Persistent Organic Pollutants in the air. Evaluation of passive air sampler measurements close to the Map Ta Phut industrial estate, Thailand

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Evaluation of passive air sampler measurements close to the Map Ta Phut industrial estate, Thailand

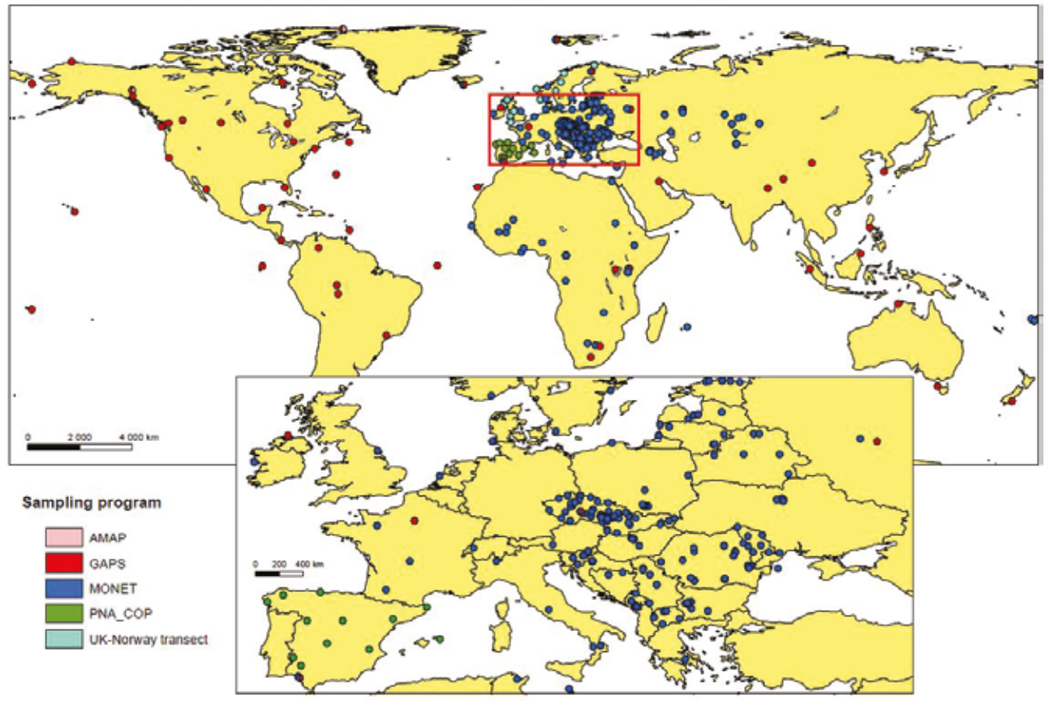
Alice Dvorská, Ph.D., December 2018

Introduction

Passive samplers are chemical accumulators that can be used to assess ambient concentrations in either homogeneous or heterogeneous media into which they are deployed. They are increasingly employed in investigations of persistent organic pollutants (POPs) (Shoeib and Harner, 2002). There are various PAS sampling media and designs used. In contrast to high-cost active air samplers, passive air samplers (PAS) do not require pumps, sampling heads and a source of electricity. They are inexpensive and small and therefore increasingly used for POPs monitoring and spatial studies at local, regional and continental scales (Pozo et al., 2009 and references therein). In some regions they are the only source of information on POP levels. Passive air monitoring programs measuring POPs include the Global Atmospheric Passive Sampling (GAPS) Network, the Monitoring Network (MONET) in Europe, Africa and Asia, the Latin American Passive Atmospheric sampling Network (LAPAN) and others (Klánová and Harner, 2013).

The objective of the Stockholm Convention (SC) on POPs is to protect human health and the environment from POPs by reducing or eliminating releases to the environment. Parties of the SC have agreed that they need a mechanism to measure whether this objective is reached. The Global Monitoring Plan (GMP) for POPs is an important component of the effectiveness evaluation of the SC. Monitoring activities under the GMP are focused on generating measurement data from core media: ambient air, human milk and human blood and surface water for water-soluble POPs. The objective of ambient air sampling is to obtain representative data for assessing the baseline levels and changes in concentrations over time and space as well as the regional and global transport of POPs. Passive (Figure 1) and active air sampling is employed under the GMP (UNEP, 2018).

Figure 1: Passive air sampling sites operating under existing air monitoring programmes for POPs that are contributing to the GMP as of 2013 (UNEP, 2013).



When using and interpreting PAS data, significant differences compared to active air samplers have to be considered. *While active sampling relates sequestered amounts of analytes to the measured volume of air in order to derive chemical concentrations in air, this volume is uncertain for passive sampling. Therefore a sampling rate (i.e. a characteristic volume of air that is stripped by the passive sampling medium per unit of time) is being determined. The calculation or estimation of compound-specific or generic sampling rates and determination of the most important parameters affecting these rates have been a subject of numerous studies (Kalina et al., 2017 and references therein).* The most precise measure of the air volume sampled may be achieved by spiking the sorbent prior to exposure with known quantities of depuration compounds. Then it is possible to report semi-quantitative concentrations for a polyurethane foam (PUF) PAS with an expected accuracy within about a factor of 2 (Gouin et al., 2005).

PUF PAS are usually deployed for three months which provides an equivalent air sample volume of approximately 360 m^3. This is sufficient for the detection of most of POPs. Shorter integration periods of 1 month have also been incorporated successfully (UNEP, 2013). In contrast to this long periods, active air samplers are deployed episodically, e.g. for 24 hours. The greater uncertainty associated with air concentration values derived from PAS is thus balanced by the benefit that PAS provide a time-weighted, average air concentration, which integrates the “highs” and “lows” that can be missed by episodic sampling (Klánová and Harner, 2013).

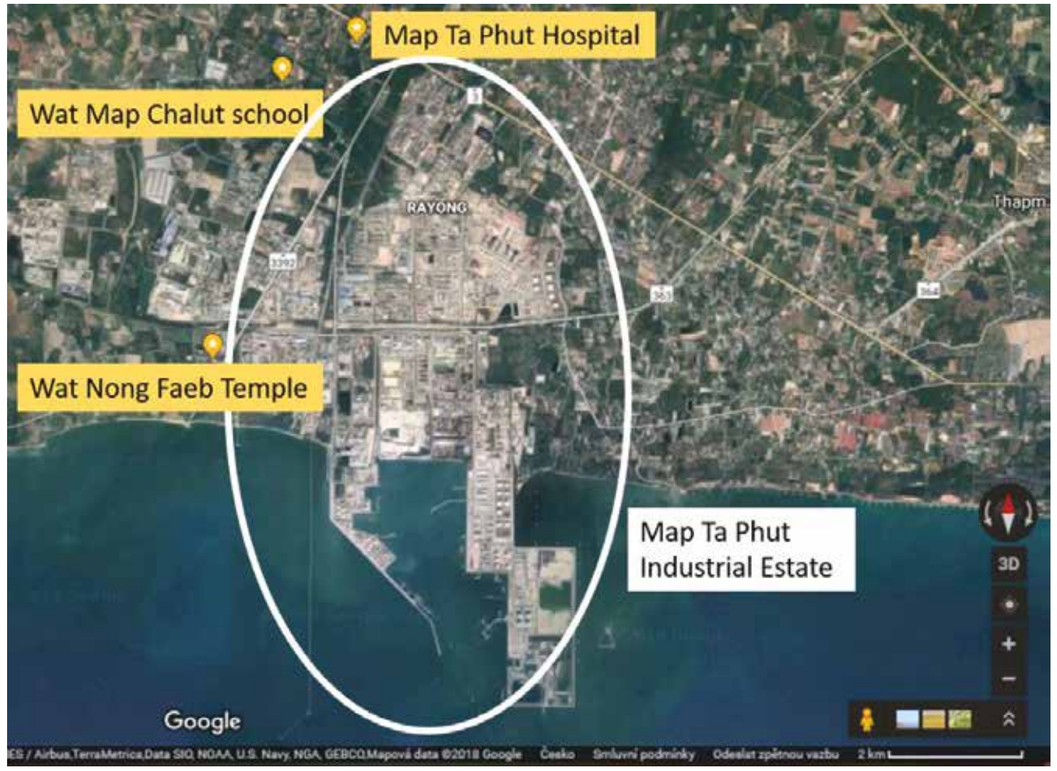
Sampling campaign

The air samples in the close vicinity of the Map Ta Phut Industrial Estate were taken by the passive sampling method. Three sampling spots of interest (see also Table 1 and Figure 2) were chosen: the Map Ta Phut Hospital, the Wat Map Chalut School and the Wat Nong Faeb Temple. Samplers were installed at all three sampling spots on July 25th, 2017 and uninstalled on September 12th, 2017. Thus, the passive air samplers were exposed for 50 days. The weather during sampling was hot with average temperatures of 28.6°C and 28.9°C in July and September 2017, respectively. The predominant wind direction was southwest in July and August and west in September.. Additionally, two blank samples were taken in order to exclude sources of unintentionally introduced contamination during transport, storage and analysis.

Table 1: List of samples

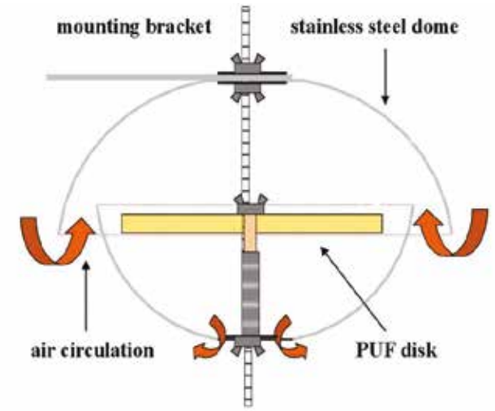
Name (sample number)	Coordinates	Sampling spot description
Map Ta Phut Hospital (MTP Air-1)	12°43‘43.9“N 101°08‘10.6“E	No combustion sources in the vicinity of the site, no waste or biomass burnt nearby, no residential houses nearby, sampled south of the hospital 6 m above ground on a water tower next to play ground
Wat Map Chalut School (MTP Air-2)	12°43‘24.6“N 101°07‘33.4“E	No combustion sources in the vicinity of the site, no waste or biomass burnt nearby, occasional cremations conducted nearby, for eventual cooking in school LPG is used, sampled at the school premises at 6 m above ground on a water tower
Wat Nong Faeb Temple (MTP Air-3)	12°41‘10.3“N 101°06‘58.9“E	Sometimes general waste and dry leaves are burnt nearby, charcoal, firewood and LPG used for cooting and heating in residential houses nearby, incense being burnt only inside of the temple and quite far from the sampling spot. Sampled at the temple tower in front of the temple, 1st floor, about 5-6 m above ground, north side
Blank - Sept		Field blank brought onsite during uninstallation of samplers in September 2017
Blank No. 2		Blank kept in the fridge

Figure 2: Map of sampling sites



The PAS used in this study consist of a PUF disc housed in a stainless steel chamber consisting of two bowls, one with a diameter of 30 cm and the other of 24 cm (Figure 3). The sampling occurs through spontaneous diffusion of the analyte to the sorbent media – PUF. POPs are sampled as air naturally diffuses into the sampler housing and around the PUF, which then sorbs the target compounds. Subsequently, the POP content in the PUF is determined using analytical methods (Monairnet, 2018).

Figure 3: Scheme and deployment of a passive air sampler



Analysis

Precleaned PUF discs for PAS were obtained from E&H services, Prague, Czech Republic. This company is specialized in POPs elimination and passive sampling techniques and runs an accredited laboratory. The PUF discs were wrapped in two layers of aluminium foil and stored in a plastic bag in a fridge. The exposed discs were analysed for content of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (DL PCBs). The analysis was conducted using high-resolution gas chromatography/high-resolution mass spectrometry at the accredited laboratories of the State Veterinary Institute, Department of Chemistry, Prague, Czech Republic. Before analysis, the discs were cut into three pieces, which were weighted individually. Table 2 contains information on the approximate weight of each disc obtained by adding up weights of individual disc pieces.

Table 2: Approximate weight of PUF discs

Sample number	PUF disc weight (g)
MTP Air-1	6.57
MTP Air-2	7.26
MTP Air-3	6.93
Blank - Sept	6.81
Blank No. 2	6.80

Results

Results of chemical analyses of PCDD/Fs and DL PCBs are presented in Tables 3 and 4, respectively. A graphical visualisation of the results is presented in Figures 4 and 5. The units used are pg of analyte per g of PUF disc as reported by the laboratory. Analyte concentrations in blanks are predominantly under the limit of detection (LOD) and considerably lower than in samples taken in the vicinity of the Map Ta Phut Industrial Estate. DL PCBs and PCDFs exhibit predominantly measurable concentrations in samples taken in the vicinity of the Map Ta Phut industrial estate, while PCDDs concentrations were often below LOD.

Table 3: Analysis results for PCDD/Fs in pg/g

	MTP Air-1	MTP Air-2	MTP Air-3	Blank Sept	Blank No. 2
2,3,7,8-TCDD	0.093	<0.061	<0.061	<0.061	<0.061
1,2,3,7,8-PeCDD	0.161	0.099	<0.074	<0.074	<0.074
1,2,3,4,7,8-HxCDD	<0.079	<0.087	<0.079	<0.079	<0.079
1,2,3,6,7,8-HxCDD	0.127	0.107	<0.066	<0.066	<0.066
1,2,3,7,8,9-HxCDD	<0.093	<0.097	<0.059	<0.059	<0.059
1,2,3,4,6,7,8-HpCDD	0.430	0.383	0.402	0.135	0.119
OCDD	0.810	0.831	0.535	0.367	0.319
2,3,7,8-TCDF	0.535	0.505	0.498	<0.039	<0.039
1,2,3,7,8-PeCDF	0.630	0.531	0.283	<0.081	<0.081
2,3,4,7,8-PeCDF	0.581	0.474	0.580	<0.073	<0.073
1,2,3,4,7,8-HxCDF	0.416	0.399	0.306	<0.080	<0.080
1,2,3,6,7,8-HxCDF	0.411	0.383	0.258	<0.061	<0.061
1,2,3,7,8,9-HxCDF	<0.057	<0.057	<0.057	<0.057	<0.057
2,3,4,6,7,8-HxCDF	<0.074	<0.068	0.239	<0.068	<0.068
1,2,3,4,6,7,8-HpCDF	0.555	0.456	0.464	<0.078	<0.078
1,2,3,4,7,8,9-HpCDF	<0.064	<0.064	<0.064	<0.064	<0.064
OCDF	<0.183	<0.183	<0.183	<0.183	<0.183
WHO-PCDD/F-TEQ*	0.637	0.498	0.483	0.212	0.212

*sum of toxicity equivalents of the 17 toxicologically most important dioxins and furans (according to the WHO 2005 scheme). Upperbound concentrations are calculated assuming that all values of the different congeners less than the LOD are equal to the LOD.

Table 4: Analysis results for DL PCBs in pg/g

	MTP Air-1	MTP Air-2	MTP Air-3	Blank - Sept	Blank No. 2
PCB 81	0.672	0.558	0.604	<0.078	<0.078
PCB 77	3.850	3.490	2.640	0.321	0.251
PCB 123	0.510	0.489	<0.317	<0.317	<0.317
PCB 118	15.700	14.100	7.420	2.530	3.110
PCB 114	0.997	1.120	0.911	<0.292	<0.292
PCB 105	6.370	6.300	2.900	0.669	0.545
PCB 126	1.350	1.290	1.440	<0.086	<0.086
PCB 167	1.050	1.150	1.230	0.393	0.361
PCB 156	2.570	2.340	2.580	1.070	0.927
PCB 157	0.492	0.594	0.542	<0.254	<0.254
PCB 169	0.202	0.149	0.165	<0.143	<0.143
PCB 189	0.359	0.468	0.661	<0.274	<0.274
WHO-PCDD/F-PCB-TEQ*	0.779	0.633	0.633	0.225	0.225

*total dioxin equivalent, i.e. the sum of WHO-PCDD/F-TEQ and WHO-PCB-TEQ (according to the WHO 2005 scheme). Upperbound concentrations are calculated assuming that all values of the different congeners less than the LOD are equal to the LOD.

Figure 4: Analysis results for PCDD/Fs in pg/g (concentrations below LOD are not displayed)

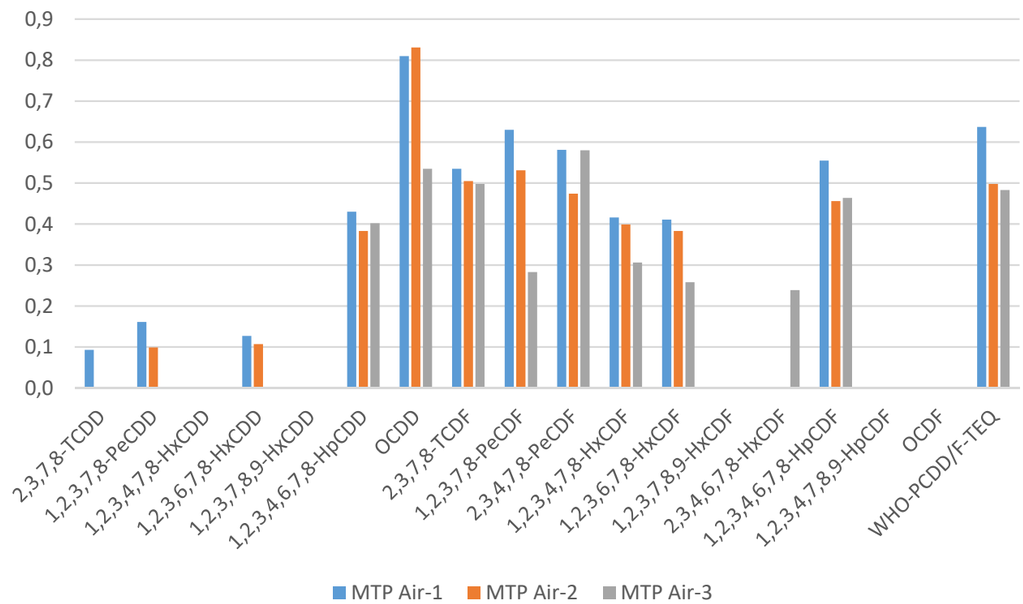
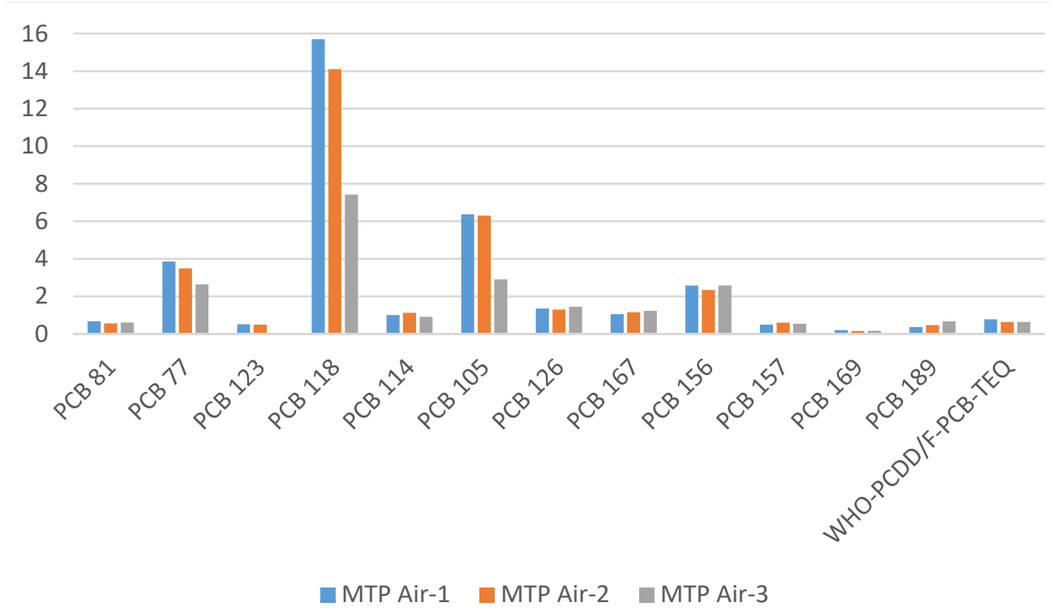


Figure 5: Analysis results for DL PCBs in pg/g (concentrations below LOD are not displayed)



Samples MTP Air-1 (Map Ta Phut Hospital) and MTP Air-2 (Wat Map Chalut School) exhibit similar concentrations of most PCDD/F congeners, while sample MTP Air-3 (Wat Nong Faeb Temple) have lower concentrations of some PCDD/F congeners. However, the WHO--PCDD/F-TEQ in sample MTP Air-3 is similar to sample MTP Air-2 and both are slightly lower than in sample MTP-Air-1. Many of DL PCB congeners have the lowest concentrations in sample MTP Air-3 (Wat Nong Faeb Temple), however, its WHO-PCDD/F-PCB-TEQ is the same as for sample MTP Air-2 (Wat Map Chalut School) and both are lower than in sample MTP Air-1 (Map Ta Phut hospital).

Discussion

When considering the WHO-PCDD/F-TEQ and WHO-PCDD/F-PCB-TEQ values (Tables 3 and 4), the Wat Map Chalut School and Wat Nong Faeb Temple samples exhibit very similar PCDD/Fs and DL PCBs concentrations. The northernmost sampling site at the Map Ta Phut Hospital exhibits the highest burden, i.e. the determined PCDD/Fs and DL PCBs levels are about a quarter higher than at the other two sites. It is interesting to note that the Wat Nong Faeb Temple as the only site with known nearby combustion sources (occasional burning of general waste, leaves and incense; Abad et al., 2006; Hu et al., 2009) seems to be the least polluted one among the investigated sites. One of the reasons might be the different land-sea breeze interactions and resulting air mixing, as the Wat Nong Faeb Temple is the site closest to the coastline. The Wat Nong Faeb Temple sample congener profile is also slightly different from the congener profile of the other two samples (Figure 4), which might suggest a different relative contribution of individual pollutant source types.

PCDD/Fs and DL PCBs congener profiles (Figures 4 and 5) and ratios determined in ambient air samples are often used for pollutant source characterization by comparing them with source specific congener profiles and ratios (e.g. Li et al., 2011). However, here we restrain from making this attempt for two reasons. First, PCDD/Fs appear mainly in the particle phase (Saral et al., 2015). However, PUF disc PAS of the design depicted in Figure 3 were originally targeting mainly gas-phase compounds and their efficiency of sampling atmospheric particles is low compared to other types of PAS and active air samplers (Markovic et al., 2015). This might shift the PUF PAS determined PCDD/Fs congener profile and ratios at the Map Ta Phut sampling sites in comparison with source specific profiles and ratios reported in scientific literature, as these are usually obtained by active air samplers. Second, a complex mixture of possible industrial, transport and residential PCDD/Fs and DL PCB sources is present in Map Ta Phut making it hard to identify individual sources due to the frequent overlap of source specific ratios (e.g. Cappelletti et al., 2016 and references therein).

As the here used PAS PUF were not spiked with depuration compounds prior to exposure, it is not possible to determine the site specific air sampling rates and thus obtain semiquantitative air concentrations within about a factor of 2 (Gouin et al., 2005), which is an approach used in scientific papers reporting PAS PUF based PCDD/Fs air concentrations. Here we use units of pg of analyte per weight of a whole PUF disc (Table 2) for the comparison of Map Ta Phut results (Tables 5) with other sites. As the approximate weight of each disc is different, the WHO-PCDD/F-PCB-TEQ for samples MTP Air-2 and MTP Air-3 is different, although it is the same when expressed in pg/g (Table 4). In order to compare the level of PCDD/Fs and DL PCBs air burden in close vicinity of the Map Ta Phut Industrial Estate with sampling at background, urban and industrial sites elsewhere, the range of 3.35-4.19 pg WHO-PCDD/F-TEQ /disc and 0.94-1.04 pg WHO-PCB-TEQ /disc (Table 5) is used.

Table 5: Analysis results for WHO-PCDD/F-TEQ and WHO-PCB-TEQ in pg/disc

	MTP Air-1	MTP Air-2	MTP Air-3
WHO-PCB-TEQ*	0.936	0.979	1.039
WHO-PCDD/F-TEQ**	4.185	3.615	3.349

* sum of toxicity equivalents of the 12 DL PCBs which have been assigned TEFs (according to the WHO 2005 scheme). Upperbound concentrations are calculated assuming that all values of the different congeners less than the LOD are equal to the LOD.

**sum of toxicity equivalents of the 17 toxicologically most important dioxins and furans (according to the WHO 2005 scheme). Upperbound concentrations are calculated assuming that all values of the different congeners less than the LOD are equal to the LOD.

Table 6 contains information on WHO-PCB-TEQ and WHO-PCDD/Fs-TEQ levels at various urban, suburban, background and remote sites. Information on PCDD/Fs and DL-PCBs air concentrations at these sites was obtained from the Global Environmental Assessment and Information System GENASIS (Borůvková et al., 2015). Samplers were exposed for three months (Lammel et al., 2009). African MONET sites were chosen because the same PAS are used in this monitoring network as were used when sampling air close to the Map Ta Phut Industrial Estate. Unfortunately, PAS PCDD/Fs and DL PCBs measurements within the MONET network do not cover tropical Asian regions. Thus, African predominantly tropical sites were chosen and coastal sites were included into the selection in order to make the comparison with the tropical and coastal Map Ta Phut site reasonable. High winds at coastal sites might lead to higher PAS sampling rates (Pozo et al., 2006) thus making such sites specific. Two industrial sites were added into the selection, although they are located in subtropical climate regions.

Table 6: WHO-PCB-TEQ and WHO-PCDD/F-TEQ median values observed at MONET-Africa sampling sites between 2008 and 2017, in pg/disc. WHO 2005 TEF scheme and upperbound concentrations were usedfor TEQ calculation. More detailed site characteristics can be obtained from MONET (2018).

Site name	Coordinates	Type of site	Observed concentrations
Cairo, Egypt	30°4‘16.1“N, 31°18‘54.3“E	Industrial	WHO-PCB-TEQ: NA WHO-PCDD/F-TEQ: 480.3
Vanderbijl Park, South Africa	26°43‘0.0“S, 27°52‘59.9“E	Industrial	WHO-PCB-TEQ: 1.29 WHO-PCDD/F-TEQ: 7.29
Nairobi, Dandora, Kenya	1°14‘35.1“S, 36°54‘22.2“E	Suburban, impacted	WHO-PCB-TEQ: 40.89 WHO-PCDD/F-TEQ: 256.37
Dakar, Ngoye, Senegal	14°38‘5.7“N, 16°25‘47.9“W	Urban background	WHO-PCB-TEQ: 0.39 WHO-PCDD/F-TEQ: 6.59
Lusaka, Zambia	15°19‘0.0“S, 28°26‘60.0“E	Urban background	WHO-PCB-TEQ: NA WHO-PCDD/F-TEQ: 1.87
Asela, Ethiopia	7°57‘0.0“N, 39°7‘0.0“E	Urban, high altitude	WHO-PCB-TEQ: 0.57 WHO-PCDD/F-TEQ: 5.49
East Legon, Ghana	5°39‘6.9“N, 0°9‘55.7“W	Urban, coastal	WHO-PCB-TEQ: 4.88 WHO-PCDD/F-TEQ: 21.69
Reduit, Mauritius	20°13‘59.5“S, 57°29‘54.5“E	Suburban, background, island	WHO-PCB-TEQ: 0.91 WHO-PCDD/F-TEQ: 10.71
Mt. Kenya, Kenya	0°1‘48.0“S, 37°13‘12.0“E	Background, remote, mountainous	WHO-PCB-TEQ: 0.11 WHO-PCDD/F-TEQ: 2.63

NA – not available

The comparison of concentration values in Tables 5 and 6 suggests, that WHO-PCDD/F--TEQ levels in the close vicinity of the Map Ta Phut Industrial Estate are two orders of magnitude lower than at the extremely polluted African sites of Nairobi, Dandora in Kenya (affected by biomass burning) and Cairo, Egypt (affected by industrial activities). They are also slightly lower than at the industrial South African Vanderbijl Park sampling site. The coastal urban East Legon site in Ghana has WHO-PCDD/F-TEQ levels an order of magnitude higher than the vicinity of the coastal Map Ta Phut Industrial Estate. The levels measured at Map Ta Phut correspond to the African urban background levels and are less than two ti-

mes higher than at the remote mountainous sampling site Mt. Kenya.WHO-PCB-TEQ levels in Map Ta Phut are similar to the South African Vanderbijl Park industrial site and suburban background site Reduit at the island of Mauritius. They are an order of magnitude lower than at the extremely polluted African site of Nairobi, Dandora in Kenya and five times lower than in coastal East Legon, Ghana. However, the Map Ta Phut WHO-PCB-TEQ concentrations are about two times higher than at the African urban sites of Dakar (Senegal) and Asela (Ethiopia) and one order of magnitude higher than at the remote mountainous sampling site Mt. Kenya. It is important to note, that the PUF PAS in Thailand were exposed for about half of the time compared to the samplers in Africa. It is reasonable to assume that if exposed only for 50 days, the African samples would exhibit lower concentrations of PCDD/Fs than reported in table 6. However, a simple recalculation of the concentrations determined in samples from Africa to a 50 days sampling period was not conducted as a linear uptake of pollutants into the PUF might not be assured during longer sampling periods and the sampling rate is dependent on local environmental conditions (Heo and Lee, 2014).

Another option is to report the PUF PAS based PCDD/Fs and DL-PCBs concentrations in pg /day units, which is an approach applied in two scientific papers reporting air levels of these pollutants in South Korea (Heo and Lee, 2014; Yoonki et al., 2014). Table 7 contains information on DL-PCBs and PCDD/Fs levels at various types of sites in South Korea. Table 8 gives information on DL-PCBs and PCDD/Fs concentrations at the three Map Ta Phut sites recalculated to pg/day units and the TEF scheme used in the South Korean papers for PCDD/Fs.

Table 7 DL-PCBs and PCDD/Fs average concentrations observed at South Korean sampling sites between 2011 and 2013 (Yoonki et al., 2014) and in 2010 and 2011 (Heo and Lee, 2014). PCDD/Fs concentrations are given in pg I-TEQ/day using the NATO international TEF scheme from 1988. DL-PCBs concentrations are given in pg WHO-TEQ/day using the WHO TEF scheme from 2005.

Site names	Type of site	Year	Observed concentrations
Suwon, Goyang, Guri	Urban, residential	2011-2013	DL-PCBs: 0.015 PCDD/Fs: 0.209
Ansan, Siheung, Bucheon	Industrial	2011-2013	DL-PCBs: 0.062 PCDD/Fs: 0.625
Yangju, Dongducheon, Pocheon	Urban, rural mixed	2011-2013	DL-PCBs: 0.040 PCDD/Fs: 0.810
Yangpyeong	Rural	2011-2013	DL-PCBs: 0.008 PCDD/Fs: 0.122
Suwon	Urban, residential	2010-2011	DL-PCBs: 0.004 PCDD/Fs: 0.123
Ansan	Industrial	2010	DL-PCBs: 0.041 PCDD/Fs: 0.661

Table 8: Analysis results for the Map Ta Phut sites. PCDD/Fs concentrations are given in pg I-TEQ/day using the NATO international TEF scheme from 1988. DL-PCBs concentrations are given in pg WHO-TEQ/day using the WHO TEF scheme from 2005.

	MTP Air-1	MTP Air-2	MTP Air-3
DL-PCBs	0.019	0.020	0.021
PCDD/Fs	0.090	0.080	0.079

The DL-PCBs WHO-TEQ/day concentrations at Map Ta Phut are very similar to the South Korean urban residential sites sampled in 2011-2013 and two to three times lower than the South Korean industrial sites. Regarding the PCDD/Fs, the Map Ta Phut I-TEQ/day levels are most similar (but still 1.5 times lower) to the lowest South Korean sampling results, i.e. rural site sampled in 2011-2013 and urban residential site sampled in 2010-2011. Other South Korean sites exhibit an order of magnitude higher PCDD/Fs I-TEQ/day levels than the three Map Ta Phut sites.

Conclusions

The here presented study gives a rough impression of the PCDD/Fs and DL PCB air concentrations in the close vicinity of the Map Ta Phut Industrial Estate, Thailand. It is not possible to determine a clear spatial gradient as only 3 samples were taken. There are no legal standards defined for POP concentrations measured in air by PAS, thus a comparison of the found concentrations with PAS determined PCDD/Fs and DL PCBs levels elsewhere was conducted. The Map Ta Phut DL PCBs levels are similar to South Korean urban residential sites and PCDD/Fs levels are an order of magnitude lower than at various South Korean sites including rural and industrial. PCDD/Fs and DL PCBs concentrations found in Map Ta Phut are also similar to levels at African urban sites and do not indicate an extremely serious pollution level as in e.g. industrial areas of Cairo, Egypt. However, it is important to consider that the sampling in Map Ta Phut was conducted at sites with an accumulation of vulnerable parts of the general population (children at the Wat Map Chalut School and patients at the Map Ta Phut Hospital) or at a site of spiritual importance (Wat Nong Faeb Temple). Unfortunately, the sampling was not conducted in the respiration height (approximately 1.5 m above ground) but higher in order to allow for free air flow around the PAS.

Concentrations of PCDDs/Fs in Africa determined by PAS measurements are similar to concentrations reported for Europe based on active air sampling (Bogdal et al., 2013). However, PAS determined PCDD/Fs levels probably underestimate the real occurence of these POPs in air, as PUF PAS do not sample PCDD/Fs with complete efficiency due to the incomplete sampling of the atmospheric particulate fraction (Markovic et al., 2015). Thus it is not possible to suggest that Map Ta Phut PCDD/Fs air concentrations are similar to European levels because they are similar to African urban levels. On the contrary, it is reasonable to anticipate real PCDD/Fs air concentrations in Map Ta Phut to be higher than reported in this study and thus higher than in Europe. This drawback does not apply for DL PCBs, as these occure predominantly in the gas-phase (Trinh et al., 2018) and differences between active and passive air sampling should be much less pronounced.

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Abbreviations

DL PCBs – Dioxin-like polychlorinated biphenyls

GMP – Global Monitoring Plan

HpCDD/Fs – heptachlorodibenzo-p-dioxins/dibenzofurans

HxCDD/Fs – hexachlorodibenzo-p-dioxins/dibenzofurans

LOD – Limit of detection

MONET – Monitoring Network

OCDD/Fs – octachlorodibenzo-p-dioxins/dibenzofurans

PAS – Passive air sampler

PCBs – Polychlorinated biphenyls

PCDD/Fs – Polychlorinated dibenzo-p-dioxins/dibenzofurans

PeCDD/Fs – pentachlorodibenzo-p-dioxins/dibenzofurans

POPs – Persistent organic pollutants

PUF – Polyurethane foam

SC – Stockholm Convention on Persistent Organic Pollutants

TCDD/Fs – tetrachlorodibenzo-p-dioxins/dibenzofurans

TEF – Toxic equivalency factor

TEQ – Toxic equivalency

WHO – World Health Organization

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