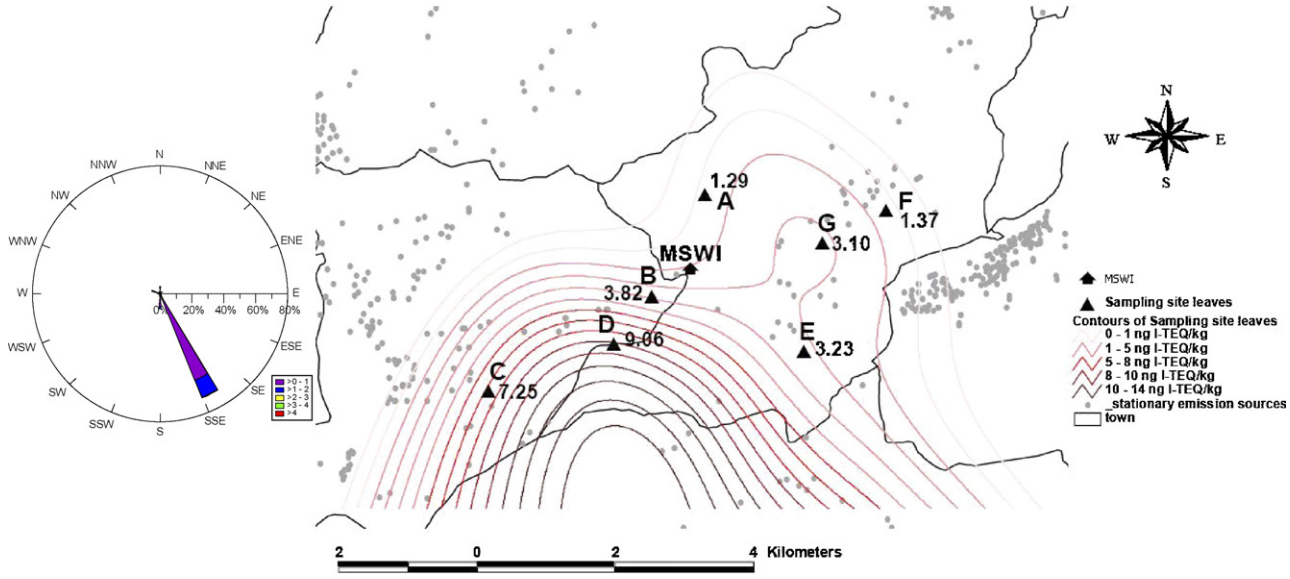


Fig. 2. The isopleths of PCDD/F contents in the ambient banyan leaves of the MSWI and the 2004 wind rose of the region.

Furthermore, to verify the pollution sources of the ambient atmosphere, we also checked on the congener profiles of the stack flue gases of the MSWI and the sites C and D. The major congeners in the stack flue gases were 1,2,3,4,6,7,8-HpCDD and OCDD, and the major ones at sites C and D were 1,2,3,4,6,7,8-HpCDD, OCDD, 1,2,3,4,6,7,8-HpCDF, and OCDF. When compared with the congener profiles of the stack flue gases of MWI, sinter plants, EAF, secondary ALS, UGFV, and DFV reported in Lee et al. [12], sites C and D were rather consistent with those of secondary ALS. Consequently, we can conclude that the PCDD/F emissions from the MSWI do not have significant impact on the ambient atmosphere.

The isopleths of PCDD/F contents in the ambient banyan leaves and the 2004 wind rose of the region are displayed in Fig. 2. The meteorological data indicate that the year-round prevailing wind direction in 2004 was from the south-east. It can be observed from the isopleths that the banyan PCDD/F contents at the year-round prevailing upwind site (E) are higher than those at the downwind one (A), implying insignificant influence of the MSWI on the ambient vegetation. The year-round prevailing wind, due to its low speed, can closely reflect the effects of stationary emission sources on the surroundings. As clearly observed from this figure, the denseness of the banyan PCDD/F concentration isopleths correlated well with the geographic locations of surrounding stationary emission sources and corresponded well with the ambient atmospheric PCDD/F concentration isopleths of Fig. 1. Based on information on the EPA-regulated stationary emission sources in the sampling region shown in Table 5, the brick kilns and foundries contributed 90% to the annual total PCDD/F emissions in the sampling area. Thus, the ambient vegetative PCDD/F contents at sites C and D, which are located in the vicinity of brick kilns and foundries, were 7.25 and 9.06 ng I-TEQ kg^{-1}, respectively, far exceeding other sites (A–B, and E–G). Consequently, the PCDD/Fs in the banyan leaves around the MSWI originated primarily from the surrounding stationary emission sources.

The isopleths of PCDD/F contents in the soils taken from the seven sampling sites and the regional wind rose in 2004 are shown in Fig. 3. The figure reveals that the denseness of the PCDD/F concentration isopleths of soil samples correlated well with the geographic locations of neighboring stationary emission sources, and was in good agreement with the ambient atmospheric and vegetative PCDD/F concentration isopleths discussed earlier. As a result, the PCDD/F content in the soil of site C, which was located north-west of the stationary emission sources of brick kilns and foundries, was the highest among the sampling sites at 11.8 ng I-TEQ kg^{-1}. Thus, it can be concluded that the PCDD/F contents in the soils around the MSWI came mostly from the existing stationary emission sources in the vicinity.

Table 5
The annual PCDD/F emission concentrations of the EPA-regulated stationary emission sources in the sampling area

Emission sources	Emission factor	Total emission concentrations (g I-TEQ/year)	Percentage (%)
Brick kilns (oil-fired)	0.2 μg I-TEQ/m^3 of oil	0.00707	5.02
Brick kilns (coal-fired)	0.6 μg I-TEQ/t of coal	0.0652	46.3
Asphalt and concrete industries	0.014 μg I-TEQ/t of asphalt	0.00566	4.01
Foundries	32.4 μg I-TEQ/t of feed stock	0.0486	34.5
Metallurgical industries	41.3 μg I-TEQ/t of feed stock	0.00625	4.43
MSWI	0.251 μg I-TEQ/t of waste	0.00813	5.77

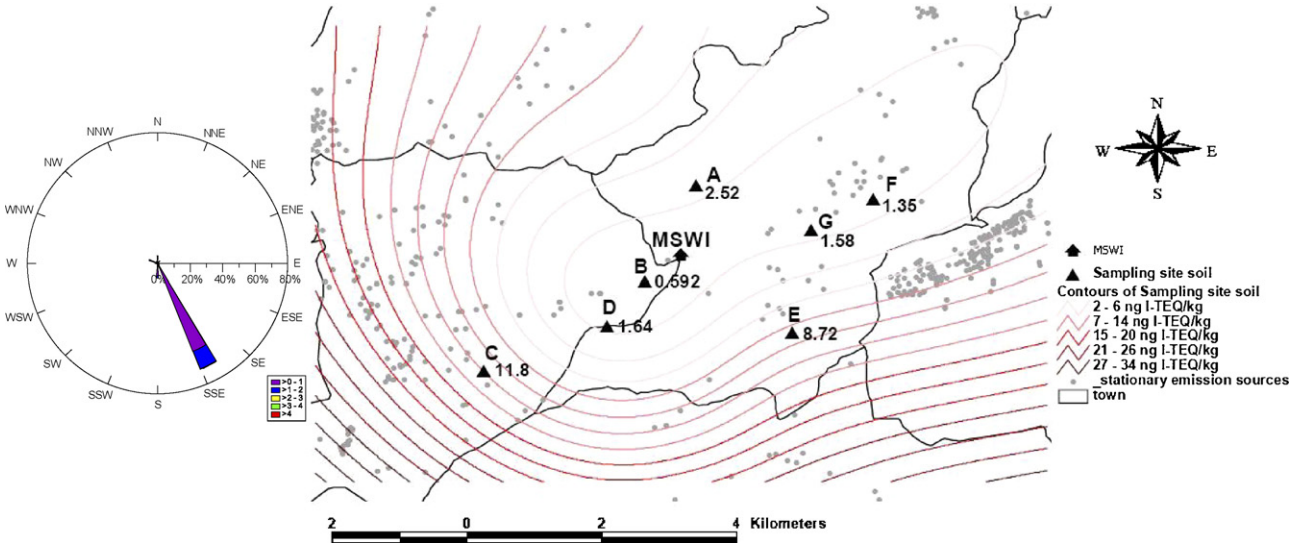
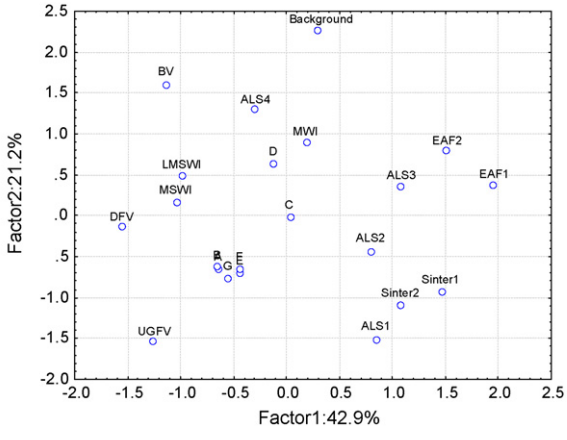


Fig. 3. The isopleths of PCDD/F contents in the ambient soils of the MSWI and the 2004 regional wind rose.

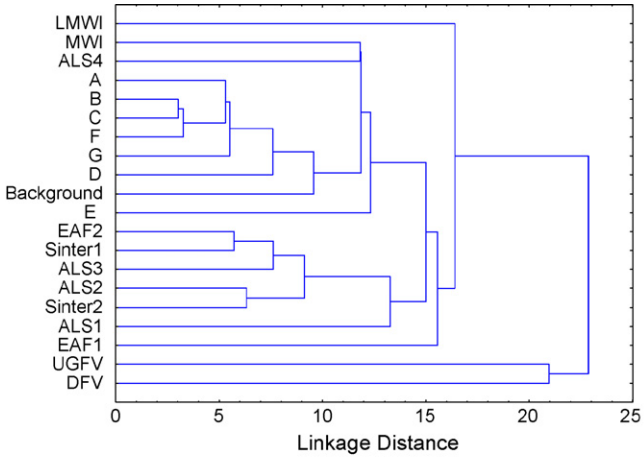
3.3. Principal component analysis (PCA) and cluster analysis

Principal component analysis has often been used as a means of source identification [13–16]. To clarify pollution sources in the ambient air around the MSWI and to relate with other assessment methods for the emissions from the MSWI, PCDD/F congener profiles from the stack flue gases of the MSWI and the seven ambient air samples together with those of the emission sources (LMSWI, MWI, sinter, EAF, secondary ALS, UGFV, DFV) reported in Lee et al. [12] were analyzed by PCA using the mass fractions of 2,3,7,8-congeners (congener profile) as the variables. Fig. 4 presents the score plot from PCA, in which factor 1 explains 42.9% of the total variance, while factor 2 explains 21.2% of the total variance. Thus, together both account for 64.1% of the total variance. The score plot indicates that the data points of sites A, B and E-G which exhibited similar PCDD/F congener profiles were closely clustered, while sites C and D displayed divergent patterns from the other five sites. The congener profiles of site C were close to those displayed by metallurgical processes, revealing that the ambient air of site C was influenced by the PCDD/F emission from the neighboring metallurgical facilities. On the other hand, the PCDD/F congener profiles of site D were close to those of secondary aluminum smelters and medical waste incinerators. The above results revealed that the ambient air of sites C and D were influenced significantly by the stationary emission sources of brick kilns and foundries to the north, thereby resulting in atmospheric PCDD/F concentrations as high as 0.630 pg I-TEQ N m^{-3}.



Note： Data for emission sources of LMSWI: municipal solid waste incinerator, MWI: medical waste incinerator, sinter: sinter plant, EAF: electric arc furnace, ALS: secondary aluminum smelter, UGFV: unleaded gas-fueled vehicles, DFV: diesel fueled vehicles, Background: sampling site in the Kenting National Park, taken from Lee et al. [16]

Fig. 4. Principal component plot of the MSWI, 7 ambient atmospheric samples and those of the emission sources reported in Lee et al. [12].



Note： Data for emission sources of LMSWI: municipal solid waste incinerator, MWI: medical waste incinerator, sinter: sinter plant, EAF: electric arc furnace, ALS: secondary aluminum smelter, UGFV: unleaded gas-fueled vehicles, DFV: diesel fueled vehicles, Background: sampling site in the Kenting National Park, taken from Lee et al. [16]

Fig. 5. Cluster analysis of the MSWI, 7 ambient atmospheric samples and those of the emission sources reported in Lee et al. [12].

Table 6
Contributions of the MSWI to ambient atmospheric PCDD/Fs

Ambient sampling sites	Mean PCDD/F concentration measured (pg I-TEQ/N m^3)	ISCST3-modeled maximum hourly PCDD/F concentration (pg I-TEQ/N m^3)	Contribution by MSWI (%) (modeled concentration/measured concentration × 100%)
A	0.0865	0.00200	2.31
B	0.0747	0.00260	3.48
C	0.229	0.00130	0.569
D	0.630	0.00230	0.365
E	0.118	0.00210	1.78
F	0.121	0.00190	1.57
G	0.0882	0.00190	2.15

Fig. 5 shows that the result of cluster analysis is similar to that of PCA. The data points of sites A, B and E–G cluster first with those of secondary aluminum smelters and medical waste incinerators, and then with metallurgical processes. Thus, the influence of metallurgical processes, including sinter plants, electric arc furnaces, and secondary aluminum smelters on the ambient air are certain, but the influence of MSWI is not obvious.

3.4. ISCST3 modeling

Based on the mean PCDD/F concentration of the stack flue gases of the MSWI, the ambient atmospheric maximum hourly PCDD/F concentrations at the sampling sites were obtained by the ISCST3 model. Table 6 shows the measured PCDD/F concentrations and the ISCST3-modeled PCDD/F concentrations. The results show that the contributions of the MSWI to the ambient atmospheric PCDD/F concentrations were quite low, ranging from 0.365 to 3.48% and averaging at 1.74%. This is comparable to the 5.77% contribution made by this MSWI based on its annual PCDD/F emission data (Table 5) and those of the surrounding stationary emission sources estimated by the emission factor of each source. Therefore, the results of ISCTS3 modeling also verify that the ambient atmospheric PCDD/F concentrations were not strongly influenced by the MSWI.

4. Conclusions

This study set out to assess the environmental impact of a municipal solid waste incinerator on the surrounding environment. From the total PCDD/F levels of atmospheric, soil and vegetative samples taken at seven sites in the vicinity of the MSWI, it has been found that the impact is not obvious. Comparing the relationships between the atmospheric, vegetative and soil PCDD/F concentration isopleths and wind roses, it revealed that the denseness of the PCDD/F concentration isopleths correlated well with the geographic locations of neighboring stationary emission sources. On the other hand, the PCA and cluster analysis on the congener profiles of the stack flue gases of the MSWI and ambient atmospheric samples proved definite influence of metallurgical facilities and medical waste incinerators on the ambient air. Furthermore, results obtained from ISCST3 modeling also demonstrated that the contribution of the MSWI to ambient atmospheric PCDD/F concentrations was limited. Consequently, we speculate that the MSWI is not the main contributor of PCDD/Fs to the surrounding environment, and other stationary emission sources of PCDD/Fs could be of greater significance.

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