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A seasonality study of polychlorinated dibenzo-*p*-dioxins and dibenzofurans in ambient air in Kaohsiung (Taiwan) clustered with metallurgical industries

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ABSTRACT

As a comprehensive monitoring survey on polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) in Kaohsiung, 40 ambient air samples taken from 10 locations in four seasons were studied. PCDD/F concentrations at 0.312–4.58 pg N m^{-3} and I-TEQ values, ranging from 0.0319 to 0.256 pg N m^{-3} were determined for these samples, which were comparable to those of other urban cities. However, unlike studies on some other urban cities, the ambient air in Kaohsiung did not exhibit regular seasonality in PCDD/F concentrations. All samples were predominated, in common, by congeners OCDD, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,6,7,8-HpCDD, OCDF and 2,3,4,7,8-PeCDF. The congener profiles of the samples generally did not display any seasonal trend, either. The insignificant seasonality and constancy of congener profiles with time were attributed to the constant influence by emission sources in a metal-producing center, thereby resulting in high atmospheric dioxin levels in the nearby district. Principal component analyses identified that dioxin emissions in ambient air of the city originated from electric arc furnaces (EAFs) and sinter plants in the center. Concentration isopleth analyses assessing pollution sources and ambient air of the district also confirmed that its atmosphere was affected largely by the EAFs and sinter plants.

1. Introduction

Since polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/Fs) were discovered in the stack 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 atmosphere are mainly from anthropogenic activities, particularly from combustion or other thermal industrial processes involving organic matters and chlorine. After emission, these pollutants are transported and diffused through the atmosphere, resulting in subsequent widespread deposition into terrestrial and aquatic ecosystems.

Because of public concerns over toxicological effects of PCDD/Fs, increasingly stringent emission regulations have been enacted in most industrialized countries. Parallel to this, great efforts have been undertaken to assess relationships between emission sources with the presence, concentration levels and trend of these pollutants in the atmosphere. In this respect, monitoring has played important roles around the world in gaining more knowledge about these toxicants in order to better formulate public decisions [2–4].

Although PCDD/F emission limit in Taiwan is among the most stringent in the world, the emission of these environmental pollutants has become one of the most concerned issues associated with thermal industrial facilities in Kaohsiung, a highly industrial city in southern Taiwan. The city, which covers an area of 153.6 km^2 and is inhabited by approximately 1.5 million residents, has 20 major industrial sources of dioxins. Most of these dioxin sources (17 out of 20) are located in the Lin Hai Industrial Park in the Hsiao Kang district of the city. Since the park was established in the 1980s, it has been planned and operated as the center of metallurgical industries in Taiwan. In view of so many dioxin sources existing in the city, a comprehensive monitoring survey was undertaken by local environmental agency to better understand seasonal variability of the ambient air concentrations of PCDD/Fs and influences of these pollution sources, especially the metallurgical facilities in the park, on the ambient air of Kaohsiung. This work is the first extensive

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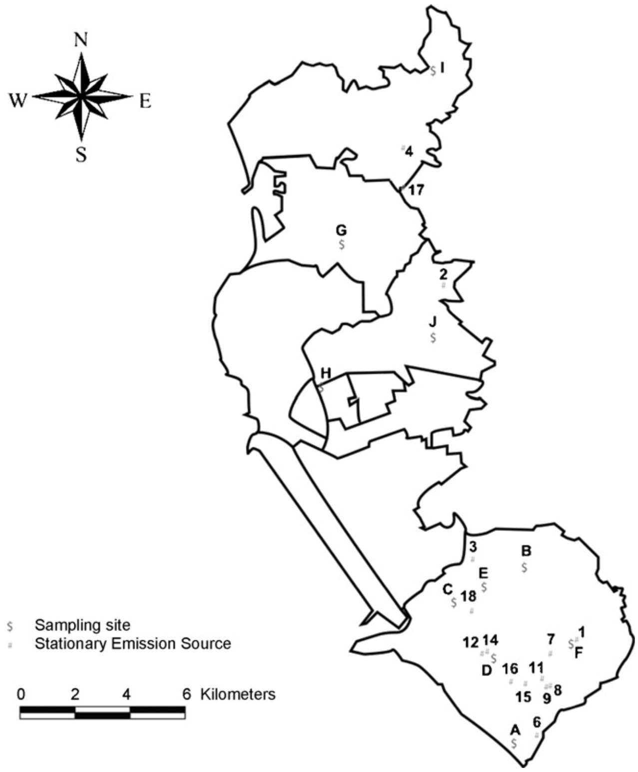


Fig. 1. Geographical locations of 10 sampling points and 20 emission sources in the city of Kaohsiung.

systematic study of its kind in which data of the concentration levels and the congeners of PCDD/Fs in ambient air of Kaohsiung are reported and elaborated.

2. Experimental

2.1. PCDD/F sampling

The industrial source complex short-term model (ISCST3) was first employed to determine 10 locations for taking ambient air samples of Kaohsiung. The dispersion parameters adopted in ISCST3 were chosen from the basic information of 20 dioxin stationary emission sources of the city, while the atmospheric stability and mixing height were based on the hourly meteorological data of the area. Table 1 gives some of the basic information of the 20 emission sources. All these facilities except sources 1, 2 and 17 were operated intermittently. As a result, six sampling points (A–F) were determined to locate in the district of Hsiao Kang, and four (G–J) were in other districts. The geographical locations of the selected 10 sampling sites and the 20 emission sources are shown in Fig. 1. Ambient air samples were collected in four seasons, i.e., in the months of April (Season 1), July (Season 2), October (Season 3) and December (Season 4) of 2005.

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 $\sim$972 m^3). The sampling flow rate was specified at $\sim$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. [5].

2.2. Analyses of PCDD/Fs

Analyses of the ambient air samples followed the US EPA Reference Method T09A. 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. 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 samples were found to be between 0.202 and 1.09 pg. The recoveries of PCDD/Fs ranged from 50% to 115%.

2.3. 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 [6].

3. Results and discussion

3.1. Ambient atmospheric PCDD/F concentrations

Table 2 shows the ambient atmospheric PCDD/F concentrations (0.312–4.58 $pg\,N\,m^{-3}$) and corresponding I-TEQ values (0.0319–0.256 $pg\,N\,m^{-3}$) of all samples collected at the 10 chosen sites in the four seasons studied. For all these samples, the dioxin concentrations measured were comparable to those reported for other urban cities [7–10]. It is evident from this table that the ratio of PCDDs/PCDFs (TEQ) of each location did not exhibit a trend of temporal variations over the sampling periods. This stands in agreement with that of Hippelein et al. [7], but in contrast to the results of Konig et al. [11], who reported four times decrease of the ratio in the summer months. It is of interest as well to investigate whether PCDD/F concentrations would exhibit any significant seasonality in Kaohsiung. In this regard, the ratio of the I-TEQ value of December to that of July was first determined from the data of Table 2 for each sampling site to be in the range of 0.289–3.96. It implies that no obvious trend of seasonal difference between summer and winter PCDD/F concentrations would exist. The temporal variability of PCDD/F levels in the atmosphere is examined further by looking into the I-TEQ concentrations obtained from the ambient air samples taken in Hsiao Kang over the periods of study and the overall mean I-TEQ values for entire Kaohsiung. The data of Table 2 clearly show that for some locations in Hsiao Kang PCDD/F concentrations in April, July or October were higher than that of December. The overall mean I-TEQ values for entire Kaohsiung in the four periods of study were determined, respectively, as 0.0765 (R.S.D., 48.7%),

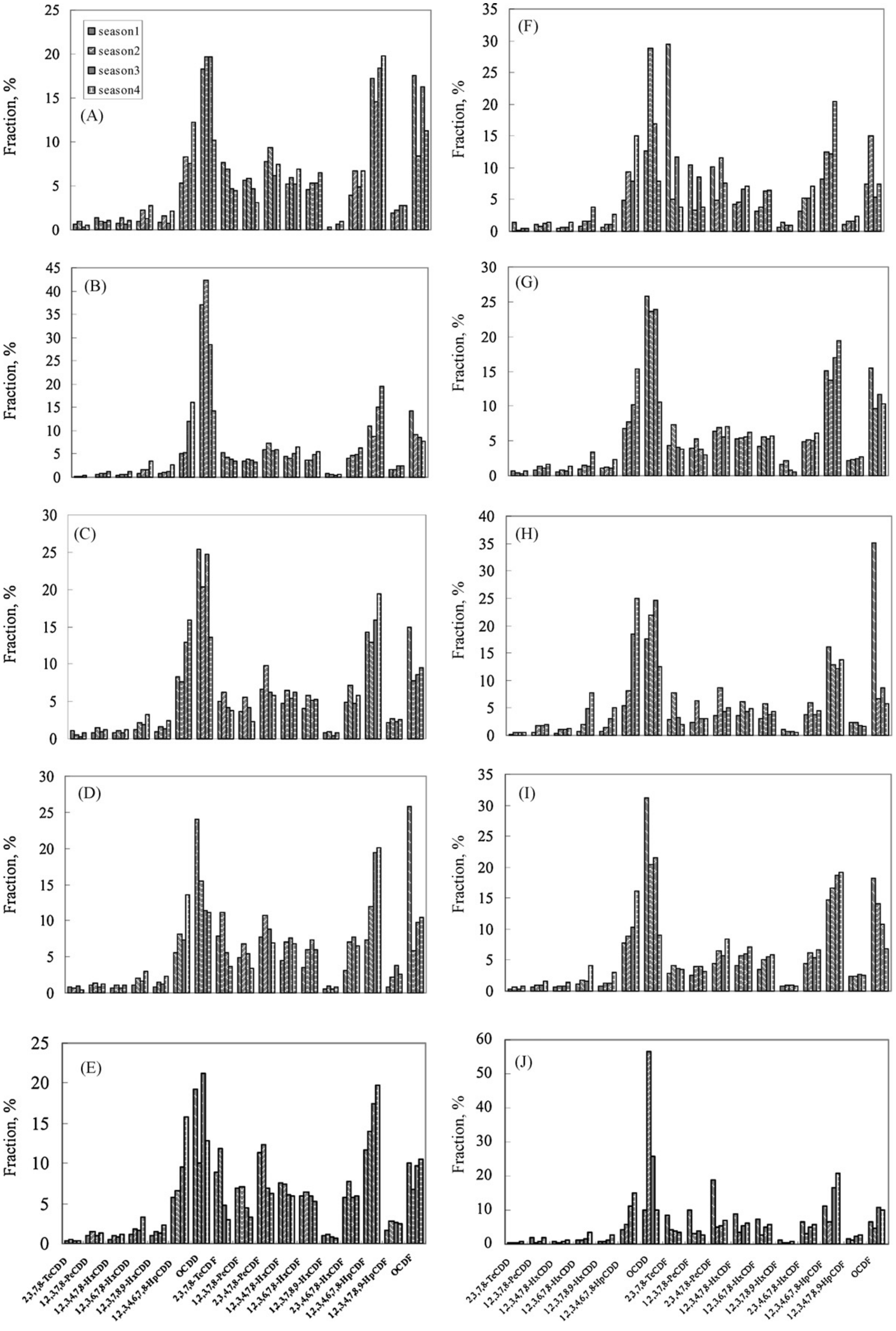
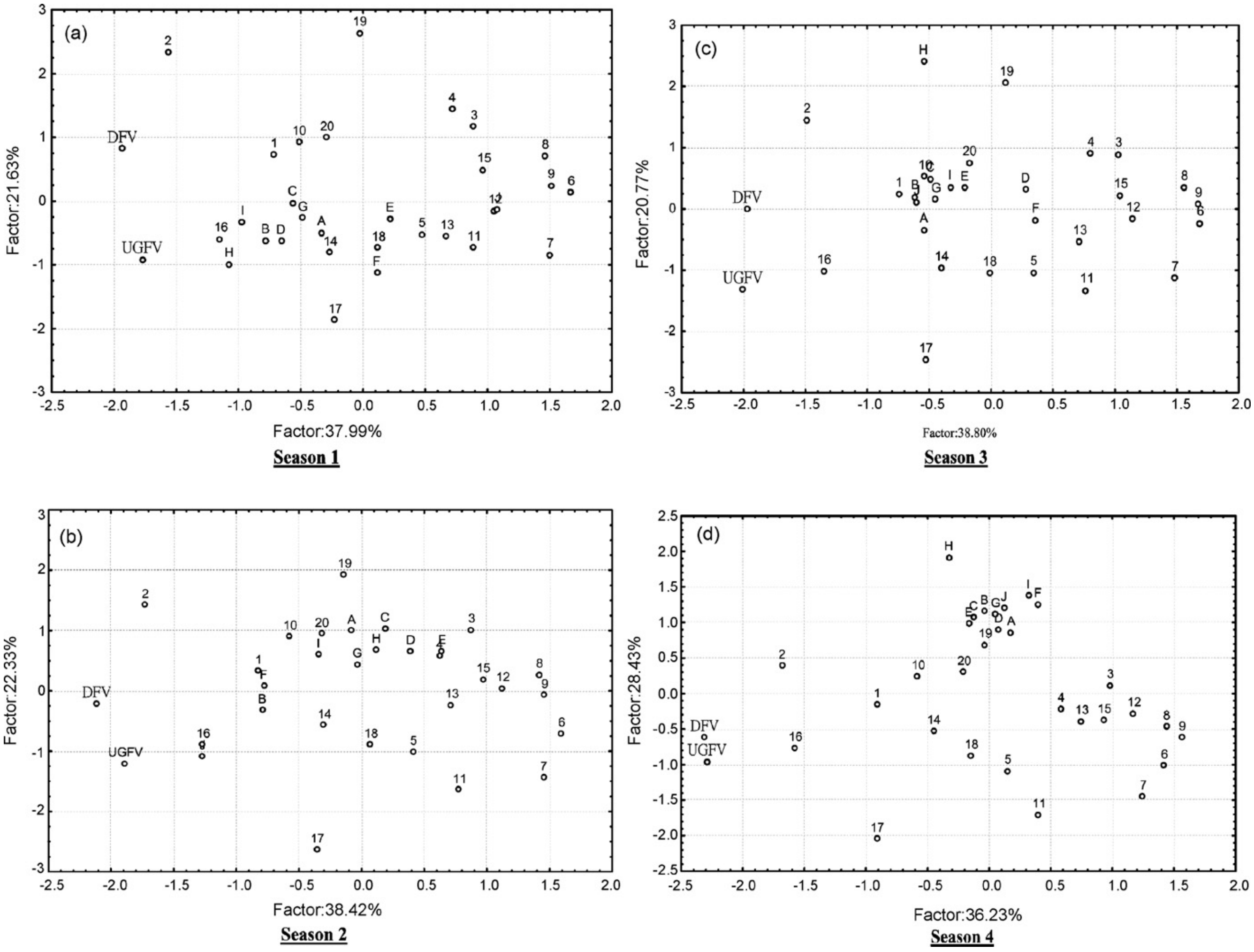


Fig. 2. Congener profiles of all samples collected at locations A–J in four seasons.

Table 1
Basic information of the stationary emission sources in Kaohsiung

Emission sources	Denotation	Feeding rate (T h^{-1})	Average temperature of stack gas (°C)	Average stack gas flow (N m^3 h^{-1})
Large municipal solid waste incinerator	1	16.4	156	119,634
Large municipal solid waste incinerator[a]	2[a]	12.1		73,529
Medium/small airport waste incinerator	3	1.0	155	5,848
Industrial waste incinerator, steel plant	4	4.1	163	22,262
Industrial waste incinerator, refinery[a]	5[a]	2	129	14,649
Clinical waste incinerator	6	0.45	92	5,160
Electric arc furnace (stainless steel)	7	51.9	62	4,014
	8	89.4	79	343,920
Electric arc furnaces	9	86.9	73	508,390
(carbon steel)	10	82.9	89	3,131
	11	24.4	59	2,585
	12	373.4	177	502,735
Sinter	13	568.5	124	945,353
plants	14	713.2	182	1,308,788
	15	746.3	203	1,108,185
Coke plant	16	219.3	176	338,235
Cement kiln[a]	17[a]	341	109	308,597
Secondary aluminum	18	1.6	46	82,701
smelters	19	7.1	265	27,380
Secondary copper smelter	20	8.4	47	40,268

[a] Located in districts other than Hsiao Kang.



Season 1

Season 3

Season 2

Season 4

Fig. 3. Principal component plot of the 10 ambient air samples, UGFV, DFV and those of the 20 emission sources in four seasons.

Table 2
Atmospheric PCDD/F concentrations taken at sites A–J in different seasons

PCDD/Fs (pg N m^{-3})	Hsiao Kang districts						Other districts			
	A	B	C	D	E	F	G	H	I	J
Season 1										
PCDDs	0.284	0.564	0.206	0.296	0.322	0.285	0.188	0.288	0.421	0.121
PCDFs	0.726	0.687	0.327	0.576	0.785	1.01	0.324	0.833	0.575	0.500
PCDDs/PCDFs ratio	0.391	0.821	0.629	0.514	0.410	0.283	0.579	0.346	0.732	0.242
Total PCDD/Fs	1.01	1.25	0.532	0.871	1.11	1.29	0.512	1.12	1.00	0.621
PCDDs/PCDFs (TEQ)	0.253	0.173	0.340	0.266	0.134	0.231	0.263	0.214	0.229	0.126
Total pg-I-TEQ (N m^3)	0.083	0.076	0.040	0.068	0.114	0.156	0.036	0.049	0.050	0.093
Mean PCDD/Fs	1.01 (R.S.D. = 27.8%, *n* = 6)						0.812 (R.S.D. = 36.0%, *n* = 4)			
Mean pg-I-TEQ (N m^3)	0.0894 (R.S.D. = 45.0%, *n* = 6)						0.0571 (R.S.D. = 43.7%, *n* = 4)			
Season 2										
PCDDs	0.130	1.36	0.195	0.238	0.301	0.254	0.146	0.115	0.263	0.540
PCDFs	0.242	1.26	0.365	0.553	1.04	0.343	0.253	0.197	0.495	0.288
PCDDs/PCDFs ratio	0.538	1.08	0.534	0.431	0.291	0.739	0.579	0.582	0.531	1.87
Total PCDD/Fs	0.372	2.62	0.560	0.791	1.34	0.597	0.400	0.312	0.758	0.828
PCDDs/PCDFs (TEQ)	0.263	0.186	0.234	0.203	0.159	0.223	0.242	0.253	0.270	0.202
Total pg-I-TEQ (N m^3)	0.036	0.178	0.055	0.087	0.157	0.035	0.032	0.029	0.056	0.042
Mean PCDD/Fs	1.05 (R.S.D. = 80.2%, *n* = 6)						0.574 (R.S.D. = 44.7%, *n* = 4)			
Mean pg-I-TEQ (N m^3)	0.0913 (R.S.D. = 68.2%, *n* = 6)						0.0397 (R.S.D. = 30.6%, *n* = 4)			
Season 3										
PCDDs	0.306	0.539	0.484	0.636	0.471	1.37	0.344	0.555	0.317	0.377
PCDFs	0.677	0.648	0.641	2.01	0.847	3.21	0.542	0.468	0.544	0.535
PCDDs/PCDFs ratio	0.452	0.832	0.756	0.317	0.556	0.426	0.635	1.19	0.583	0.705
Total PCDD/Fs	0.984	1.19	1.12	2.64	1.32	4.58	0.886	1.02	0.861	0.912
PCDDs/PCDFs (TEQ)	0.201	0.259	0.245	0.240	0.211	0.161	0.250	0.612	0.231	0.248
Total pg-I-TEQ (N m^3)	0.066	0.077	0.077	0.256	0.099	0.503	0.058	0.066	0.058	0.058
Mean PCDD/Fs	1.97 (R.S.D. = 71.7%, *n* = 6)						0.921 (R.S.D. = 7.77%, *n* = 4)			
Mean pg-I-TEQ (N m^3)	0.180 (R.S.D. = 96.8%, *n* = 6)						0.0601 (R.S.D. = 6.92%, *n* = 4)			
Season 4										
PCDDs	0.220	0.282	0.214	0.946	0.618	0.508	0.243	0.398	0.267	0.246
PCDFs	0.513	0.441	0.343	1.95	1.05	1.04	0.449	0.335	0.471	0.458
PCDDs/PCDFs ratio	0.428	0.640	0.624	0.485	0.588	0.489	0.542	1.19	0.566	0.537
Total PCDD/Fs	0.733	0.724	0.557	2.90	1.67	1.55	0.692	0.733	0.738	0.704
PCDDs/PCDFs (TEQ)	0.273	0.276	0.431	0.294	0.339	0.321	0.382	0.724	0.369	0.419
Total pg-I-TEQ (N m^3)	0.062	0.051	0.043	0.235	0.125	0.139	0.059	0.056	0.070	0.061
Mean PCDD/Fs	1.35 (R.S.D. = 65.5%, *n* = 6)						0.717 (R.S.D. = 3.08%, *n* = 4)			
Mean pg-I-TEQ (N m^3)	0.109 (R.S.D. = 67.1%, *n* = 6)						0.0616 (R.S.D. = 10.0%, *n* = 4)			

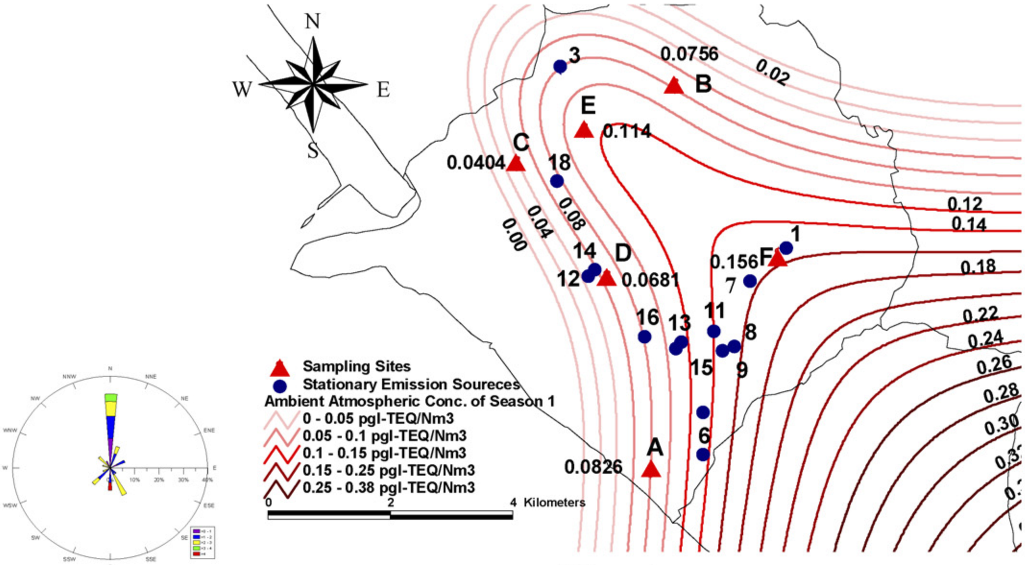
0.0707 (R.S.D., 76.4%), 0.132 (R.S.D., 109%) and 0.0903 (R.S.D., 66.6%) pg N m^{-3}. The October I-TEQ level was relatively much higher than that of December. The high I-TEQ level in October for the entire city reflected the high I-TEQ concentration in this month obtained for sites D and F in Hsiao Kang. Therefore, it can be rationally inferred that regular seasonality of PCDD/Fs did not occur to the ambient air of Kaohsiung. This observation agrees with the work by Jones and Duarte-Davidson who saw no trend of seasonality in an urbanized area of the UK [12]. In contrast, seasonal variability of ambient air concentrations of PCDD/Fs have been reported by several other workers, who attributed such observation to the seasonal changes in the source strengths of PCDD/Fs (because of the domestic combustion of fuels for space heating) and/or changes in long range air mass transport over the sites of study [3,4,7–10,13]. For instance, Hippelein et al. [7] reported that in the industrial city of Augsburg, Germany a clear annual cycle of the PCDD/F levels was observed with four to eight times higher levels measured in winter compared to summer. In particular, Sin et al. [4] ascribed the seasonal variation of PCDD/Fs in Hong Kong to the strong influence of prevailing monsoon in summer, as there is no significant increase of domicile heating due to its mild winter. It deserves to note here that, climatically, Kaohsiung is similar to Hong Kong in that monsoon prevails in summer, and enhanced domestic heating is not needed during winter. Thus, the aforesaid insignificant seasonality of this study, in Hsiao Kang and in Kaohsiung as a whole, would imply that the seasonal change in atmospheric conditions plays a fairly unimportant role in the ambient air of the city. Instead, this leads to the implication that the atmosphere of the city was constantly affected by pollution sources which do not display seasonality. Accordingly, it provides clues suggesting that the atmospheres of Hsiao Kang and entire Kaohsiung were persistently affected by the pollution sources in Hsiao Kang since it is well known that emissions from municipal solid waste incinerators, metal smelting, and the iron and steel industry are not seasonal and remain essentially consistent throughout the year [10].

Table 2 also indicates that the mean PCDD/F concentrations in the ambient air of Hsiao Kang in the months of April, July, October and December were determined as 1.01 (R.S.D., 27.8%), 1.05 (R.S.D., 80.2%), 1.97 (R.S.D., 71.7%), and 1.35 (R.S.D., 65.5%) pg N m^{-3}, respectively, while the corresponding concentrations expressed in I-TEQ were 0.0894 (R.S.D., 45.0%), 0.0913 (R.S.D., 68.2%), 0.180 (R.S.D., 96.8%) and 0.109 (R.S.D., 67.1%) pg N m^{-3}, respectively. In parallel, for sampling points located in districts other than Hsiao-Kang the mean atmospheric PCDD/F concentrations were analyzed as 0.812 (R.S.D., 36.0%), 0.574 (R.S.D., 44.7%), 0.921 (R.S.D., 7.77%) and 0.717 (R.S.D., 3.08%) pg N m^{-3}, respectively, and the associated mean I-TEQ values in the respective months were found as 0.0571 (R.S.D., 43.7%), 0.0397 (R.S.D., 30.6%), 0.0601 (R.S.D., 6.92%) and 0.0616 (R.S.D., 10.0%) pg N m^{-3}. It is apparent that the dioxin concentrations in the ambient air of Hsiao Kang were higher than those determined for the locations in other districts. Thus, these results demonstrate that the emission sources of Hsiao Kang played a very important role in the atmosphere of Kaohsiung, and Hsiao Kang was more heavily impacted because of the high industrial activities occurring in the district.

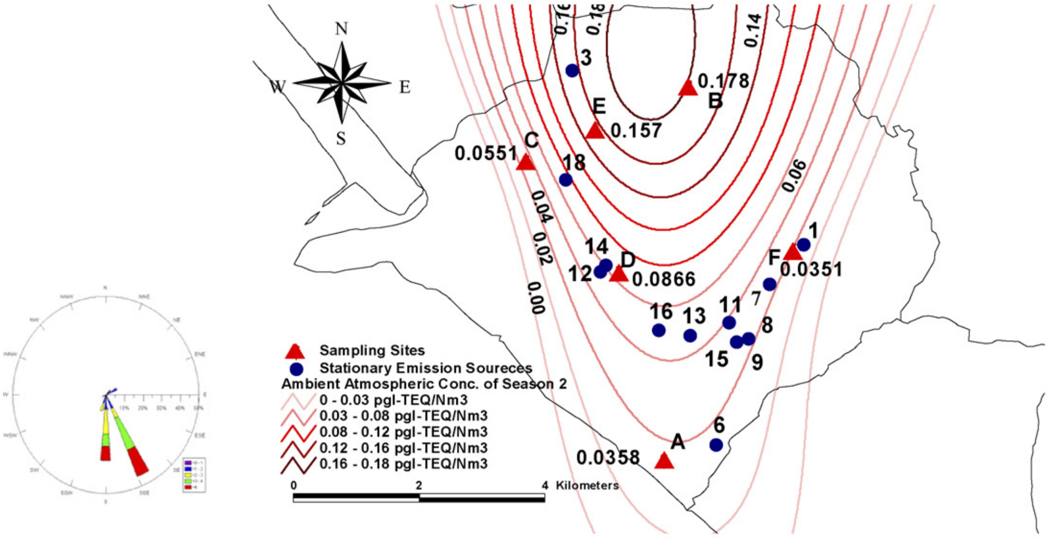
The resulting PCDD/F concentrations in the ambient air of Hsiao Kang, ranging from 0.0894 to 0.180 pg-I-TEQ N m^{-3}, are comparable to those of 0.071–1.161 pg I-TEQ N m^{-3} by Oh et al. [14] for areas of incinerators and large scale iron mills, as well as close to the value of 0.08 pg I-TEQ N m^{-3} reported by Abad et al. [15] for a zone of high industrial activity. Nevertheless, these concentrations are lower than the value of 0.28 pg I-TEQ N m^{-3} published by Abad et al. [15] for a municipal waste influenced zone with high traffic-industrial activities. On the other hand, the atmospheric PCDD/F concentrations in districts other than Hsiao Kang, in the range of 0.0397–0.0616 pg I-TEQ N m^{-3}, are close to the ambient urban air of 0.016–0.062 pg I-TEQ N m^{-3} in Sydney, Australia [16], the rural area data of 0.025–0.070 pg I-TEQ N m^{-3} by Fiedler [17], and the levels of 0.048–0.064 pg I-TEQ N m^{-3} in suburban areas of Germany [3].

3.2. Congener profiles of ambient air

The congener profiles of the seventeen 2,3,7,8-chlorinated substituted PCDD/Fs detected from all samples taken in the four scheduled periods are displayed in Fig. 2. Each selected congener was normalized by reference to the total weight of all 2,3,7,8-congeners. The most abundant congeners in common in all these samples were OCDD, 1,2,3,4,6,7,8-HpCDF, 1,2,3,4,6,7,8-HpCDD, OCDF and 2,3,4,7,8-PeCDF. The congener profiles of atmospheric PCDD/F samples taken in Hong Kong [4], in an indus-

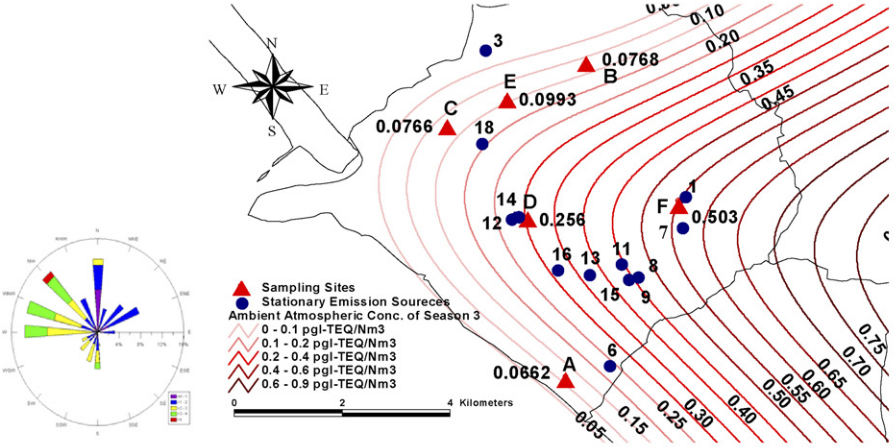


(a) Season 1

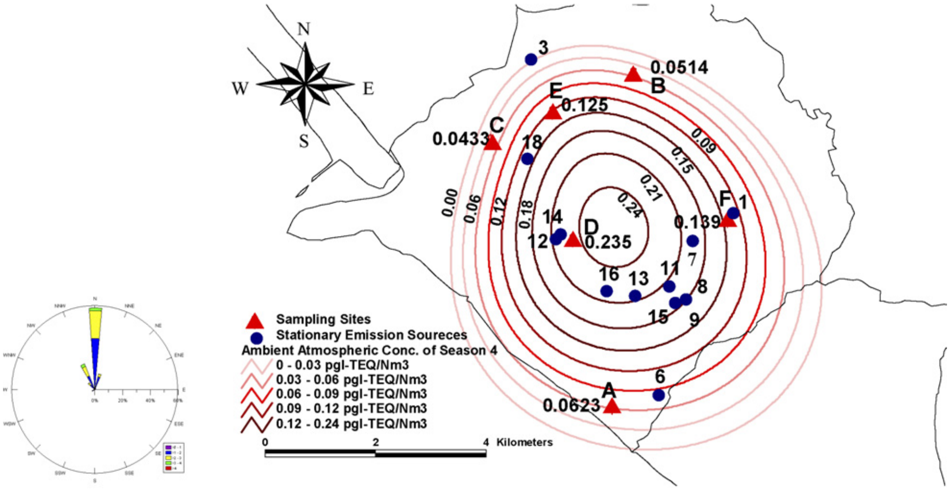


(b) Season 2

Fig. 4. PCDD/F concentration isopleths for ambient air samples collected in Hsiao Kang in (a) Season 1, (b) Season 2, (c) Season 3 and (d) Season 4, and the corresponding wind roses.



(c) Season 3



(d) Season 4

Fig. 4. (*Continued*).

trial city in southern Germany [7] and in the UK [8,9] were found to be dominated by most of these congeners as well. Having established insignificant seasonality in the concentrations of PCDD/Fs as depicted in the foregoing section, we also found from Fig. 2 that the congener profiles of all samples did not, in general, change considerably over time. Moreover, it is worthwhile to note that the congener patterns of samples collected at sites in Hsiao Kang were different from those obtained for other districts. Consequently, it is conceivable that the mixture of atmospheric PCDD/Fs sampled in Hsiao Kang were more ‘unusual’ [8] in that the ambient air of Hsiao Kang could be more characteristic of the emission sources operated in the industrial park in the district and was constantly influenced by these sources throughout the year.

In order to clearly clarify the influences of possible pollution sources on the ambient air of Kaohsiung, the PCDD/F congener profiles of the 10 sampling sites together with those obtained from each facility of the 20 stationary emission sources of Kaohsiung plus two mobile emission sources of unleaded gas-fueled vehicles (UGFV) and diesel-fueled vehicles (DFV) adopted from the database of US EPA were analyzed by PCA, using the mass fractions of 2,3,7,8-congeners (congener profile) as the variables. The score plots from PCA for the four studied months are displayed in Fig. 3. In these score plots, the data points with similar congener profiles were closely located, while those which had divergent patterns were located further apart.

Of the first period of study as shown in Fig. 3(a), factor 1 explains 37.99% of the total variance, while factor 2 21.63%, together both accounting for 59.62% of the total variance. It can be found that the data points of non-Hsiao Kang sampling points except J were more closely located, apart from those of sites in Hsiao Kang. This implies that the pollution sources in Hsiao Kang were different from those in other districts. In particular, the PCDD/F congener profiles of sites A, E and F in Hsiao Kang appeared fairly similar to those displayed by the stack flue gases of electric arc furnaces (EAFs) and sinter plants operated in Hsiao Kang [18,19]. This suggests that these three sites were primarily influenced by the metallurgical facilities in the vicinity. As a result, the ambient atmospheric PCDD/F concentrations at A, E and F turned out, as displayed in Table 2, to be the highest in the district, i.e., 0.083, 0.114 and 0.156 pg I-TEQ N m^{-3}, respectively.

Likewise, in the second round of study the score plot in Fig. 3(b), with factor 1 explaining 38.42% of total variance and factor 2 22.33%, reveals that the congener profiles of sites B, D and E in Hsiao Kang corresponded well with those of stack flues of metallurgical processes in the neighborhood, thereby bringing about a high PCDD/F concentrations of 0.178, 0.087 and 0.157 pg I-TEQ N m^{-3}, respectively at these sites. The score plots of the third and fourth seasons shown in Fig. 3(c) and (d) disclose also that locations D, E and F were largely influenced by the nearby metal-producing industries, resulting in a high PCDD/F concentration of 0.256, 0.099 and 0.503 pg I-TEQ N m^{-3}, respectively, in October, and 0.235, 0.125 and 0.139 pg-I-TEQ N m^{-3}, respectively, in December for the three locations.

3.3. Ambient atmospheric PCDD/F concentration isopleths in Hsiao Kang

PCDD/F concentration isopleth analyses were conducted in this study to further assess relationships between pollution sources and ambient air of Hsiao Kang. The PCDD/F concentration isopleths for ambient air samples collected at sites A–F in Hsiao Kang in each studied season and wind roses at the time of sampling are depicted in Fig. 4, utilizing the ArcView GIS software developed by Environmental Systems Research Institute. The points in the figure represent the 6 sampling sites together with 17 stationary emission sources of Hsiao Kang (out of 20 of entire Kaohsiung). Fig. 4(a) shows that the prevailing winds at the time of sampling in April were from north, southwest, south–southeast and east–northeast among which the northerly wind was of the strongest. Thus, it can be found clearly from the concentration isopleths of April that high PCDD/F concentrations were obtained in the ambient air downwind of the emission sources of electric arc furnaces and sinter plants in the district. Fig. 4(b) and (c) indicate that in July the prevailing winds blew from south–southeast (the high wind) and south, while in October the northwesterly wind was the most prevailing, followed by the ones from west, west–northwest and north. As in April, the isopleths of July and October show that higher PCDD/F concentrations in air could be achieved at sampling points on the downwind side of the electric arc furnaces and sinter plants as well. In addition, the meteorological data of December in Fig. 4(d) point out that the prevailing wind directions were from the north (the high wind) and north–northwest. The resulting concentration isopleths appear to match closely with the distribution of stationary emission sources in Hsiao Kang. Consequently, high ambient PCDD/F concentrations were found at sites D and F. Thus, based on the above analyses on the concentration isopleths of four seasons, PCDD/F levels in the ambient air of Hsiao Kang were considered to be largely affected by emissions from the electric arc furnaces and sinter plants in the industrial park.

4. Conclusions

Air samples were collected from 10 chosen sites and then analyzed to study the levels and characteristics of PCDD/Fs in ambient air of the city. It was found the regular seasonal variation of PCDD/Fs did not occur in the atmosphere of the city although monsoon prevails in summer, and the congener profiles of all samples generally did not change considerably with time either. The irregular seasonal variability of PCDD/Fs of the samples and the constancy of congener profiles over time were considered to be related to the emission sources in the district of Hsiao Kang where a park specifically devoted to metal processing is located. Therefore, the dioxin concentrations in the ambient air of the district were higher than those of other districts in the city. Results of principal component analyses identified PCDD/F emissions in Kaohsiung as originating from electric arc furnaces and sinter plants operated in the park. Further, PCDD/F concentration isopleth analyses verified also that the ambient air of the district was affected considerably by those EAFs and sinter plants.

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