



Characteristics of air pollution by polychlorinated dibenzo-*p*-dioxins and dibenzofurans in the typical industrial areas of Tangshan City, China

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Abstract

The ambient air in vicinity of different industrial sources for PCDD/PCDFs was sampled by TSP/PM₁₀ active samplers and passive PUF disk samplers in Tangshan City, a metropolis containing clusters of various industrial plants. The TEQ concentrations of PCDD/PCDFs ranged from 44.2 to 394.1 fg I-TEQ/m³ with an average of 169.9 fg I-TEQ/m³. 2,3,4,7,8-PeCDF was the dominant contributor to Σ TEQ, contributing 41% (12% to 55%), while 1,2,3,4,6,7,8-HpCDF, OCDD and OCDF were the major congeners for the total concentrations. The ratios of Σ PCDF/ Σ PCDD reached 2.54 on average, suggesting that *de novo* synthesis in thermal processes played an important role to the airborne pollution of PCDD/PCDFs. The similarities congener profiles indicated that TSP and PM₁₀ active sampling methods are comparable for the determination of the PCDD/PCDFs in ambient air, and the ratios of concentrations determined by the two methods suggested that the PCDD/PCDFs tended to stay in fine particles. It was found that 2,3,7,8-TCDF and OCDD were the dominating congeners in the passive PUF disks samples. Through principal components analysis, the coke industry was suggested to be a relatively high potential emission source for PCDD/PCDFs in the ambient air of Tangshan, which was possibly formed by *de novo* synthesis mechanism. In this study, the atmospheric impacts to the environment from different industrial sources could be ranked as follows (from high to low): coking, iron sintering, steel making, power generation and chlorinate alkali chemical production industries.

Key words: ambient air; dioxins; inhalable particles; total suspended particles; metropolis

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Introduction

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), two focal groups of persistent organic pollutants (POPs), can be commonly detected in environmental mediums and biotical tissues. Due to their toxicity, persistence, bioaccumulation and long-range transport, the ubiquitous PCDD/PCDFs could pose a potential risk to environmental ecology and human health, even at trace concentrations (Fiedler, 2003). Because of the semi-volatile nature of the compounds, ambient air is the most important medium for their distribution and transport of PCDD/PCDFs in the atmospheric environment (Alcock and Jones, 1996). Furthermore, ambient temperature, humidity and particle properties could be important factors that could affect the atmospheric distribution of PCDD/PCDFs (Lohmann and Jones, 1998).

Total suspended particles (TSP) refer to particles of any size, while PM₁₀ particles refer to particle matter smaller than 10 μ m, also called inhalable particles (Kaupp et al., 1994). Compared with the larger particles, the

inhalable PM₁₀ could remain longer in the air and therefore cause greater concern for human health (Martinez et al., 2006). The TSP and PM₁₀ active sampling systems are comparable in general, as the PCDD/PCDFs are prone to stay in fine particles (Kaupp and McLachlan, 2000). Compared with the active samplers, the passive atmospheric sampling (PAS) method showed merit in terms of their low installations and labors costs, and could be used for long term monitoring of atmosphere quality. Many studies have proved that passive sampling is suitable to determine the concentrations of airborne PCDD/PCDFs in the areas with potential emission sources (Lohmann et al., 2001; Harner et al., 2006; Mari et al., 2008). In this study, both TSP and PM₁₀ in the ambient air were collected by active samplers, and the passive samplers were also applied to collect the ambient air as an extra.

Economic development has led to key metropolises in China being designed and established as both economic and industrial centers, with various industrial plants embedded in the urban areas. As a typical example, Tangshan is an urbanized city with 7.1 million inhabitants, and ranked 19 among cities in China by GDP (356 billion

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RMB) in 2008 (National Bureau of Statistics, 2009). Over the last century, Tangshan has become a greatly industrialized city and now contains with clusters of industrial plants (Cai et al., 2009). The statistical analysis in the previous study indicated that PCDD/PCDFs are emitted predominately by the industries (Ren and Zheng, 2009). Certain pillar industries of Tangshan City, e.g., metallurgies, coking, chlorinate-chemical industries are listed in Stockholm Convention on POPs and Standardized toolkit for identification and quantification of dioxin and furan releases as high potential emission sources of PCDD/PCDFs (Stockholm Convention, 2001; UNEP, 2005). The flue gas containing PCDD/PCDFs which are unintentionally produced from these industries as the byproducts may pose health risks to the residents nearby, if not properly dealt. Although there have been many studies on emission sources mentioned above (Dyke and Amendola, 2007; Wang et al., 2009b), few has involved in various sources simultaneously in the same region. In this study, the ambient air at the sites of various industrial clusters was monitored to evaluate their environmental impacts.

1 Material and methods

1.1 Sampling sites

By using Hi-Vol samplers, 30 TSP and PM₁₀ samples were gathered in the downwind areas of several typical industrial plants, at eight sites in three main urban regions (Fig. 1): Downtown (Sites A, B, C, D), Nanpu industrial development zone (Sites E, F) and Guye industry park (Site G, H). The Downtown of Tangshan City is embedded with various industries; Nanpu industrial development zone has several resource based industries, like chlorine alkali chemicals and noble metal industries (e.g., titanium

smelting); Guye industry park is a typical heavy industry zone, remarkable for its coking, ferrous smelting, etc. These sites were set to evaluate the ambient air for ferrous industries (A, B), coking industries (C, G), power generation (D), chemical production industries (E), rural area (F) and mixed industrial zone (H), respectively. All of the sampling sites were settled in residence areas, on the roofs of buildings or on the open grounds in vicinity of industrial plants (about 1–2 km). Site A is settled on the south of a large steel industrial park, the steel production of which could reach 8×10^6 tons/yr. Site B is set in rural-urban cross area, 1500 m south-east to a steel factory with a production capacity of 2×10^6 tons/yr. Site C is in a village 1000 m far away from a coking plant and Site D is placed on the roof of a six-floor building, 3000 m away from a power plant. Site E is located in the chlorine alkali chemicals industrial park and Site F is in a rural courtyard at the edge of Nanpu industrial development zone. Site G is surrounded by several coking plants and Site H is encircled by metal smelting and coking plants.

Moreover, three passive samplers were settled near a steel smelting plant (YSX), amid a group of heavy industrial plants (GY) and in the downtown area (XSD), respectively. During the active sampling process, the PUF disks were retrieved and restored.

1.2 Sample collection

The sampling procedure was performed following the guidelines of the US-EPA method TO-9A. Six high volume samplers (three for TSP, and three for PM₁₀ with the PM₁₀ filters, Echo Hi-Vol, Tecora Co., Italy) were equally distributed into three groups. The active sampling work was executed during June 16–26, 2009, in three batches. Before and after sampling, the core components of the air inlet-tunnel were cleaned with alcohol. Specially, the PM₁₀ filter was smeared with vaseline gel to capture the abandoned particles. The sampler was equipped with a quartz fiber filter (QFF) (Whatman, 10.16 cm) for collecting particle-bound PCDD/PCDFs, which was baked at 450°C for 12 hr to remove organic contaminants in advance. Using the QFF, a polyurethane foam extracted by accelerated solvent extraction (Dionex 300, USA), 2 hr, 1:1 hexane (J. T. Baker, USA) and acetone (J. T. Baker, USA), 100°C; PUF, Tisch Environmental, 6.3 cm diameter, 7.6 cm length) was placed to absorb the gaseous chemicals. The airflow of the TSP sampler was about 0.25 m³/min, lasting for 24 hr, and the flux of the PM₁₀ sampler was set as 0.22 m³/min, proceeding within 48 hr continuously. On completion of sampling, the QFFs and PUFs were tightly wrapped in aluminum foil and packaged in sealed polyethylene bags to avoid contamination and loss.

1.3 Sample analysis

The analysis process followed the US-EPA Method 1613B. In pretreatment process, the QFFs and PUFs were extracted by accelerated solvent extraction method (100°C, 1500 psi, 5 min, Hexane, 40 mL, ASE Dionex 300). Afterwards, the extracts were spiked with ¹³C₁₂-PCDD/PCDFs internal standards (Wellington-1613LCS,

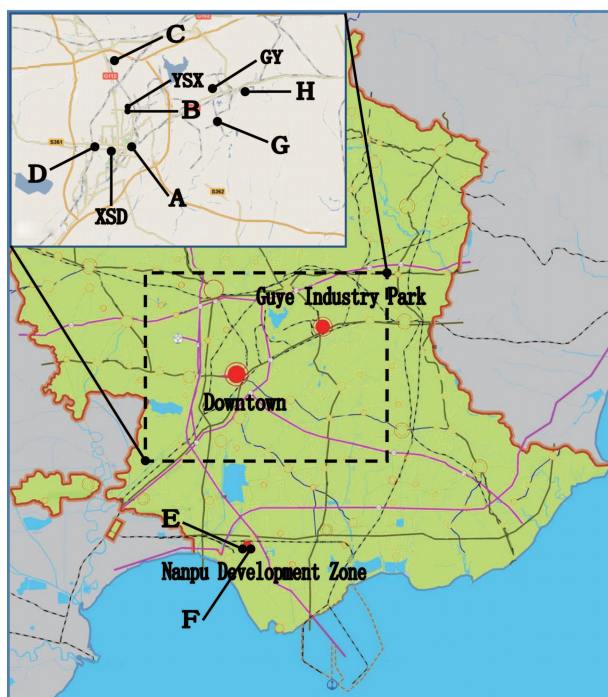


Fig. 1 Sampling sites in Tangshan City, China.

Canada), and then concentrated before subjected to an acid silica column, a sandwich column (filled with acid and alkali silica) and an alumina column, in sequence. Prior to a 6890 gas chromatograph (Agilent, USA) coupled with an Autospec Ultima high-resolution mass spectrometer (Waters, USA), the extract was spiked with the $^{13}\text{C}_{12}$ -labeled injection standards (Wellington-1613IS, Canada). Chromatographic separation was achieved with a DB-5ms fused-silica column (60 m \times 0.25 mm i.d. \times 0.25 μm). The mass spectrometer was tuned and operated in SIM mode at $R \geq 10,000$ with 38 eV EI energy.

1.4 Quality assurance and quality control

All of the samples were spiked with $^{13}\text{C}_{12}$ -labeled PCDD/PCDFs to monitor the recoveries of the target compounds in pretreatment process. The recoveries for the internal standards were 40%–110%, except 20%–116% for $^{13}\text{C}_{12}$ -OCDD (average 53%) and 26%–110% for $^{13}\text{C}_{12}$ -1,2,3,4,7,8,9-HpCDF (average 60%).

In general, the field blanks and the laboratory blanks

meet the requirements of the analytical method. The International TEF scheme was applied for calculating TEQs. The volumes of air samples were converted into the standard condition ($T = 20^\circ\text{C}$). And if the results were below the limits of detections (LODs), they were replaced by the LODs.

2 Results and discussion

2.1 Concentrations and profiles of PCDD/PCDFs in the ambient air

The concentrations and I-TEQs of PCDD/PCDFs congeners for the ambient air of Tangshan are summarized in Table 1. By using active sampling methods, the concentrations of PCDD/PCDFs in ambient air of Tangshan ranged from 44.2 to 394.1 fg I-TEQ/ m^3 with an average of 169.9 fg I-TEQ/ m^3 , which were lower than the ambient air standard of 0.6 pg I-TEQ/ m^3 proposed by Japan (Ministry of the Environment, 1999). The results are comparable with that of other metropolises in China, as listed in

Table 1 PCDD/PCDFs concentrations in ambient air in Tangshan by TSP and PM₁₀ Hi-Vol samplers and PUF disks passive samplers

Congener	PM ₁₀ (fg/Nm ³)								
	A	B	C	D	E	F	G	H	
1	2,3,7,8-TCDF	54.9	66.3	102	148	52.3	33.4	158	118
2	1,2,3,7,8-PeCDF	60.5	80.7	124	138	51.2	27.6	178	136
3	2,3,4,7,8-PeCDF	92.5	132	198	225	81.6	52.3	321	216
4	1,2,3,4,7,8-HxCDF	72.1	106	202	162	67.6	43.9	248	183
5	1,2,3,6,7,8-HxCDF	74.9	106	167	163	64.2	33.4	175	184
6	2,3,4,6,7,8-HxCDF	82.6	124	173	180	63.5	26.1	216	212
7	1,2,3,7,8,9-HxCDF	28.2	40.3	104	55.7	16.7	< 4.4	47.8	70.5
8	1,2,3,4,6,7,8-HpCDF	220	308	489	396	190	109	667	604
9	1,2,3,4,7,8,9-HpCDF	27	41.7	84	28.2	31.1	< 24.4	107.2	83.4
10	OCDF	88.5	153.5	285	181	85.7	64.3	325	338
11	2,3,7,8-TCDD	< 3.2	< 4.7	9.7	7.6	< 3.5	< 2.6	7.2	13.6
12	1,2,3,7,8-PeCDD	11.4	24.5	53.1	25.6	< 6.2	< 7.3	21.6	232
13	1,2,3,4,7,8-HxCDD	8.4	12.6	21.4	19.1	< 4.1	< 5.2	22.3	61.7
14	1,2,3,6,7,8-HxCDD	16.2	40.8	99.8	31.3	10.9	< 4.3	26.3	231
15	1,2,3,7,8,9-HxCDD	9.8	27.7	68.1	21.4	< 4.2	< 4.7	25.9	112
16	1,2,3,4,6,7,8-HpCDD	89.6	130	226	215	71.1	36.3	167	247
17	OCDD	138	187	207	364	174	133	277	777
	Σ Conc. (fg/Nm ³)	1078	1586	2614	2361	978	612	2989	3819
	Σ TEQ (I-TEQ fg/Nm ³)	96.4	144.4	243.7	225	81.5	51.2	289.1	372.2

Congener	TSP (fg/Nm ³)								PAS (fg/Nm ³)			
	A	B	C	D	E	F	G	H	GY	XSD	YSX	
1	2,3,7,8-TCDF	64.6	52.1	97	65.2	27.6	24.3	181	155	77.1	28.3	136
2	1,2,3,7,8-PeCDF	61	72.2	184	< 23.8	35.3	23.1	231	164	< 2.0	< 1.2	< 1.6
3	2,3,4,7,8-PeCDF	96.4	86.2	200	98.7	36.7	< 21.7	315	253	< 1.5	< 1.2	< 1.5
4	1,2,3,4,7,8-HxCDF	83	86.6	172	84.3	46.3	51.5	245	203	4.5	< 0.4	8.3
5	1,2,3,6,7,8-HxCDF	82.2	84.4	171	78	48.6	46.4	246	206	6.2	< 0.4	13.8
6	2,3,4,6,7,8-HxCDF	126	145	363	101	53.5	42.5	309	255	29.5	0.7	43.3
7	1,2,3,7,8,9-HxCDF	28.9	34.8	74.7	27	< 15.4	10.7	89.7	75.1	< 0.9	0.7	10.2
8	1,2,3,4,6,7,8-HpCDF	248	315	677	186	157	159	706	660	35.7	0.7	62.4
9	1,2,3,4,7,8,9-HpCDF	36	48	107	21.5	24.6	19.9	103.4	96.4	9.3	< 0.7	12.1
10	OCDF	151	222	557	107	68	117	377	493	43.6	< 0.8	52.4
11	2,3,7,8-TCDD	< 8.5	< 6.5	< 12.7	< 17.9	< 4.3	< 10.6	< 12.1	15.5	5	3.8	11.9
12	1,2,3,7,8-PeCDD	11.5	18.7	< 15.8	< 15.0	17.6	15.7	< 15.1	42.8	10.5	< 1.2	27.9
13	1,2,3,4,7,8-HxCDD	8.6	7.4	18.7	< 6.4	< 5.9	8.2	< 15.1	17.1	1.4	< 0.5	2.9
14	1,2,3,6,7,8-HxCDD	20.1	38.4	56	15.1	12.9	10.5	28.4	107	5.2	< 0.5	8.6
15	1,2,3,7,8,9-HxCDD	10.3	21.9	33.7	11.9	6.4	< 8.0	22.6	44.7	6.7	< 0.5	8.1
16	1,2,3,4,6,7,8-HpCDD	95.2	119	238	89.9	53.7	69.3	210	194	32.4	2.4	44.5
17	OCDD	263	274	461	337	278	355	592	674	125	46	362
	Σ Conc. (fg/Nm ³)	1394	1631	3437	1285	892	993	3698	3654	396	90	807
	Σ TEQ (I-TEQ fg/Nm ³)	112	115	239.4	118.2	57.6	53.7	313.8	288.4	25.2	8.3	51.3

TEQ: toxic equivalent.

Table 2 PCDD/PCDFs concentrations of ambient air in the main economic regions in China

Region	City	Period	Remarks	Type	Σ TEQ (fg I-TEQ/m ³)	Reference
Yangtze River Delta Region	Hangzhou	2007–2008	MSWI	Industry	495 (59–3030)	Xu et al., 2009
	Shanghai	2006		Urban	268 (143–497)	Li et al., 2008a
	Taizhou	2005	E-waste	Industry	1100 (200–3450)	Li et al., 2008c
Pearl River Delta Region	Chendian	2005		Rural	1350	Li et al., 2007
	Guiyu	2005	E-waste	Industry	12,400 (972–51,200)	Li et al., 2007
	Guangzhou	2005		Urban	520 (81–1828)	Yu et al., 2006
	Tap Mun, HK	2004–2005		Remote	69.8 (7.3–154)	Choi et al., 2008
	Yuen Long, HK	2004–2005	Residence	Urban	152 (10.0–5791)	Choi et al., 2008
	Tsuen Wan, HK	2004–2005	Industry	Urban	102 (7.4–312)	Choi et al., 2008
Circum-Bohai Sea Gulf Region	Hong Kong	2000		Urban	18–430	Sin et al., 2002
	Beijing	2006		Urban	268 (18–644)	Li et al., 2008b
	Downtown, TS	2009	Multi-industry	Urban	158 (84–314)	This study
	Guye, TS	2009	Heavy industry	Industry	311 (233–394)	This study
	Nanpu, TS	2009	Chlorine alkali industry	Urban	59 (39–82)	This study
Taiwan	Kaohsiung, TW	2005		Urban	31.9–256	Wang et al., 2009a
	Northern Taiwan	1999–2000	Winter	Suburban	188–348	Chang et al., 2003
	Northern Taiwan	2000	Summer	Suburban	56–166	Chang et al., 2003
	Hsinchu, TW	2000–2001	MSWI	Industry	85 (58–127)	Cheng et al., 2003
	Taiwan	2005	Waelz plant	Industry	206–568	Chi et al., 2007

HK: Hong Kong, TS: Tangshan, TW: Taiwan; MSWI: municipal solid waste incineration.

Table 2.

Amongst the 2,3,7,8-substituted PCDD/PCDFs, 2,3,4,7,8-PeCDF is the dominant contributor to Σ TEQ, reaching 41% (12% to 55%). The result is accordant with the previous studies (Chang et al., 2003; de Assuncao et al., 2005; Shih et al., 2006; Wang et al., 2009a). Meanwhile, 1,2,3,4,6,7,8-HpCDF (18%) and OCDD (20%) were the greatest contributors for the total concentrations, followed by other 2,3,7,8-substituted PCDFs and 1,2,3,4,6,7,8-HpCDD. Hepta and Octa chlorinated PCDD/PCDFs contributed approximately 50% of the total concentration.

In general, the ratio of Σ PCDF/ Σ PCDD ($R_{DF/DD}$) could normally indicate different pathways of PCDD/PCDFs formations. The $R_{DF/DD}$ from precursors formation is less than 1 while *de novo* synthesis normally requires a $R_{DF/DD}$ greater than 1 (Huang and Buekens, 1995; Altarawneh et al., 2009; Cunliffe and Williams, 2009). In this study, the $R_{DF/DD}$ varies from 0.94 to 4.50 (2.54 on average). The characters of the profiles were in accordant with the thermal formation processes driven by *de novo* synthesis (Xhrouet et al., 2001; Conesa et al., 2002; Takasuga et al., 2004). It hinted that *de novo* synthesis could be the main formation mechanism for the sources of the PCDD/PCDFs in the ambient air.

2.2 Congener patterns obtained by different sampling methods

2.2.1 Comparison of PCDD/PCDFs concentrations as determined by active PM₁₀ and TSP sampling methods

As shown in Fig. 2, the patterns of PCDD/PCDFs congeners are of great similarities in PM₁₀ and TSP at the same sampling sites. The PCDFs congeners are commonly more significant than the PCDDs congeners, except 1,2,3,4,6,7,8-HpCDD and OCDD, of which the concentrations are also considerable.

In the TSP and PM₁₀ samples, the ratios of $\Sigma C_{PM_{10}}/\Sigma C_{TSP}$ varied from 0.6 to 1.1 (0.9 on average).

Therefore, the concentration ratios suggested that the PCDD/PCDFs tended to stay in fine particles. The congener concentrations showed significant correlation ($R = 0.887$, at 0.01 level) for the same sites (Fig. 3). This indicated that the two active sampling methods are comparable for the determination of the PCDD/PCDFs in the ambient air as has been found previously (Martinez et al., 2006; Mari et al., 2008).

2.2.2 Comparison of active and passive sampling methods

In the passive air samples, 2,3,7,8-TCDF and OCDD were the dominating congeners. Moreover, 2,3,4,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF and OCDF were prevalent at the industrial sites. The Site XSD is located in the commercial and residential area, far away from the industrial plants. Thus, the air sample from this site was much cleaner than the other two. The PCDD/PCDFs concentrations and congener ratio patterns of active and passive sampling methods were not completely consistent in this study. As can be seen from Fig. 4, the profiles of PCDD/PCDFs in TSP and PM₁₀ sampled at Site B were similar. Although Site YSX is very close to Site B, comparing with the congener patterns of TSP and PM₁₀ samples collected at Site B, a different pattern of PCDD/PCDFs that OCDD and 2,3,7,8-TCDF are the two dominating congeners among the 17 PCDD/PCDFs is observed in the sample collected at Site YSX by PAS. In general, the active sampling method provides the average air quality results for 24–48 hr, while the passive method reflects the long term air quality. Despite of the inconsistent patterns by the active and passive methods, the differences in this study might be explained by some uncertainties such as stochastic emissions and meteorological conditions.

2.2.3 PCA analysis of PCDD/PCDFs in ambient air

By using SPSS 13.0, the principal components analysis was executed on the 17 congeners of 2,3,7,8-substituted PCDD/PCDFs. The first two main principal components

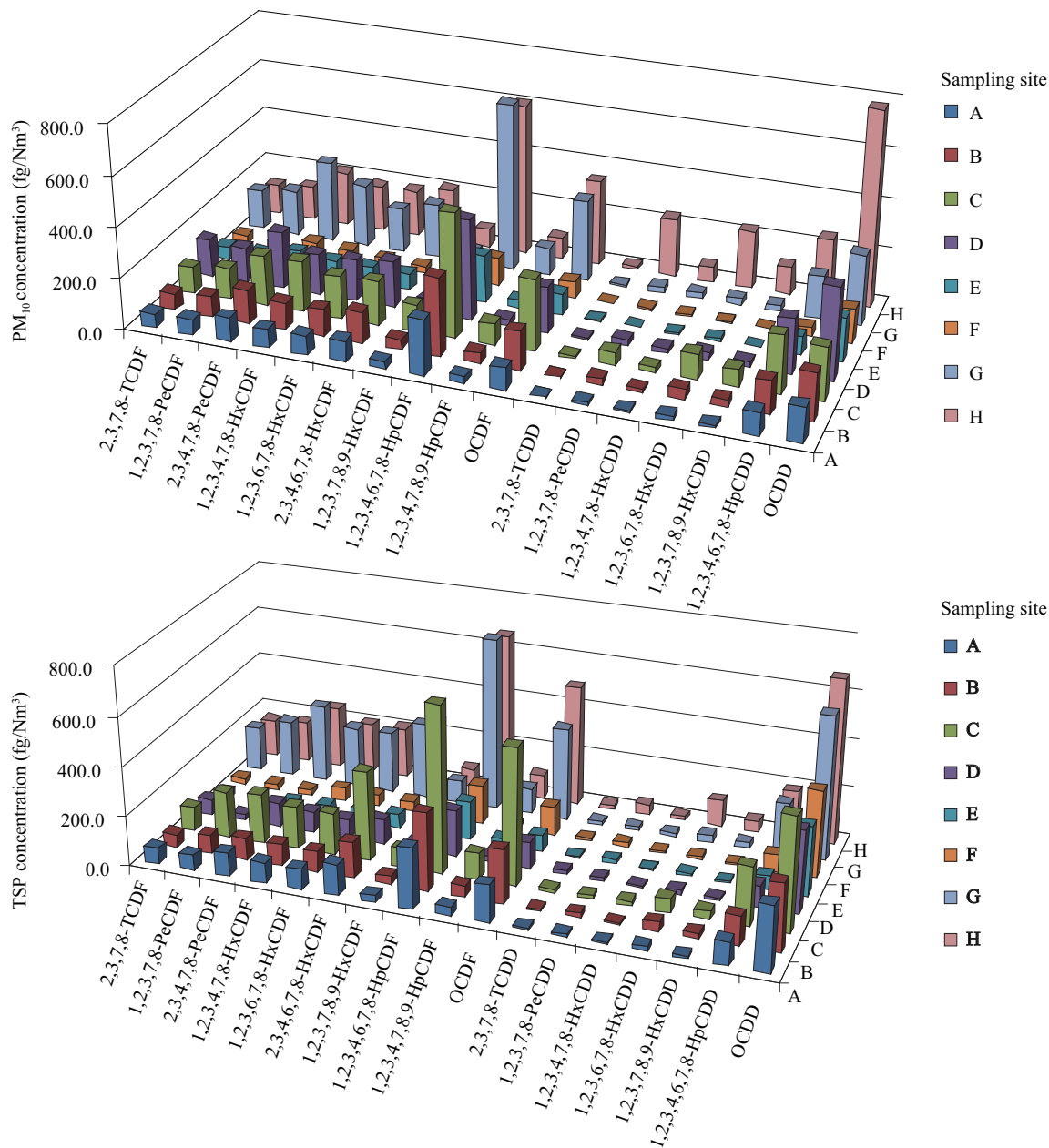


Fig. 2 Profiles of PCDD/PCDFs in PM₁₀ (a) and TSP (b).

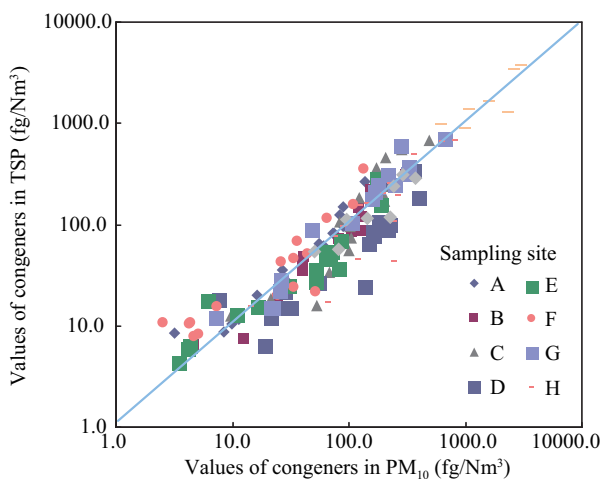


Fig. 3 Comparison between congeners concentration as determined by in TSP and PM₁₀ from the same sites.

contributed 82.2% to the total variance (67.8% and 14.4%, respectively). As shown in Fig. 5, all the congeners contribute to PC1 with positive factors, which could be seen as a positive indicator for the total emission tentatively; with positive contributions from PCDDs and negative contributions from PCDFs, PC2 is negatively related with $R_{DF/DD}$, which could roughly represent $R_{DF/DD}$ inversely.

In Fig. 6, most of the samples from Site C and Site G were concentrated in “A1” area, and both sites are in the vicinity of coking plants. With scores of PC1 > 0.5 and PC2 < -0.5, the ambient air near the coking plants was suggested with relatively high concentrations of PCDD/PCDFs which could possibly be formed by *de novo* synthesis. The air samples from Site E and Site F (Nanpu Industry Park, industrial-chemical processes, “A3”) got relatively low PC1 scores and high PC2 scores, hinting a low concentration level of PCDD/PCDFs and a less contribution from the *de novo* synthesis formation pathway.

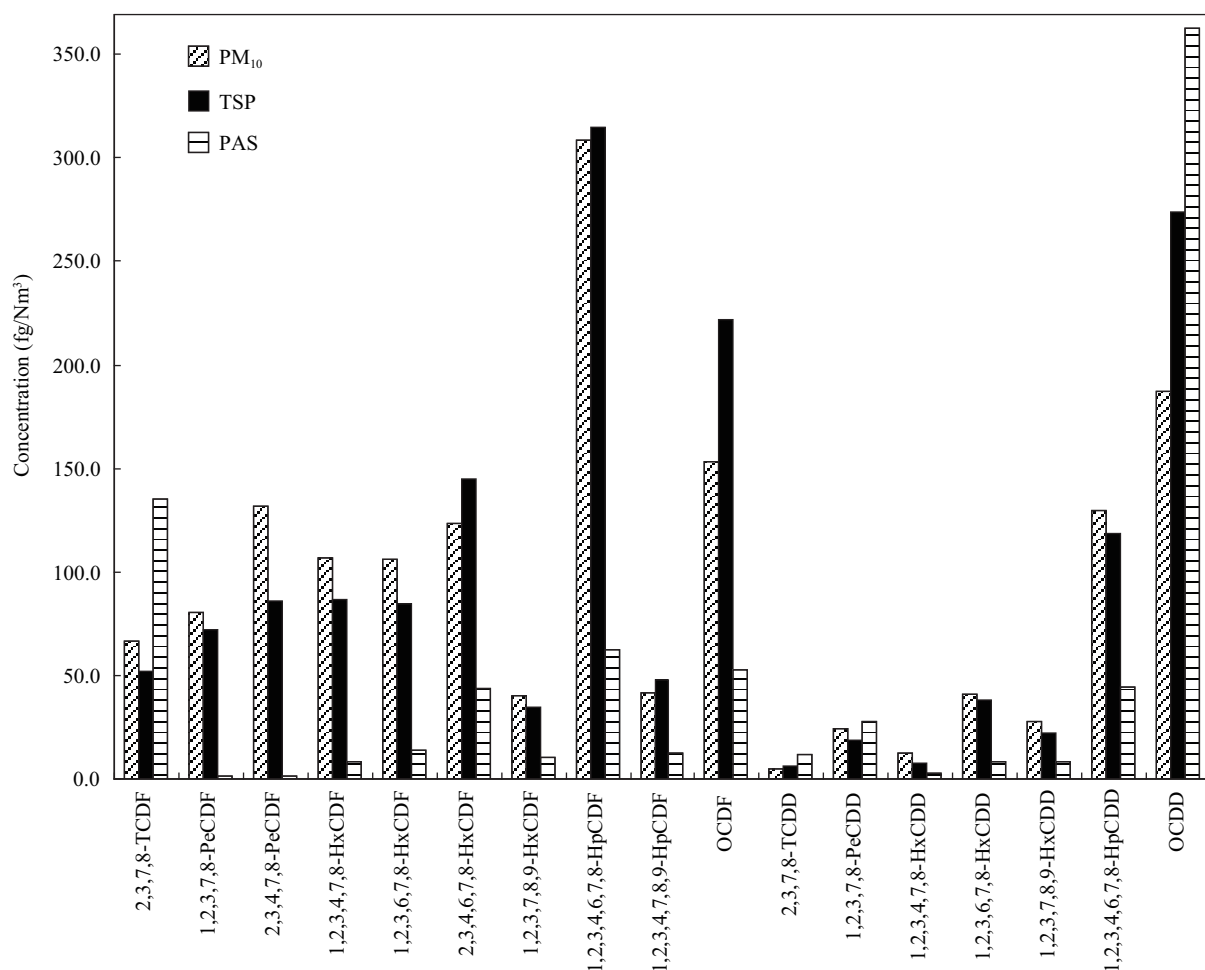


Fig. 4 Comparison between profiles determined by different sampling methods from the same site.

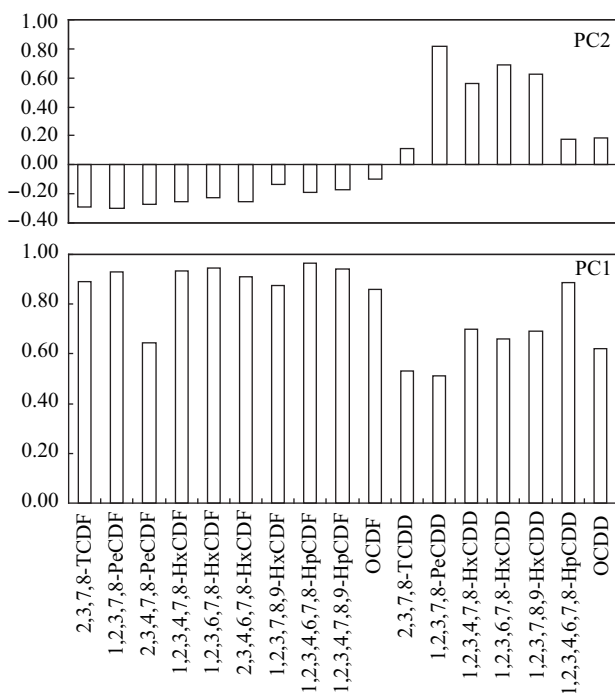


Fig. 5 Contribution coefficients of the seventeen 2,3,7,8-substituted PCDD/PCDFs on the principal components.

Samples from Sites A, B and D are mostly included in “A2” area, which are probably sourced from steel industry and power generation, with scores of $-1.0 < PC1 < 0.5$ and $-0.5 < PC2 < 0.5$. Because Site H is located at a mixed-industry area, the PC1 scores maintained constantly high while the PC2 scores of the samples vary extremely.

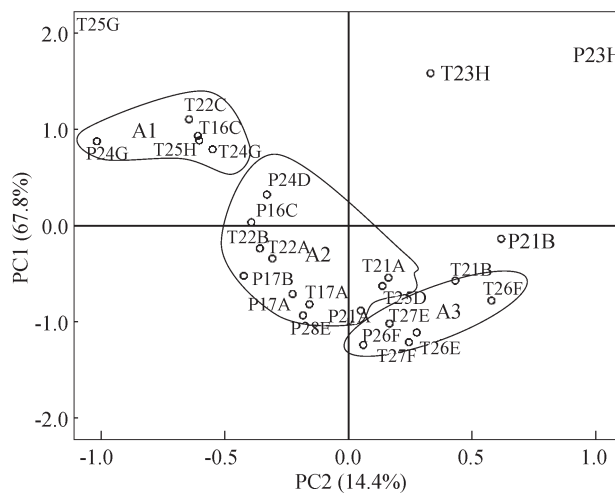


Fig. 6 Comparisons on principal components scores (PC1 vs. PC2). T/P represents TSP or PM₁₀, different ingredient of the air samples, A-F are the sampling sites.

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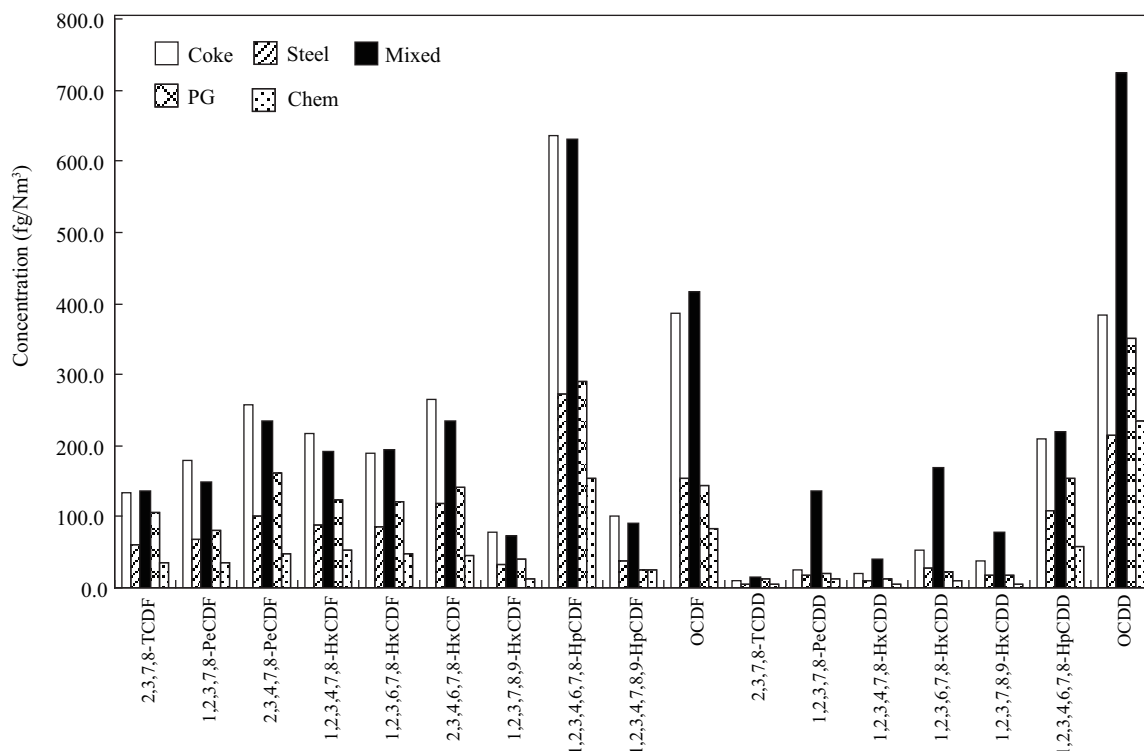


Fig. 7 Distribution of the PCDD/PCDFs congeners from various industries. Coke: coke industry; Steel: steel industry; Mixed: mixed area of Coke and Steel industries; PG: power generation plant; Chem: chlorinated alkali chemistry.

2.3 Analysis of the emissions as related to various industries

In the vicinity of coke plants, the concentrations (272 fg I-TEQ/m³ on average) are obviously higher than those measured around other industries. As shown in Fig. 7, the congener patterns of PCDD/PCDFs in the air concur with those of coking plant flue gas in the previous studies (Liu et al., 2009). It is suggested that the airborne PCDD/PCDFs rooted from the coking plants could have some impact to the environment.

Sites A and B were located close to two large-scaled ferrous facilities, including iron ore sintering and steel making plants. The plants are both equipped with electric arc furnaces and electrostatic precipitators. According to the previous studies, ferrous industries were recognized as high potential emission sources. However, it is unexpected that the ambient air near the ferrous production plants was relatively clean for PCDD/PCDFs.

Site E and Site F are located in Nanpu industrial development zone, which is a chlorinate alkali chemical industrial park with state of the art techniques. Although chlorinate alkali industry is an potential emission source of PCDD/PCDFs, these pollutants are mostly concentrated in products or residues, and are seldom released to air due to the physicochemical properties. Thus, the concentrations of PCDD/PCDFs in the ambient air near chlorinate-alkali chemical industrial park were as low as 59 fg I-TEQ/m³.

3 Conclusions

In this study, the TEQs of PCDD/PCDFs in Tangshan City were compared with that of other metropolises in

China. By principal components analysis, it is demonstrated that the coke industries would bring some impact to the surrounding atmosphere in terms of PCDD/PCDFs concentrations in Tangshan.

Although there are tremendous potential emission sources of various industries in Tangshan, the results showed the airborne PCDD/PCDFs pollution is not as serious as expected. Owing to the complexities of the transportation process and the uncertain factors for the PCDD/PCDFs emissions, further studies basing on the emission sources should be taken place to obtain more conclusive results.

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