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# Dioxin/Furan Level in the Malaysian Oil Palm Environment

(Tahap Kandungan Dioksin/Furan di Persekitaran Sawit Malaysia)

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ABSTRACT

*Environmental samples collected from oil palm premises were evaluated for dioxins/furans contamination. The samplings were carried out at oil palm premises located in Banting (Premise A) and Teluk Intan (Premise B), involving two environmental matrices namely ambient air and soil. The soil samples were collected in the plantations while ambient air samples were collected in the vicinity of the mills and refineries. The results of the analyses showed that the level of dioxins/furans in ambient air were generally higher in oil palm premise located adjacent to industrial establishments. The concentration levels at premise A mill and refinery located adjacent to industrial establishments, ranged from 64.14 WHO–TEQ fg $m^{-3}$ to 131.87 WHO–TEQ fg $m^{-3}$, while for premise B mill and refinery located in the rural area, ranged from 9.93 WHO–TEQ fg $m^{-3}$ to 16.66 WHO–TEQ fg $m^{-3}$. Meanwhile for soil samples, the highest concentrations were recorded in soil collected near roads used heavily by vehicles. The concentration levels of soil samples collected at premise A and premise B plantations ranged from 1.910 WHO-TEQ pg $g^{-1}$ dry weight to 3.305 WHO-TEQ pg $g^{-1}$ dry weight.*

*Keywords: Ambient air; contamination; dioxins/furans; soil*

ABSTRAK

*Sampel di kawasan persekitaran premis sawit telah diambil untuk dijalankan penilaian tahap pencemaran dioksin/furan. Persampelan dijalankan di dua premis sawit yang terletak di Banting (Premis A) dan Teluk Intan (Premis B) dan melibatkan dua matriks alam sekitar iaitu udara persekitaran dan tanah. Persampelan tanah dijalankan di ladang sawit manakala sampel udara persekitaran di kawasan sekitaran kilang pemprosesan dan kilang penapisan. Keputusan analisis menunjukkan aras dioksin/furan di udara persekitaran secara umumnya adalah lebih tinggi di kawasan premis sawit yang berdekatan dengan penempatan industri. Aras dioksin/furan di kawasan tersebut (Premis A) adalah daripada 64.14 WHO-TEQ fg $m^{-3}$ hingga 131.87 WHO-TEQ fg $m^{-3}$ manakala Premis B yang terletak di kawasan pedalaman menunjukkan aras dioxins/furans daripada 9.93 WHO-TEQ fg $m^{-3}$ hingga 16.66 WHO-TEQ fg $m^{-3}$. Manakala untuk sampel tanah pula, aras yang paling tinggi direkodkan di kawasan tanah yang berdekatan dengan jalan yang sering dilalui oleh kenderaan. Aras dioksin/furan yang dicatatkan di kedua-dua ladang Premis A dan B adalah 1.910 WHO-TEQ pg $g^{-1}$ berat kering hingga 3.305 WHO-TEQ pg $g^{-1}$ berat kering.*

*Kata kunci: Dioksin/furan; pencemaran; tanah; udara persekitaran*

## INTRODUCTION

Polychlorinated dibenzo-*p*-dioxins(PCDDs)/polychlorinated dibenzo furans (PCDFs), collectively known as dioxins/furans are two major persistent organic pollutants (POPs) that are widespread all over the world. Centers for Disease Control (CDC 1994, 1998) has classified these chemical compounds as toxic, carcinogenic, stable, ubiquitous and bio-accumulate in the environment. These compounds have also been related with various health effects such as chloracne, reproductive damage, birth defects, decrease in fertility and increase rates of miscarriages (CDC 1994, 1998). Dioxins/furans are not produced intentionally but are released into the environment in ultra-trace amounts from various combustion processes and they are unwanted by-products in various chlorinated chemical formulations (Alcock & Jones 1996). The presence of dioxins/furans compound in the atmosphere particularly in ambient air is greatly influenced by a few sources. Combustion and chemical usage are believed to be the principal sources of dioxins/furans in the atmosphere (Jones & Lohmann 1998). Combustion such as biomass open burning, solid-waste incinerator plant, industrial emission, backyard burning of rubbish and trash, haze and forest fires, are the major contributors to the level of dioxins/furans in the environment (Luthardt et al. 2002; Radojevic 2003; Shih et al. 2006, 2008; Wevers et al. 2004). Meanwhile the liphophilic and semi-volatile characteristics of dioxins/furans allow this contaminant to be easily accumulated in the organic rich environmental matrices such as soil and sediment.

The objective of this study was to assess the level of this contaminant in the environment of the oil palm industry, by conducting environmental monitoring for dioxins/furans at selected palm oil processing premises. Samples from ambient air in the vicinity of palm oil processing facilities and soil samples from oil palm

plantations were collected for analyses. The congener profiles were evaluated to observe the trend of dioxins/furans contamination in both matrices.

## Materials and Methods

### Sampling Sites

Two oil palm producers were selected for this study. The selected oil palm producers are located in Banting (Selangor) and Teluk Intan (Perak) and for the purpose of this study the oil palm premises are known as Premise A and B, respectively. Sampling at Premise A was carried out from March to April 2009 while Premise B was conducted from February to March 2010. Figure 1 shows the locations of Premise A and B sampling sites.

### Samples Collection

Air samples were collected using high volume sampler, HVS-6 (Altamon GmbH, Germany). The sampler was equipped with glass fiber filter to collect dioxins/furans in suspended particulate matter and polyurethane foam plug to collect dioxins/furans in the gas phase. The samplers were operated continuously for 72 h (Coutinho et al. 2007). The soil samples were collected randomly from three different plots of each plantations at the surface layer (top 1–5 cm) using pre-cleaned stainless steel scoop and stored in glass bottle (Method 1613, US EPA 1994).

### Analytical Method

*Extraction*. Method of extraction was based on US EPA Method 1613 and 8290 for soil samples and US EPA Method TO-9A for ambient air (US EPA 1994, 1999). Dried soil samples (10 g) were mixed with hydromatrix (previously mixed with sodium sulfate anhydrous) and the mixture was ground into finely divided solid. The mixture was then spiked with 250 ppb of $^{13}C_{12}$ labeled EDF 8999 dioxins/furans Internal Standard solution before loading into the accelerated solvent extraction (ASE) cell. The extraction was completed within 15 min with temperature and pressure set at 110°C and 2000 p.s.i and with toluene as the extraction solvent. The ambient air samples were extracted using conventional Soxhlet extraction. The polyurethane foam plug and glass fiber filter (previously spiked with 100 ppb of $^{13}C_{12}$ labeled EDF 8999 dioxins/furans Internal Standard solution) were taken out from the sampling cartridge and placed in a Soxhlet extractor fitted with 500 mL boiling flask containing 300 mL toluene. The samples were then extracted for 16 h.


FIGURE 1. Location of Premise A and Premise B sampling sites

*Clean-up*. All samples were then subjected for clean-up and purification using multi column power-prep™ clean-up system supplied by fluid management system (Watertown, MA, USA). The collected dioxins/furans fractions were then concentrated to near dryness using rotary evaporator. The fractions were spiked again with 250 ppb (for soil samples) and 100 ppb (for ambient air samples) of $^{13}C_{12}$ labeled EDF 5999 dioxins/furans recovery standard solution before being further concentrated using nitrogen stream to approximately 10-15 µL. The final extracts were then transferred into auto sampler vial for GC/HRMS analysis. The recoveries for ambient air samples analyzed ranged from 74% to 99% while the percentage recoveries for soils ranged from 61% to 74%. The percentage recoveries for both matrices were satisfactory based on US EPA method 1613 and US EPA TO 9A method (US EPA 1994, 1999).

*Instrumentation*. The chromatographic separations for dioxins/furans congener were done using gas chromatography/high resolution mass spectrometry (GC/HRMS) system. Separations of dioxins/furans congener were carried out on Trace GC ultra gas chromatography coupled to double focusing sector (DFS) high resolution mass spectrometry (Themo Finnigan, Bremen, GER). The system was operated at 10000 resolutions with PFTBA as reference standard for mass calibration. The chromatography column used was Rtx®-Dioxin2 (60 m, 0.25 mm i.d. capillary clomun) obtained from Restek, USA.

## RESULTS AND DISCUSSION

### CONCENTRATION AND CONGENER PROFILE OF DIOXINS/FURANS IN AMBIENT AIR

The concentration of dioxins/furans in ambient air samples ranged from 64.14 WHO–TEQ fg $m^{-3}$ to 131.87 WHO–TEQ fg $m^{-3}$ for Premise A and 9.93 WHO–TEQ fg $m^{-3}$ to 16.66 WHO–TEQ fg $m^{-3}$ for Premise B. Table 1 shows the dioxins/furans concentration of ambient air at mill and refinery of Premises A and B. The results from the analysis of ambient air samples indicated higher concentrations in Premise A compared with Premise B. The high concentration of dioxins/furans in all sampling points at Premise A is believed to be contributed by the location of the palm oil processing facilities at Premise A. The mill and refinery of Premise A is situated in an industrialized area, while the mill and refinery of Premise B is situated in a rural area where there are not many industrial establishments nearby. The refinery of Premise A which exhibited the highest concentration of dioxins/furans is surrounded by factories, incinerators and processing plants.

This observation was consistent with the previous literature, given that combustion was believed to be one of the principal sources of dioxins/furans in the environment (Jones & Lohmann 1998). Jones and Lohmann (1998) also suggested that the typical increasing trend of the general gradient for dioxins/furans concentration in the environment is as follows: remote (∑ TEQ 10 fg $m^{-3}$); rural (∑ TEQ 20-50 fg $m^{-3}$) and urban industrial (∑ TEQ 100-400 fg

TABLE 1. Dioxins/furans concentration of ambient air from Premise A and B mill and refinery

| | Concentration (in pg $m^{-3}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | AA-1 | AA-2 | AA-3 | AA-4 | AB-1 | AB-2 | AB-3 | AB-4 |
| 2,3,7,8–TetraCDD | 3.10 | 1.50 | 0.80 | 1.50 | 0.66 | 0.46 | 0.35 | 2.66 |
| 1,2,3,7,8–PentaCDD | 11.60 | 6.00 | 5.00 | 5.60 | 2.49 | 1.32 | 0.77 | 0.64 |
| 1,2,3,4,7,8–HexaCDD | 3.40 | 3.00 | 2.50 | 0.60 | 0.67 | 0.36 | 0.19 | 0.21 |
| 1,2,3,6,7,8–HexaCDD | 5.40 | 7.60 | 5.10 | 2.00 | 5.10 | 1.75 | 0.63 | 0.54 |
| 1,2,3,7,8,9–HexaCDD | 3.50 | 3.90 | 2.90 | 1.40 | 2.55 | 0.90 | 0.37 | 0.45 |
| 1,2,3,4,6,7,8–HeptaCDD | 15.60 | 11.30 | 15.40 | 2.40 | 38.72 | 7.22 | 5.96 | 2.88 |
| OctaCDD | 28.80 | 11.30 | 5.10 | 1.40 | 263.86 | 63.02 | 66.30 | 32.58 |
| 2,3,7,8–TetraCDF | 32.00 | 10.90 | 12.70 | 11.50 | 1.32 | 2.97 | 2.88 | 2.86 |
| 1,2,3,7,8–PentaCDF | 23.80 | 10.70 | 11.20 | 9.70 | 0.84 | 2.42 | 2.23 | 1.86 |
| 2,3,4,7,8–PentaCDF | 33.00 | 23.80 | 22.70 | 15.50 | 0.93 | 2.90 | 2.41 | 2.21 |
| 1,2,3,4,7,8–HexaCDF | 27.30 | 27.70 | 24.50 | 12.10 | 0.70 | 2.44 | 1.95 | 1.71 |
| 1,2,3,6,7,8–HexaCDF | 23.60 | 20.70 | 19.90 | 7.50 | 0.78 | 1.84 | 1.39 | 1.58 |
| 1,2,3,7,8,9–HexaCDF | 19.30 | 32.20 | 22.20 | 8.00 | 0.81 | 1.91 | 1.44 | 1.64 |
| 2,3,4,6,7,8–HexaCDF | 6.20 | 1.40 | 7.90 | 0.90 | 0.84 | 1.71 | 0.86 | 1.18 |
| 1,2,3,4,6,7,8–HeptaCDF | 38.10 | 64.40 | 44.60 | 14.00 | 0.39 | 0.30 | 0.15 | 0.20 |
| 1,2,3,4,7,8,9–HeptaCDF | 3.70 | 2.10 | 3.40 | 1.00 | 0.40 | 0.31 | 0.16 | 0.21 |
| OctaCDF | 8.90 | 0.30 | 1.40 | 1.50 | 5.52 | 0.45 | 0.70 | 0.41 |
| Sum PCDD | 71.40 | 44.60 | 36.80 | 14.90 | 314.05 | 75.03 | 74.57 | 39.96 |
| Sum PCDF | 215.90 | 194.20 | 170.5 | 81.70 | 12.53 | 17.25 | 14.17 | 13.86 |
| WHO-TEQ DIOXINS/FURANS (pg $m^{-3}$) | 0.1319 | 0.0908 | 0.0861 | 0.0641 | 0.0151 | 0.0131 | 0.0009 | 0.0170 |
| WHO-TEQ DIOXINS/FURANS (fg $m^{-3}$) | 131.87 | 90.84 | 86.13 | 64.14 | 15.06 | 13.11 | 9.93 | 16.66 |

AA-1 = Ambient air at Premise A refinery (sampling point 1)
AA-2 = Ambient air at Premise A refinery (sampling point 2)
AA-3 = Ambient air at Premise A mill (sampling point 3)
AA-4 = Ambient air at Premise A mill (sampling point 4)
AB-1 = Ambient air at Premise B mill (sampling point 1)
AB-2 = Ambient air at Premise B mill (sampling point 2)
AB-3 = Ambient air at Premise B refinery (sampling point 3)
AB-4 = Ambient air at Premise B refinery (sampling point 4)

$m^{-3}$). Therefore, by using this characterization, the level of dioxins/furans at Premise A falls under the urban industrial area category while Premise B falls under the rural area category. The concentrations of dioxins/furans in samples at Premise A were more varied. The highest concentration recorded was 131.87 WHO-TEQ fg $m^{-3}$ while the lowest concentration was 64.14 WHO-TEQ fg $m^{-3}$. Similar trend of ambient air dioxins/furans concentration was reported by Martinez et al. (2010) in the study conducted to assess the influence of dioxins/furans emissions from an industrial estate on the ambient air of a town in Catalonia, Spain. The concentrations reported from the study were in the range of 41.39 i-TEQ fg $m^{-3}$ to 121.91 i-TEQ fg $m^{-3}$. Another study carried out by Coutinho et al. (2007) to monitor the ambient air dioxins/furans levels in several places in Portugal also showed similar profile of dioxins/furans ambient air concentration in the urban industrial area. The ambient air dioxins/furans concentrations reported from the study ranged from of 39.0 i-TEQ fg $m^{-3}$ to 151.0 i-TEQ fg $m^{-3}$.

The concentration of dioxins/furans at various points at the mill and refinery of Premise B were more comparable with each other. The comparable level of dioxins/furans concentrations at all sampling points in Premise B is believed to be contributed by the adjacent locations of both the mill and refinery. As defined by Jones and Lohmann (1998), the concentration level of ambient air dioxins/furans sampled at Premise B falls under the rural area category. The results obtained from this study were in agreement with the level of ambient air dioxins/furans recorded by Coutinho et al. (2007). The study conducted by Coutinho et al. (2007) to monitor the ambient air dioxins/furans level in Portugal showed a range between 4.0 WHO-TEQ fg $m^{-3}$ and 25 WHO-TEQ fg $m^{-3}$ for ambient air samples collected in the rural area. However, in Italy, a decreasing level of dioxins/furans was reported by Menichini et al. (2007) with values between 2.95 WHO-TEQ fg $m^{-3}$ and 5.07 WHO-TEQ fg $m^{-3}$ for samples collected from the rural area.

Congener profile was analyzed in order to determine and observe the congener profile distribution of dioxins/furans in the ambient air samples collected at the mills and refineries of the two premises. Observation from this study indicated a significant difference of a dioxins/furans profile between Premises A and B ambient air samples. Figures 2 and 3 show the congener profile of dioxins and furans from ambient air samples collected at Premises A and B, respectively. The congener profile of Premise A was slightly scattered between dioxins and furans homologues. However, the furans congeners dominated the congener profile of Premise A ambient air samples, with 1,2,3,4,6,7,8–HeptaCDF contributed the highest percentage of concentration (29.67%) followed by 2,3,4,7,8–PentaCDF > 1,2,3,4,7,8–HexaCDF > 2,3,4,6,7,8–HexaCDF. As for Premise B, the congener profile was mostly dominated by dioxins homologues with OctaCDD contributed more than 60% of the concentration, followed by 1,2,3,4,6,7,8–HpCDD and 2,3,7,8–TCDF with concentrations of 5.35% and 5.31%, respectively. With different congener profiles of dioxins and furans observed in Premises A and B ambient air samples, the contribution of dioxins and furans also differed for both premises. The ambient air samples of Premise A were mostly influenced by furans homologues while the ambient air samples of Premise B were dominantly influenced by dioxins homologues. Furans homologues in Premise A contributed about 75% to 85% of the concentration while in Premise B the dioxins homologues represent 74% to 96% of the concentration.

As observed in this study, both premises had different congener profiles of dioxins and furans. The profile of dioxins/furans at mill and refinery of Premise A was dominated by 1,2,3,4,6,7,8–HeptaCDF > 2,3,4,7,8–PentaCDF

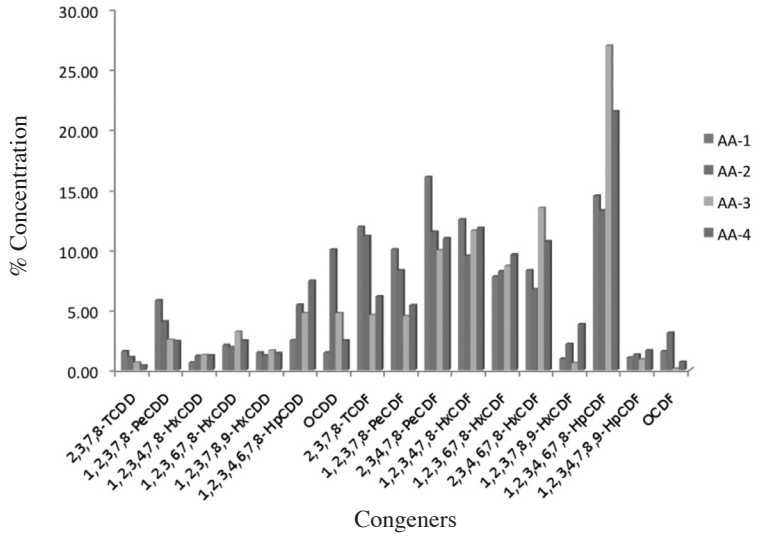


FIGURE 2. Congener profile distribution of dioxins/furans from ambient air samples collected at Premise A

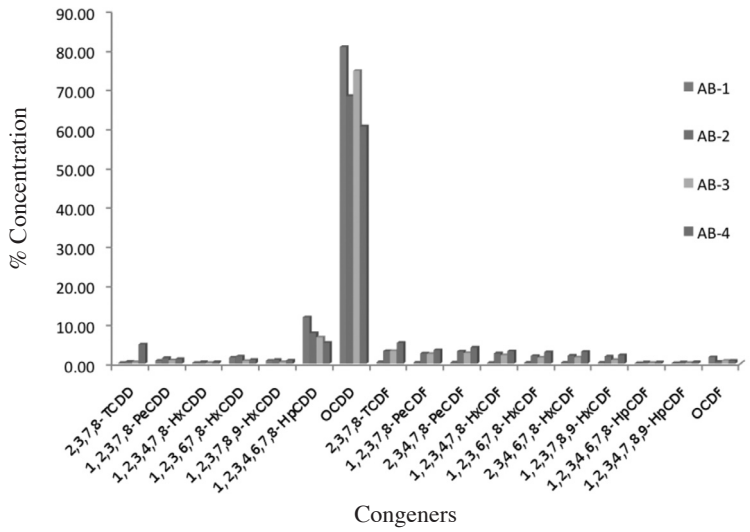


FIGURE 3. Congener profile distribution of dioxins/furans from ambient air samples collected at Premise B

> 1,2,3,4,7,8–HexaCDF > 2,3,4,6,7,8–HexaCDF while mill and refinery of Premise B was dominated by OctaCDD > 1,2,3,4,6,7,8–HpCDD > 2,3,7,8–TCDF. The difference between the congener profiles of Premises A and B are due to the locations of both premises where Premise A is located in an industrial area while Premise B is located in a rural area. A thorough literature review on ambient air measurement from Europe, USA, Japan and Australia was done by Jones and Lohmann (1998) and they concluded that the relative contribution of OctaCDD to the sum of dioxins/furans appeared to be generally higher in rural area. The contribution of OctaCDD to the sum of dioxins/furans could be expected to be more than 50%. The findings from the literature review were in agreement with the results obtained from this study, where OctaCDD contributed more than 60% of the dioxins/furans in the ambient air samples collected at Premise B which is located in a rural area.

## CONCENTRATION AND CONGENER PROFILE OF DIOXIN/FURAN IN SOIL

The concentrations of dioxins/furans in the soil at Premises A and B plantations ranged from 1.910 WHO-TEQ pg $g^{-1}$ dry weight to 3.305 WHO-TEQ pg $g^{-1}$ dry weight. Table 2 shows the dioxins/furans concentrations of soil samples collected at Premises A and B plantations. The highest concentration of dioxins/furans was observed in the soil collected at Premise A (SA-1) while the lowest concentration of dioxins/furans was also recorded at Premise A plantation (SA-2). The concentration of dioxins/furans in the soil at Premise B was comparable with the concentration values ranged from 2.298 WHO-TEQ pg $g^{-1}$ dry weight (SB-1), 2.212 WHO-TEQ pg $g^{-1}$ dry weight (SB-2) and 2.210 WHO-TEQ pg $g^{-1}$dry weight (SB-3). These indicated that the level of dioxins/furans in the soil at Premise B plantation was uniformly distributed among the plots, whereas the level of dioxins/furans of the plots in the soil at Premise A plantation was varied. The highest content of dioxins/furans in SA-1 was probably attributed to the location of the plot which was situated beside the main road of the plantation. The road was heavily used by vehicles (lorry, truck) and the exhaust gases and soot emitted from the vehicle combustion could have deposited onto the soil further leading to the high dioxins/furans content in the soil. A study carried out by Choi et al. (2003) showed a significant contribution of exhausts from vehicle combustion towards dioxins/furans concentration in soil samples collected along the edges of several highways in the Republic of Korea. Thus, it was evident that the observed levels of dioxins/furans concentration in soil could also be influenced by the vehicle combustion. The other sampling plots were located far from the main road where there was not much vehicle activities observed during the period of the sampling.

The average concentration of dioxins/furans in soil samples collected in this study was 2.340 WHO-TEQ pg $g^{-1}$ dry weight. This value was lower than the average concentration of dioxins/furans in agriculture soil collected at several places in Taiwan (Jou et al. 2007) but higher than average concentrations of dioxins/furans in agriculture and background soil observed in numerous locations of eastern China (Liu & Lin 2009). As described by Nieuwoudt et al. (2009), the concentrations of dioxins/furans in the samples differed depending on the location and activities done on the soil. For example, soils from industrial area of South Africa contained up to 11.10 WHO-TEQ pg $g^{-1}$ dry weight of dioxins/furans concentration while that from residential area, the levels of dioxins/furans were up to 5.4 WHO-TEQ pg $g^{-1}$ dry weight.

In order to protect human health from this toxic compound, the Canadian Council of Ministers of the Environment (CCME 2002) has established guidelines for the level of dioxins/furans in the soil. The soil quality for dioxins/furans in all types of soil uses (agriculture, residential/parkland, commercial, industrial) was set at 4

TABLE 2. Dioxins/furans concentration of soil samples collected from Premise A and B plantations

| | Concentration (in pg $g^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | SA-1 | SA-2 | SA-3 | SB-1 | SB-2 | SB-3 |
| 2,3,7,8–TetraCDD | 0.70 | 0.11 | 0.13 | 0.16 | 0.31 | 0.14 |
| 1,2,3,7,8–PentaCDD | 0.82 | 0.71 | 0.63 | 0.64 | 0.64 | 0.72 |
| 1,2,3,4,7,8–HexaCDD | 2.30 | 1.86 | 1.64 | 0.63 | 0.70 | 0.66 |
| 1,2,3,6,7,8–HexaCDD | 2.56 | 2.10 | 1.83 | 1.89 | 1.51 | 1.57 |
| 1,2,3,7,8,9–HexaCDD | 4.39 | 3.68 | 3.33 | 5.27 | 3.42 | 4.43 |
| 1,2,3,4,6,7,8–HeptaCDD | 30.45 | 29.41 | 26.08 | 41.40 | 29.74 | 36.12 |
| OctaCDD | 341.62 | 314.63 | 179.24 | 343.87 | 245.06 | 295.93 |
| 2,3,7,8–TetraCDF | 0.37 | 0.18 | 0.18 | 0.28 | 0.78 | 0.48 |
| 1,2,3,7,8–PentaCDF | 0.65 | 0.27 | 0.23 | 0.46 | 0.61 | 0.54 |
| 2,3,4,7,8–PentaCDF | 0.57 | 0.18 | 0.15 | 0.19 | 0.38 | 0.26 |
| 1,2,3,4,7,8–HexaCDF | 0.38 | 0.12 | 0.15 | 0.23 | 0.23 | 0.21 |
| 1,2,3,6,7,8–HexaCDF | 0.41 | 0.17 | 0.17 | 0.27 | 0.34 | 0.25 |
| 1,2,3,7,8,9–HexaCDF | 0.56 | 0.16 | 0.15 | 0.28 | 0.35 | 0.26 |
| 2,3,4,6,7,8–HexaCDF | 0.67 | 0.25 | 0.32 | 0.21 | 0.24 | 0.18 |
| 1,2,3,4,6,7,8–HeptaCDF | 2.31 | 0.92 | 0.71 | 0.12 | < 0.04 | < 0.03 |
| 1,2,3,4,7,8,9–HeptaCDF | 0.23 | < 0.04 | 0.10 | 0.12 | < 0.04 | < 0.03 |
| OctaCDF | 18.53 | 4.28 | 0.84 | 6.04 | 0.40 | < 0.09 |
| Sum PCDD | 382.84 | 352.5 | 212.88 | 393.86 | 278.36 | 339.57 |
| Sum PCDF | 24.68 | 6.57 | 3.00 | 8.2 | 3.41 | 2.33 |
| WHO-TEQ DIOXINS/FURANS (pg $g^{-1}$) | 3.305 | 2.132 | 1.910 | 2.298 | 2.212 | 2.210 |

SA-1 = Soil at Premise A (sampling point 1)
SA-2 = Soil at Premise A (sampling point 2)
SA-3 = Soil at Premise A (sampling point 3)
SB-1 = Soil at Premise B (sampling point 1)
SB-2 = Soil at Premise B (sampling point 2)
SB-3 = Soil at Premise B (sampling point 3)
< below limit of quantification

WHO-TEQ pg $g^{-1}$ d.w. In this study, the concentrations of dioxins/furans in the soil analyzed were lower than the value imposed by the Canadian Council of Ministers of the Environment (CCME).

The congener profiles of dioxins/furans in all soil samples collected were mostly dominated by OctaCDD which contributed more than 80% of the total dioxins and furans concentration. This pattern of congener profile was in agreement with the study conducted on the soil in eastern China (Liu & Liu 2009) and samples of soil and sediment in the industrial area of central South Africa (Nieuwoudt et al. 2009) which reported similar proportion of OctaCDD in the samples analyzed. The other congeners such as TetraCDF, PentaCDF, HexaCDF, TetraCDD, PentaCDD were less significant compared with the total concentration of dioxins/furans in the soil samples. In this study, the congener profile for the soil samples analyzed under oil palm cultivation area was dominated by OctaCDD > 1,2,3,4,6,7,8-HeptaCDD > 1,2,3,7,8,9- HexaCDD > OctaCDF. Figures 4 and 5 show the congener profile patterns of dioxins/furans in the soil samples collected from Premises A and B, respectively. These congener profiles were comparable with the dioxins/furans profiles reported in agricultural soil of Taiwan (Jou et al. 2007). However, the congener profiles of dioxins/furans in soil were comparatively different depending on the location of the sampling area. Zhang et al. (2009) reported the congener profile of dioxins and furans in order of 1,2,3,7,8–PentaCDD > 1,2,3,4,6,7,8–HeptaCDD > OCDD > 1,2,3,4, 7,8–HexaCDF in the soil samples collected from Pearl River Delta of China, while the congener pattern of dioxins and furans reported in paddy soil of Matsuyama, Japan were dominated by 1,3,6,8–TetraCDD > 1,3,7,9–TetraCDD > 2,4,6,8–TetraCDF (Seiki et al. 2001).

## CONCLUSION

The dioxins/furans level in ambient air of palm oil processing facilities is significantly influenced by the location of the facilities, especially when it is surrounded by many industrial establishments. The congener profiles of dioxins/furans were different between ambient air samples analyzed from Premises A and B. The congener profile of Premise A was dominated by furan congeners with all samples showing congener pattern in the following order : 1,2,3,4,6,7,8–HeptaCDF > 2,3,4,7,8–PentaCDF > 1,2,3,4,7,8–HexaCDF > 2,3,4,6,7,8–HexaCDF. Meanwhile, the congener profile for Premise B was dominated by dioxin congeners with OctaCDD contributing more than 60% of the concentration followed by 1,2,3,4,6,7,8–HeptaCDD and 2,3,7,8–TetraCDF. The level of dioxins/furans in soils of Premises A and B plantations ranged from 1.910 WHO–TEQ pg $g^{-1}$ dry weight to 3.305 WHO–TEQ pg $g^{-1}$ dry weight. Vehicle combustion emitting gases and soot was a probable source contributing to the higher level of dioxins/furans in soil as samples collected near the main road heavily used by vehicles (lorry and truck) recorded the highest concentration compared with other samples. The concentration for dioxins/furans did not exceed the limit of the soil quality guidelines imposed by Canadian Council of Ministers of the Environment (CCME). The congener profile

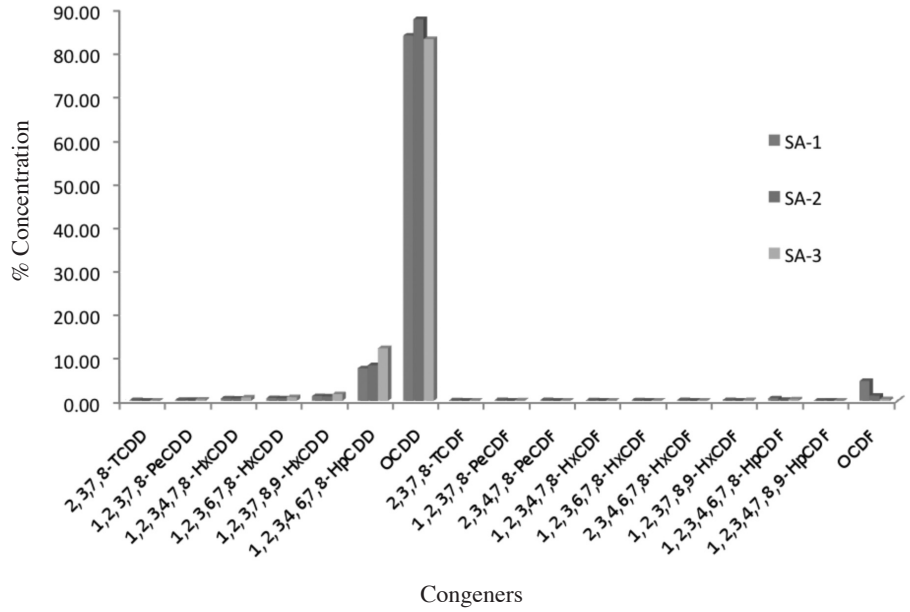


FIGURE 4. Congener profile of dioxins/furans in soil of Premise A

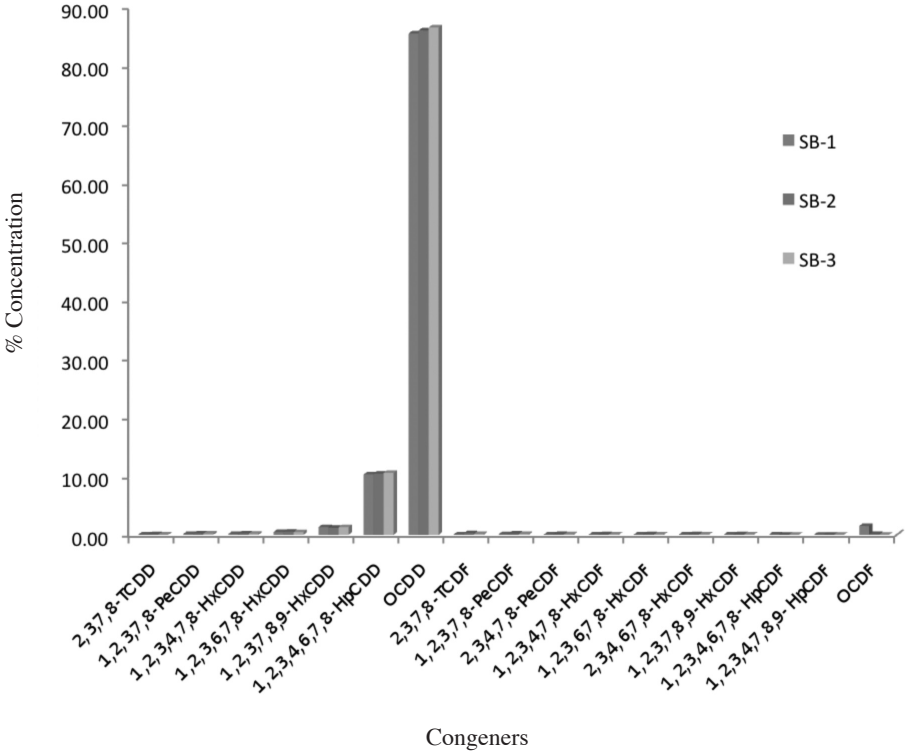


FIGURE 5. Congener profile of dioxins/furans in soil of Premise B

for soils in both premises demonstrated similar pattern of dioxins/furans congener with the profile in the order of OctaCDD > 1,2,3,4,6,7,8–HeptaCDD > OctaCDF.

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