Can well-managed municipal solid waste incinerator be an environmental threat anymore?--a case study based on four consecutive year monitoring in Beijing

Qi L[1], Ren Y[1], Zhou Z[1], Xu P[1], Zheng S[1], Zhao H[1], Fan S[1], Liu A[1], Huang Y[1], Li H[2], Zhao Z[2], Wang J[2]

[1] National Research Center for Environmental Analysis and Measurement, 1 South Yuhui Rd, Chaoyang District, Beijing 100029, China
[2] Beijing Chaoyang District Environmental Protection Monitoring Station, Beijing 100125, China

Introduction

Previous studies indicated that the ambient PCDD/Fs characteristics around MWSI were proportional to those of flue gases from the nearby facilities in many cases. Therefore, MSWI are regarded as significant source in urban area affecting atmospheric environment surrounded. Few researches have been conducted to investigate the ambient PCDD/Fs pollution around MSWI in China, however, suggest well-managed MSWIs have limited influence on surrounding atmosphere.

Beijing has been expanding dramatically in recent years leading to sharp increase in municipal solid waste. MSWI has become the most important treatment method due to the land constraint required for sanitary landfill. Considering the potential adverse effects that may bring out to the surrounding environment and human health, building MSWI facilities used to be strongly opposed by residents nearby. In this study, we monitored the ambient PCDD/Fs concentrations at different seasons every year from 2013 to 2016 and investigated the seasonal and inter-annual variations around a typical MSWI in Beijing to comprehensively evaluate the potential effects resulted from the incineration activities.

Materials and methods

Sampling-Seven sampling sites within 6 km radius to the MSWI (denoted as the trapezoidal zone) as illustrated in Fig. 1 were chosen based on the wind direction and residency distribution in the region. Ambient air were sampled at each season and collected using high-volume sampler (Shibata, HV-1000F, Japan) to capture both vapor and particle bound phases simultaneously at flow rate of 500 L min^{-1} for 72 hours from year 2013 to 2016. QFFs were baked at 450°C for 6 h and dried in a clean atmosphere prior to use. PUF was pre-cleaned with purified water and acetone and then subject to a 48 h Soxhlet extraction with methylene chloride and then air dried and placed in glass cartridges.

Analysis-Pretreatment of air samples followed HJ 77.2-2008 standard method (MEP, 2008). PCDD/Fs were determined using HRGC-HRMS (Agilent 6890N/Waters Autospec Ultimate NT, U.S.) equipped with a DB-5MS capillary column (60 m long, i.d. 0.25 mm, film thickness 0.25μm) in EI mode at 650 μA ionization current and 8 kV ionization accelerate voltage with a mass resolution of >10000. A blank test was added per batch samples (seven per batch). All the congeners in blanks were below the detection limits. Recovery of the labeled standards ranged from 33% to 115% for tetra- to octa-CDD/Fs which all fell within the acceptable ranges set by HJ 77.2-2008 method.

Results and discussion

Atmospheric PCDD/Fs concentrations and spatial variations-The toxic equivalent (TEQ) concentrations of 17 2,3,7,8-substituted congeners ranged from 0.057 to 2.4 pg·m^{-3} (seasonal average: 0.13-2.2 pg·m^{-3}). The concentrations from all sites are comparable to typical urban atmospheric PCDD/Fs concentrations reported in Beijing area previously (0.25-0.27 pg·m^{-3}) and fall within the range of urban ambient PCDD/Fs concentrations (0.100~0.400 pg·m^{-3}) proposed by Lohmann et al. (1998) except for the samples acquired during haze weather which normally occurred in late autumn and winter seasons.

Fig.1 Ambient air sampling sites around the MSWI

There is no apparent correlation between the concentrations and the distances away from the MSWI facility as for the spatial variation. Due to the fact that there were no sustained wind directions during the sampling periods, the spatial variation did not exhibit obvious characteristics consistent with the prevailing wind direction of NW and SE to the source. Previous study indicated that the maximum ground concentration point of ambient PCDD/Fs that affected mainly by MSWI located around 1.0-1.5 km downwind the facility using air dispersion model (Zhang et al., 2013). In this study for example, the air samples from site #1 that is located within the range of maximum ground concentration and downwind of the prevailing wind direction in summer, however, had comparable levels with other sampling sites, suggesting that the contribution of MSWI to the surrounding atmosphere via air dispersion and transport is limited.

Studies of gas-particle partitioning of PCDD/Fs showed that PCDD/Fs dominantly distributed in the particulate phase. Therefore, the relationship between the PCDD/Fs and particulate matter (PM) mass concentration was also investigated to enlighten the probable origins of atmospheric PCDD/Fs. The results from 2014 to 2015 were analyzed as representative and illustrated in Fig. 2. It revealed a consistent correlation between PCDD/Fs and PM concentrations, suggesting the emission sources of these pollutants may be the same in the studied region. The ratios of PCDD/Fs to PM are relatively steady and did not exhibit distinct seasonal variation except that PCDD/Fs have tendency to partition in the gas phase due to the high temperature in summer leading to a lower fraction in PM.

Inter-annual and seasonal variations of atmospheric PCDD/Fs

The average atmospheric PCDD/Fs from all sites during each sampling episode based on four consecutive year monitoring was illustrated in Fig.3. The inter-annual and seasonal variations of atmospheric PCDD/Fs exhibit consistent characteristics that the highest and lowest concentration was observed in winter and summer/spring, respectively. And the concentrations in spring, summer and autumn are comparable in each year whereas the concentration in winter decreased as the air quality improved during the sampling periods in different year.

The local sources are relatively steady, therefore the seasonal variation may be closely associated with domestic heating, air mass movement and boundary layer height change with seasons. It is hot and rainy in summer resulting in high wet deposition flux and photo-degradation of PCDD/Fs. It is dry and windy in spring which

promotes the atmospheric dispersion and thus dilution of ambient pollutants. However, in winter the coal combustion surges for heating as well as frequent occurrence of temperature inversion, which altogether leads to highly accumulative concentrations of PM and thus high PCDD/Fs levels in winter.

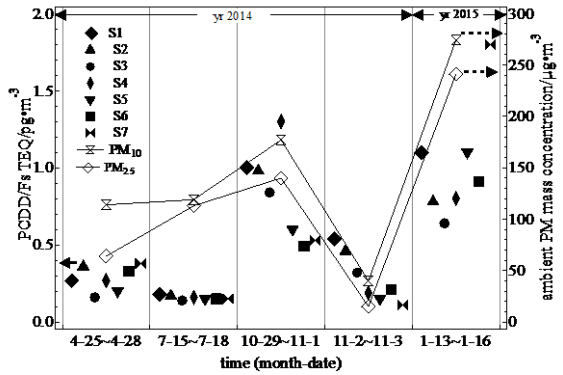

Fig.2a Correlation between TEQ in the samples at each sampling site and average PM_{10} and $PM_{2.5}$ concentrations

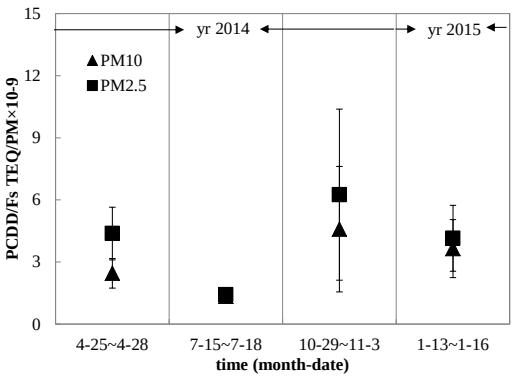

Fig.2b The ratios of average TEQ from all sampling sites to PM_{10} and $PM_{2.5}$ concentrations

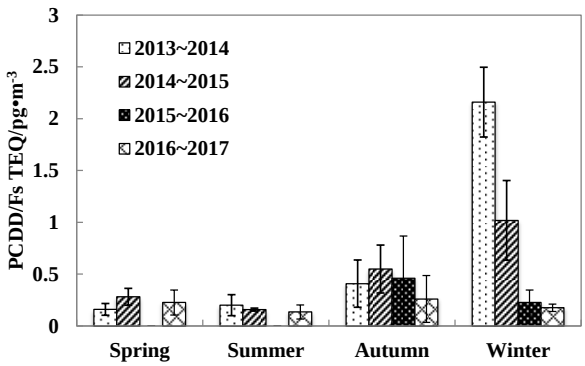

Fig. 3 Annual comparison of average atmospheric concentrations of PCDD/Fs in different seasons in the studied area

Toxic congener profiles of PCDD/Fs

Relative abundance of toxic congeners and homologues of PCDD/Fs in air samples and flue gases from the studied MSWI were also calculated and compared. Among seventeen 2,3,7,8-substituted PCDD/Fs congeners, the main contributors to total PCDD/Fs mass are 1,2,3,4,6,7,8-HpCDF and OCDF for all sites and seasons. The congener profiles of air samples differed from those of flue gas characterized by the lower contribution of 2,3,4,7,8-PeCDF and higher contributions of 1,2,3,4,6,7,8-HpCDF and OCDF in air samples. Previous studies indicated that 1,2,3,4,6,7,8-HpCDF and OCDF mainly originated from gasoline and diesel vehicles, suggesting the atmospheric PCDD/Fs in this area may be attributed to mobile sources besides the MSWI simultaneously. For example, the contribution fraction of OCDF decreased dramatically at all sites during November, 2014 when APEC meeting was held in Beijing and more stringent traffic restriction measures were implemented. Among

these sampling sites, the contribution fraction of OCDF at S5, S6 and S7 where are located adjacent to the 2nd Airport Express way and the East 5th ring road, were reduced to a greater extent compared to the other sites, confirming that other than the MSWI, the traffic emissions may also affect the studied area.

Potential emission sources of PCDD/Fs

In addition to the MSWI, field survey suggests that fugitive coal-fired boiler, crematory and traffic emissions may be the joint sources affecting the studied area. To identify the possible major pollution sources for the atmospheric PCDD/Fs in the studied area, congener profiles of air samples together with those obtained from facilities of the four investigated types of stationary and mobile emission sources were analyzed by principle component analysis using the mass fractions of 17 2,3,7,8-substitued congener as variables (shown in Fig.4). Figure 4 presents the score plot from PCA, which factor 1 and factor 2 explains 42.1% and 21.9% of the total variance, respectively. The data points with similar congener profiles were closely located, whereas those which had divergent patterns were located further apart. The score plot reveals that the data points of air samples were closely located and more clustered with season that suggests the ambient PCDD/Fs may have steady sources with slight changes in relative contributions at different seasons. Since the congener profiles of air samples and those of fugitive coal-fired boiler and gas-fuel vehicle were closely located, especially more clustered with fugitive coal-fired boiler in winter, we extrapolate that these two sources may jointly affect the atmospheric PCDD/Fs in the studied area as opposed to significant influence of the MSWI.

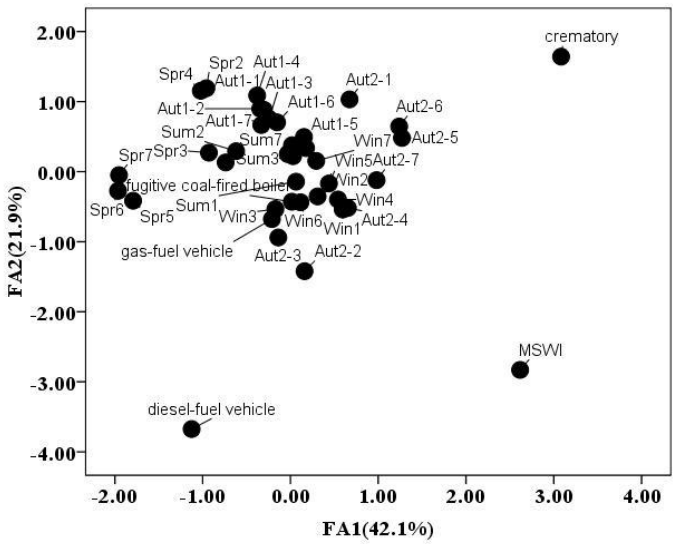

Fig.4 Correlation of PCDD/Fs profiles in emission sources and air samples

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References

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