Report about sampling and monitoring in the surrounding of waste incinerators in Phuket

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Our report has focused on additional monitoring of food and biota in surrounding of Phuket waste incinerator, and few samples from Map Ta Phut industrial area as well. The aim of sampling an monitoring in surrounding of municipal waste incinerator in Phuket was to obtain more additional data about food chains and biota contamination by POPs. We had chance to look at mercury levels as well.

Waste Incinerators in Phuket and monitored area

There are two waste incinerators in Phuket, larger one burning municipal waste, and smaller one burning medical waste, but working only occasionally according information from old lady living next door to medical waste incinerator. Close to waste incinerators is also garbage dump.

Picture 1: Map of the Phuket waste landfill/waste incinerator complex with description of its parts. Google Earth map was used as basis at this picture.

The Phuket landfill/incinerator complex is located along side the BangYai canal downstream

from the city and close to its confluence with the sea. Whole complex was built in mangrove wetland. More detailed situation is visible from map below.

Description of the complex gives Greenpeace report from 2000: *"The municipal waste incinerator underwent test burns between April and June 1998. Bottom ash/clinker and fly ash from these operations had been dumped or stored in ash pits constructed within the boundaries of the complex. The storage area containing bottom ash residues was partly filled with water, giving it the appearance of a waste lagoon. The visible presence of glass medical waste containers within one area of this lagoon suggested that bottom ash from the incineration of medical waste had also been dumped there; this was confirmed by the manager of the medical waste incinerator."*(Labunska, Stephenson et al. 2000).

Municipal waste incinerator was constructed with capacity 250 tons/day (91 thousand tons per year), but according the data in the article published in 2004 it burned 233 tons/day, 85.5 thousand tons per year. Fly ash was produced in the amount of almost 2 thousand tons and bottom ash in the amount of 15,5 thousand tons per year according the same article (Liamsanguan and Gheewala 2004). During our visit in December 2010 a new municipal waste incinerator was under construction next to operating one.

While Liamsanguan and Gheewala claim that waste incinerator in Phuket sends fly ash for „specific landfilling" in fact it was long time landfilled next to the waste incinerator together with bottom ash as stated in Greenpeace report (Labunska, Stephenson et al. 2000). Fly ash was found by Swedish scientist during his sampling in 2009 in the area close to waste incinerator (UU 2009). At least part of the landfill with fly ash was most likely removed during the construction of new waste incinerator. It is clear that area has changed during the years from comparison of current photomap at Google Earth with another one from 2007 (see Picture 2).

Picture 2: From the comparison between photomap from 2007 (left side) and 2010 (right side) is clear, that land use has changed around waste incinerator in Phuket. Large grey area at south east edge of the incinerator was area with fly ash dumping in 2007.

Fly ash was sampled several times at Phuket municipal waste incinerator. First time it was sampled by Greenpeace in 1999 for analyses for heavy metals and screening analysis for

organic compounds (PCDD/Fs were not followed); (Labunska, Stephenson et al. 2000). Later on it was analyzed for PCDD/Fs within the study by Fiedler (UNEP Chemicals); (Fiedler 2001), although it is not specified in the report, it is clear that Phuket municipal waste incinerator was sampled, because of the size of its capacity and there was no other municipal waste incinerator that size in years 2000/2001 (when sampling had to occur) in Thailand. Levels of dioxins measured in fly ash ranged between 228 – 686 pg I-TEQ g-1 and bottom ash 5 and 10.6 respectively.

Swedish Umea University has undertaken study of the Phuket waste incinerator residues on their dioxin and dioxin-like PCBs content. They found PCDD/Fs, dl-PCBs and sum of PCDD/F + DL PCB in TEQ levels in fly ashes ranging from 2,140 up to 8,230, from 47 up to 248 or from 2,180 up to 8,490 pg TEQ g^{-1} dry weight respectively. Levels observed in bottom ash directly sampled at the incinerator were 5.7, 0.16 or 4.3 pg TEQ g^{-1} dry weight respectively (UU 2009).

Second analyses for dioxin levels in fly ash are more close to those observed in untreated fly ash (Petrlik and Ryder 2005).

Map Ta Phut industrial area

After visit at Phuket we went to do some sampling into Map Ta Phut industrial zone, Rayong Province to obtain rather additional data from Thailand, than really broad picture. In Map Ta Phut is located broad range of petrochemical industries and power plants dedicated to serve primarly as energy sources for this complex. Our sampling zone was located in bay close to coal firing power plant and discharge canal from chemical factories. Discharged waste waters come from petrochemical factories including chlorine and PVC production. Pictures of the area are in Annex 1 with photos.

Sampling in December 2010

We have sampled ashes, sediment and biota samples in surrounding of Phuket waste incinerators together with team of EARTH (Ecological Alert and Recovery - Thailand) Penchom Sae Tang, Walaiporn Mooksuwan and Arpa Wangkeit at the beginning of December 2010. On 10th December we went to look at the site and to interview local fishermen as well as other local residents and to see potential sampling sites. On 11th December we have taken samples of what we thought was mixture of fly ash and bottom ash according its consistence (see also photo at Picture ….). We have taken also sample of sediments in mangrove area near the outlet from waste management complex area (see the star sign at map on Picture 1).

Local fishermen caught some crabs and fish at two sites in sea bay near waste complex area. They are marked in the map at Picture 3: 1) bay east from canal (approx 800 m from the shore) and 2) bay near mangrove (approx 500 m from mangrove). Local residents, who use to pick food in mangrove area provided us with samples of shellfish, crabs and fish from two other sites: 3) mangrove area next to the waste complex and 4) river mouth south from the waste complex. Two days later local residents picked also sample of two bird eggs. They did not recognize which species the birds were, but most likely some passerine birds.

Table 1 gives a detailed overview of samples together with those taken later in Map Ta Phut area. All samples from Map Ta Phut come from local people or fishermen.

Picture 3: Map showing sampling sites in Phuket at Google Earth map. Both waste incinerators and eggs sampling area are marked by pins sign, other sampling areas are marked by red lines with their names in yellow, black and white letters.

Table 1: Overview of samples taken during joint EARTH/Arnika visit in Phuket and Map Ta Phut areas, Thailand in December 2010. The same numbering of samples is used in following tables with results of chemical analyses.

Number	Locality	Date of sampling	Matrix	Specie(-s)	Amount/sample	Analyses	Specification
P1/Fish 1	Phuket - mangrove	11-Dec-2010	Fish	Spotted scat (Scatophagus argus)	One fish	PCDD/F + DL PCB (DR CALUX); mercury	Caught in mangrove wettland by local boy
P2/Crabs 1	Phuket - mangrove	11-Dec-2010	Crabs	Mud crab, mangrove crab (Scylla serrata)	2 crabs/pooled sample	PCDD/F + DL PCB (DR CALUX)	Caught in mangrove wettland by local boy
P3/Shellfish 1	Phuket - river mouth	11-Dec-2010	Shellfish	Oyster	larger amount of oysters/pooled sample (n=32)	PCDD/F + DL PCB (DR CALUX)	Picked up by local people in the river mouth - south from the dumpsite and waste incinerator
P4/Shellfish 2	Phuket - mangrove	11-Dec-2010	Shellfish	Green lipped sea mussel (Perna canaliculus)	Larger amount of mussels/pooled sample (n=41)	PCDD/F + DL PCB (DR CALUX)	Picked up in mangrove wettland by local boy
P5/Fish 2	Phuket - bay east from the canal	11-Dec-2010	Fish	Blacktip catfish (Plotosus lineatus)	One fish	PCDD/F + DL PCB (DR CALUX); mercury; HCB	Caught in the sea bay cca 500 m from the shore by local fishermen
P6/Crabs 2	Phuket - bay near mangrove	11-Dec-2010	Crabs	Mud crab, mangrove crab (Scylla olivacea)	3 crabs/pooled sample	Mercury; HCB	Caught in the sea bay cca 500 m from the shore by local fishermen
P7/Crabs 3	Phuket - bay near mangrove	11-Dec-2010	Crabs	Blue swimmer crab (Portunus pelagicus)	4 crabs/pooled sample	PCDD/F + DL PCB (DR CALUX)	Caught in the sea bay cca 500 m from the shore by local fishermen
P8/Fish 3	Phuket - bay near mangrove	11-Dec-2010	Fish	Black jew (Protonibea diacanthus)	2 fish/pooled sample	Mercury	Caught in the sea bay cca 800 m from the edge of mangrove area by local fishermen
P9/Fish 4	Phuket - bay near mangrove	11-Dec-2010	Fish	Lattice monocle bream (Scolopsis taeniopterus)	7 fish/pooled sample	Mercury	Caught in the sea bay cca 800 m from the edge of mangrove area by local fishermen
P10/Fish 5	Phuket - bay near mangrove	11-Dec-2010	Fish	Needlefish; belonidae family	2 fish/pooled sample	PCDD/F + DL PCB (DR CALUX); mercury; HCB	Caught in the sea bay cca 800 m from the edge of mangrove area by local fishermen

P11/Sediment	Phuket - near the waste incinerator	11-Dec-2010	Sediment	Sediment from mangrove wettland	Sediment/pooled sample	PCDD/F + DL PCB (DR CALUX)	There were taken 10 individual samples 2 - 10 cm deep at 5x20 m area and homogenized
P12/Ash 1	Phuket - near the waste incinerator	11-Dec-2010	Bottom ash	Mixed ash with some small unburned waste pieces	Ash/pooled sample	PCDD/F + DL PCB (DR CALUX)	There were taken 10 individual samples 2 - 10 cm deep at 3x5 m area and homogenized
P13/Ash 2	Phuket - near the waste incinerator	11-Dec-2010	Bottom ash	Mixed ash with some small unburned waste pieces	Ash/pooled sample	PCDD/F + DL PCB (DR CALUX)	There were taken 10 individual samples 2 - 10 cm deep at 2x1 m area and homogenized
P14/Bird eggs	Phuket – Down	13-Dec-2010	Bird eggs	Most likely some passerine birds	2 boiled eggs/pooled sample	PCDD/F + DL PCB (DR CALUX)	From garden at living zone cca 2 km north north west from waste incinerator.
M1/Fish 6M	Map Ta Phut - Ko Saket	14-Dec-2010	Fish	Fourfinger threadfin (Eleutheronema tetradactylum)	One fish	Mercury; HCB	Caught close to Ko Saket island by local fishermen
M2/Shellfish 3M	Map Ta Phut – bay	14-Dec-2010	Shellfish	Green lipped sea mussel (Perna canaliculus)	Larger amount of mussels/pooled sample (n=48)	PCDD/F + DL PCB (DR CALUX)	Picked up in the bay close to coal power plant by local fishermen
M3/Shellfish 4M	Map Ta Phut – bay	13-Dec-2010	Shellfish	Green lipped sea mussel (Perna canaliculus)	Larger amount of mussels/pooled sample (n=35)	Mercury; HCB	Bought at fish market close to coal power plant on the shore next to chemical industry area

Biota samples were put into cooling boxes and frozen in EARTH office afterwards. They were kept frozen except flights and transport from Thailand to the Czech Republic and from the Czech Republic to Netherlands. Bird eggs were boiled before they were transported for analyses.

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like PCBs (DL PCBs) in ash, sediments, fish, shellfish and crabs from Phuket area

Waste incineration residues

Two ash samples, one sediment, three fish samples, two shellfish samples, two crab samples, and bird eggs from Phuket as well as one shellfish sample from Map Ta Phut were analyzed for PCDD/Fs and DL PCBs in Bio Detection Systems (BDS) laboratory in Amsterdam, Netherlands by DR CALUX[1] method. Results of the analyses are given in Tables 2 and 3.

Table 2: Overview of results of analyses for PCDD/Fs and DL PCBs by DR CALUX method.

Locality	**Sample**	**CALUX TEQ** (pg TEQ g-1 lipid)
Phuket - mangrove	Fish 1	42.5
Phuket - mangrove	Crabs 1	43.6
Phuket - river mouth	Shellfish 1	34.6
Phuket - mangrove	Shellfish 2	3,0
Phuket - bay	Fish 2	<LOQ (13)
Phuket - bay	Crabs 3	119,6
Phuket - bay	Fish 5	<LOQ (10)
Phuket - town	Eggs	6.1
Locality	**Sample**	**CALUX TEQ** (pg TEQ g-1 dry matter)
Phuket - near waste incinerator	Ash 1	3.9
Phuket - near waste incinerator	Ash 2	4.3
Phuket - mangrove	Sediment	24.5

Levels of PCDD/Fs + DL PCBs found in sampled ashes are not very high comparing to those observed in both Umea University report (UU 2009) and Fiedler's report (Fiedler 2001). Although we thought there is a mixture of fly ash and bottom ash landfilled next to lagoon

[1] For the method DR CALUX and the parameter PCDD/PCDF and dl-PCBs (only total TEQ) the used method is extraction with organic solvents; the extracts are cleaned on an acid silica column. The cleaned extracts are dissolved in DMSO. The DR CALUX activity is determined (24h exposure) and benchmarked against 2,3,7,8-TCDD. The DR CALUX analysis is done according to p-bds-051. All DR CALUX analysis results comply with EU requirements as indicated in COMMISSION REGULATION (EC) No 1883/2006 (laying down the sampling methods and the methods of analysis for the official control of dioxins and the determination of dioxin-like PCBs in foodstuffs. Intralaboratory repeatability and reproducibility are less than 15 and 30% respectively.

between two waste incinerators, the levels of dioxins and dioxin-like PCBs were very low and it seems there was either only bottom ash during our sampling, or dioxins were already diluted from the ashes which lay there longer time. Another explanation can be, that the ashes were mixed with soil and dumped here afterwards.

Sediment

PCDD/Fs + DL PCBs in sediment from mangrove area were found at level of 24.5 CALUX-TEQ g^{-1}. There are not available data about dioxin-like compounds levels in marine sediments from Thailand, however we can compare this figure with data from other parts of Asia or Pacific region.

In Asia, Müller, Gaus et al. (2002) found between 4 and 33 pg TEQ g^{-1} dm (only PCDD/PCDF) in sediments from Hong Kong Harbour and between 3 and12 pg TEQ g^{-1} dry matter at sampling locations that were considered as representative background for the region. One of the recent studies on sediments in Asia examined 122 coastal sediments from heavily industrialized areas in Korea. Toxic equivalent (TEQ) concentrations of PCDD and PCDF (PCDD/F) and DLPCB ranged from 0.44 to 38.5 pg g-1 dry weight and from 0.01 to 38.4 pg g-1 dry weight, respectively. Overall PCDD/F and DLPCB concentrations were elevated in estuarine and inner bay locations close to industrial complexes, indicating that these contaminants derived from local discharges (Moon, Choi et al. 2008). Yu et al. (2002) evaluated dioxin-like chemicals in the northern Caspian Sea in Russia and found between 0.7-28 pg I-TEQ g^{-1} dry matter. Levels in sediments from estuarine areas in Australia ranged between 0,066 and 520 pg WHO_{98}-TEQ g^{-1} with median level at 2.3 pg WHO_{98}-TEQ g^{-1} (Müller, Muller et al. 2004).

The level of dioxin-like compounds found in sediment from Phuket can be considered as elevated in comparison with results of above mentioned studies.

Seafood samples

Results of DR CALUX analyses of shellfish, crabs and fish are given in Table 3 expressed per wet weight (ww) as well as per grams of lipid (lipid weight = lw). Levels per grams of lipid are in general better for comparison with other samples, because it gives more objective picture not influenced by percentage of lipid. Dioxin-like compounds concentrations in fresh weight are however more relevant to evaluate contamination of food and the limit values for food are on fresh weight basis for fish. As Wenning, Mackey et al. (2003) reported seasonal differences in the lipid content may contribute to the differences in PCDD/Fs levels in their research oysters focused on California. This illustrates that lipid based values are better common basis for comparison of contamination in different regions or sites.

All fish, crab and shellfish samples from Phuket as well as shellfish sample from Map Ta Phut were below the European guideline of 8 pg TEQ g-1 ww for PCDD/F and DL PCB (EC 2006). Also all samples were below 1 pg TEQ g^{-1} ww of PCDD/F, a level that according to information obtained by Wenning, Mackey et al. (2003) from the US FDA warrants further investigation.

Table 3: Overview of DR CALUX analyses results for PCDD/F + DL PCB levels in fish, shellfish and crab samples from Phuket on both fresh weight and lipid basis. For comparison is give also result of analyses of small fish samples from Umea University report (UU 2009).

Locality	**Sample**	**Matrix**	**Lipid content** (%)	**CALUX TEQ** (pg TEQ g-1 fresh weight)	**CALUX TEQ** (pg TEQ g-1 lipid)
Phuket - mangrove	Fish 1	Fish (Spotted Scat)	1.6	0.68	42.5
Phuket - mangrove	Crabs 1	Crabs (Mud crab)	0.84	0.37	43.6
Phuket - river mouth	Shellfish 1	Oyster	2.1	0.73	34.6
Phuket - mangrove	Shellfish 2	Shellfish (Green Lipped Sea Mussel)	4.8	0.14	3.0
Phuket – bay	Fish 2	Fish (Catfish)	0.84	<LOQ (0.11)	<LOQ (13)
Phuket – bay	Crabs 3	Crabs (Blue Swimmer Crab)	0.47	0.56	119.6
Phuket – bay	Fish 5	Fish (Needlefish)	0.38	<LOQ (0.04)	<LOQ (10)
Map Tha Put	Shellfish 3M	Shellfish (Green Lipped Sea Mussel)	2.5	0.47	18.7
Locality	**Sample**	**Matrix**	**Lipid content** (%)	**PCDD/F; DL PCB** (pg TEQ g-1 fresh weight)	**PCDD/F; DL PCB** (pg TEQ g-1 lipid)
Phuket – pond	3 fish samples	Fish (unkown species)	NA	NA	1.2 - 5.6

Fish

A survey by the Environment Agency in Japan included the analysis of aquatic biota from 368 sites and reported a median concentration of 1.1 pg TEQ g^{-1} ww with range from 0.0022 to 30 pg TEQ g^{-1} ww (EAJ 1999). Tsutsumi, Amakura et al. (2003) analyzed about 65 fish samples from different locations in Japan and reported the median levels across different species ranged from 0.18 to 3.3 pg TEQ g-1 ww and the maximum level in a tuna sample of 23 pg TEQ g^{-1} ww or 4.6 pg TEQ g^{-1} ww in a sample of Yellowtail respectively.

Dioxin-like chemicals were also analyzed in 23 fish samples from around the Australia and middle bound concentrations ranged from 0.011 to about 0.85 pg TEQ g^{-1} ww. The level of dioxin-like chemicals was highest in a fish sample obtained from the Sydney/Port Jackson area. On lipid basis values ranged from 0,72 to about 68 pg TEQ g^{-1} lw (Müller, Muller et al. 2004).

Total TEQs in 31 sample of fish from Masan Bay, South Korea fish ranged from 0.32 to 0.53 pg g^{-1} ww (Chang, Im et al. 2003). Total TEQs in fish from Tokyo Bay, Japan ranged from 0.32 to 2.07 pg g^{-1} ww (Sakurai, Kim et al. 2000).

Results of measurements of dioxin in fish were published by Kumar, Kannan et al. (2001). Fishes from the Ganges River in Patna contained the highest concentration of total TEQ (18 pg g^{-1}, lw) whereas those collected from the Bay of Bengal in Chennai contained the lowest concentration (1.9 pg g^{-1}, lw). As we have sampled fish in sea, more relevant for comparison is data about fish from the Bay of Bengal in this study.

While levels of dioxin-like compounds in fish catch in the bay further from the shore as well as from mangrove area in Phuket were low, level observed in fish from mangrove can be seen as elevated and much higher than those observed in fish samples taken by Swedish scientists from Umea University (UU 2009) ranging from 1.2 to 5.6 pg g^{-1}, lw, see also Table 3.

Shellfish

The middle bound concentrations of dioxin-like chemicals in 18 bivalves samples in Australian report on dioxins in marine environment ranged from 0.0043 pg TEQ g^{-1}, ww to about 1.2 pg TEQ g^{-1}, ww when expressed using fish toxic equivalent factors (Müller, Muller et al. 2004). Concentrations of TEQs in mussel and clam from Masan Bay, South Korea were 0.97 and 12 pg g^{-1}, lw, respectively and/or 0.02 and 0.16 pg g^{-1}, ww, respectively (Chang, Im et al. 2003). Tsutsumi, Amakura et al. (2003) reported levels of dioxin-like compounds in oyster and crab samples from different locations in Japan ranged from 0.22 to about 1.10 pg g^{-1}, ww, and from 0.07 to about 2.40 pg g^{-1}, ww respectively with median levels 0.39 and 0.12 pg g^{-1}, ww respectively.

Levels of dioxin-like compounds in TEQs in samples of shellfish (oyster and mussels) and crabs presented in this study ranged from 0.14 to about 0.73 pg g^{-1}, ww and from 0.37 to about 0.56 pg g^{-1}, ww respectively or from 3.0 to about 34.6 pg g^{-1}, lw and from 43.6 to about 119.6 pg g^{-1}, lw respectively. In comparison with other samples from Asia and Australia can be these levels considered as elevated except sample of mussels from Phuket – mangrove area, which had rather low levels of PCDD/F and DL PCB (0.14 pg g^{-1}, ww; 3.0 pg g^{-1}, lw).

Crabs

Highest level of dioxin-like substances was observed in blue crabs from Phuket bay. Blue crabs have high concentrations of dioxin-like substances in general. While levels of PCDD/F and PCB in crabs' hepatopancreas reported from Taiwan in mid 90-s (Huang, Lu et al. 1994) and Newark Bay in 80-s (Rappe, Bergqvist et al. 1991) were much higher than those in crabs from Phuket, in comparison with measurements from the New York Bight from 80-s it is above 3 from four results for blue crabs presented in the report by Belton, Ruppel et al. (1988) Explanation can be, that our sample was measured as total level for edible parts of crab, while highest concentrations were found in hepatopancreas (ATSDR 2007), (Rappe, Bergqvist et al. 1991).

Birds' eggs

Levels of dioxin-like compounds in wild birds' eggs were not studied so often. There is detailed research on passerine birds in Michigan, USA (Fredricks 2009). Levels of dioxin-like compounds in birds' eggs reported in that study were higher than the level observed in the eggs from Phuket.

Suggestions for next steps

While there have been found elevated levels in some of fish and shellfish samples from Phuket it should be important to have available congeners patterns in the samples from this area, which is not possible to obtain from bioassay analyses such as DR CALUX. There are also no comparative data from Thailand on background levels of dioxin-like compounds in

fish, shellfish and crabs meat. These two loopholes should be solved by new analyses, which can help to show also potential pathways and the level of contamination in seafood from Phuket area. Level of dioxin-like compounds in shellfish from Map Ta Phut shows also importance of new analyses for this area as well.

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