PLASTIC WASTE FLOODING INDONESIA LEADS TO TOXIC CHEMICAL CONTAMINATION OF THE FOOD CHAIN

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PLASTIC WASTE FLOODING INDONESIA LEADS TO TOXIC CHEMICAL CONTAMINATION OF THE FOOD CHAIN

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IPEN is a global network of public interest non-governmental organizations (NGOs) forging a toxics-free future. IPEN is comprised of over 550 NGOs in more than 122 countries. Together we work to ensure that toxic chemicals and metals are no longer produced, used, or disposed of in ways that harm human health and the environment. IPEN and its Participating Organizations have become a leading force in chemicals and waste regulation and are catalyzing an international movement to promote chemicals without harm and an end to the production of the world's most hazardous substances.

www.ipen.org

Nexus3 or Nexus for Health, Environment, and Development (formerly known as BaliFokus Foundation) is an organization in Indonesia that works to safeguard the public, especially vulnerable populations, from the impact of development to health and the environment, towards a just, toxics-free, and sustainable future.

www.nexus3foundation.org

Arnika Association is a Czech non-governmental organisation established in 2001. Its mission is to protect nature and a healthy environment for future generations both at home and abroad. Since its beginnings, Arnika has worked on protection of consumers from chemically hazardous products.

www.arnika.org

ECOTON works to improve access to information, access to participation and access to justice and fighting for the rights to healthy environment and clean water through investigations, empowering pollution victim groups, and litigations.

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Cover: Bangun, Indonesia (Bottom). Photo: Fulli Syafi Handoko

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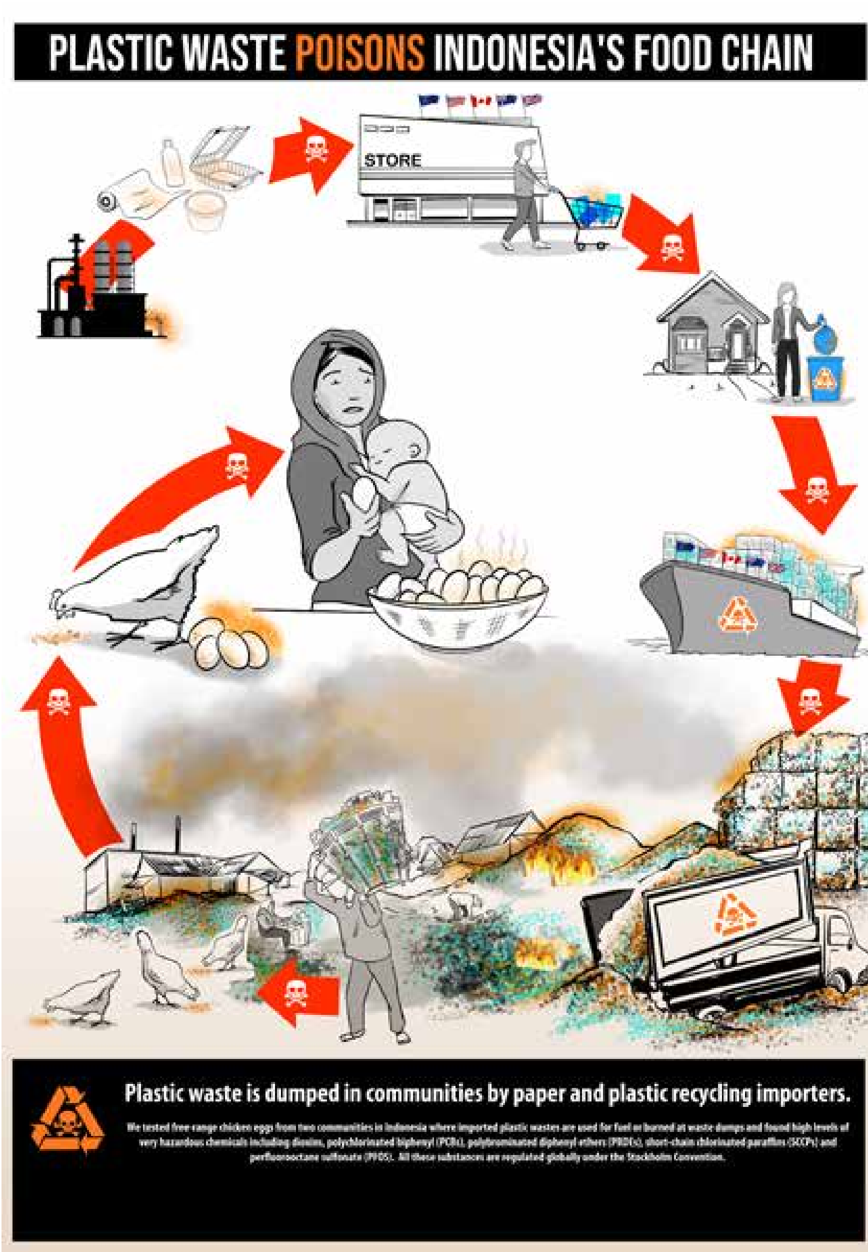
EXECUTIVE SUMMARY

After China closed its doors to plastic waste imports in 2018, developed countries sharply increased exports of non-recyclable plastic waste to Indonesia and other Southeast Asian countries. As a result, Indonesia's plastic waste imports doubled to 320,000 tonnes in 2018 compared to 2017. Based on observations by Ecoton and Nexus3, between 25% to 50% of the plastic wastes imported by Indonesian plastic and paper recycling companies were mismanaged.

An analysis of free-range chicken eggs sampled at Tropodo and Bangun, two sites in Indonesia where imported plastic wastes are dumped and used for fuel or burned to reduce volume, revealed:

- Significant levels of very hazardous chemicals including dioxins, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), short-chain chlorinated paraffins (SCCPs) and perfluorooctane sulfonate (PFOS), which are all regulated globally under the Stockholm Convention.
- The second-highest level of dioxins in eggs from Asia ever measured was found in samples collected near a tofu factory in Tropodo that burns plastic wastes for fuel.
- The dioxin level in the Tropodo eggs (200 pg TEQ g^{-1} fat) is similar to the highest recorded level of dioxins in eggs from Asia (248 pg TEQ g^{-1} fat) which occurred at the Bien Hoa site in Vietnam, a former US Army airbase where the soil was contaminated by historic Agent Orange use.
- An adult eating just one egg from a free-range chicken foraging in the vicinity of the tofu factory in Tropodo would exceed the European Food Safety Authority (EFSA) tolerable daily intake (TDI) for chlorinated dioxins by 70-fold.
- Eggs collected near a rural plastic waste dump site in Bangun were contaminated by PFOS at levels comparable to highly industrialized areas in Europe. An adult eating just one egg per week from a free-range chicken foraging in the vicinity of the Bangun dump site would exceed the proposed EFSA tolerable weekly intake of PFOS by approximately 1.3-fold.
- Eggs from Tropodo and Bangun contained SCCPs and PBDEs, which are flame retardant chemicals used in plastics.

To our knowledge, this is the first study to demonstrate food chain contamination in Southeast Asia, with high levels of hazardous chemicals as a consequence of waste mismanagement and poor controls on plastic waste trade.



INTRODUCTION

China closed its doors to imports of plastic in 2018. As a result, large volumes of dirty, mixed plastic wastes from developed countries, mainly from the United States and Europe, were diverted to Southeast Asia, primarily Malaysia, as well as Indonesia, Thailand, Vietnam, and Taiwan. Communities in East Java, Indonesia, especially in Tropodo and Bangun villages, are among the new destinations for foreign plastic waste traded and declared for recycling. As a big portion of this waste is non-recyclable plastic, they have become dumping grounds for vast amounts of remaining waste. This report looks at contamination of the food chain at these two localities affected by waste imports.

TOXIC ADDITIVES IN PLASTICS MAKE THE WASTE TOXIC

Plastics and food packaging contain chemical contaminants from manufacturing along with many additives to make them inflammable (flame retardants), more flexible (plasticizers), grease-resistant (fluorinated chemicals known collectively as PFAS), sterile (biocides), and other substances to create many other properties. Many of these additives are toxic and they leak from products during use and can be released during recycling and from recycled products. As noted by Hahladakis *et al.*,

> *"sound recycling has to be performed in such a way as to ensure that emission of substances of high concern and contamination of recycled products is avoided, ensuring environmental and human health protection, at all times" (Hahladakis, Velis et al. 2018).*

Some phthalates used as plasticizers are toxic to reproduction (Swan 2008, Lyche, Gutleb *et al.* 2009), increase the risk of allergy and asthma, and have an adverse impact on children's neurodevelopment (Jurewicz and Hanke 2011). Brominated flame retardants such as polybrominated diphenyl ethers (PBDEs) are known as endocrine disrupting chemicals (EDCs), and adversely impact the development of the nervous system and children's intelligence (POP RC 2006, POP RC 2007, POP RC 2014). Substances of concern in plastics were well described in a report prepared for the last meeting of the Conferences of Parties to both the Basel and

Stockholm Conventions (Marine Litter Topic Group 2019). Many of the additives in plastics were found to last for a long time in the environment and accumulate in animals, and some of them belong to the group of persistent organic pollutants (POPs) regulated by the Stockholm Convention (Cole, Lindeque *et al.* 2011, Rochman, Hoh *et al.* 2013).

When plastics are burned as fuel, new toxic chemicals can be created. For example, burning chlorine-containing plastics such as PVC forms polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs). These highly toxic substances are commonly referred to as dioxins. Burning plastics containing brominated flame retardants creates brominated dioxins and furans (PBDD/Fs), a group of toxic chemicals similar to chlorinated dioxins.

Some of the additives in plastics such as short-chain chlorinated paraffins (SCCPs), polybrominated diphenyl ethers (PBDEs), hexabromocyclododecane (HBCD) as well as by-products of their burning (PCDD/Fs, dioxin-like PCBs or hexachlorobenzene), are already regulated under the Stockholm Convention (Stockholm Convention 2010, Stockholm Convention 2017). In addition, some chemicals used in food packaging are toxic and some fluorinated chemicals are also regulated under the Stockholm Convention, notably PFOS and PFOA. All of these chemicals can leach from plastic and paper wastes when dumped or burned.

IPEN, in cooperation with its participating organizations Arnika, Nexus3/BaliFokus Foundation and Ecoton, conducted chemical analyses of free-range chicken egg samples collected by local groups, in order to assess the potential presence of toxic substances in the environment of villagers in East Java. To our knowledge, this is the first study to examine globally regulated substances in communities affected by plastic waste imports in Southeast Asia.

WASTE EXPORTS FROM DEVELOPED COUNTRIES TO INDONESIA

According to a recent report of the Ministry of Environment and Forestry of Indonesia, in 2016 the average waste collection rate in Indonesian cities was 76%. Approximately 67% of the waste was managed by city authorities, 57% was sent to landfills, and 11% was sent for reduction and recycling (~9,350 metric tons); (Ismawati Drwiega, Septiono *et al.* 2019). This

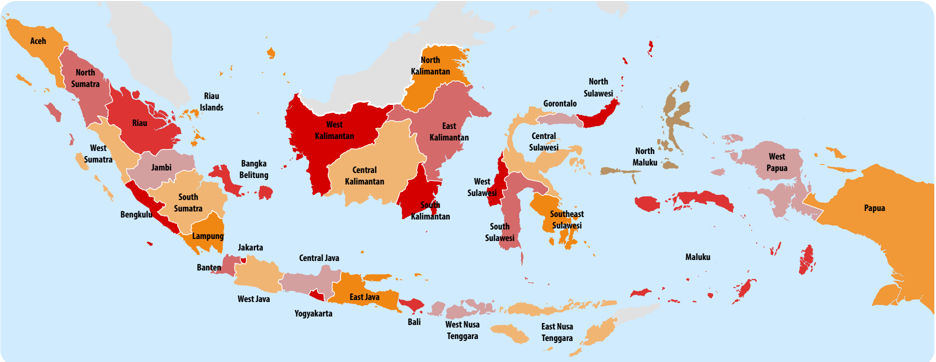


Figure 1. Map of Indonesia

Figure 2. Map showing East Java Province

leaves an unmanaged quantity of about 33%, or approximately 28,000 metric tons of waste a year (Tahar 2018).

Furthermore, a World Bank study identified that recycling in Indonesia accounts for about 15% of the total wastes, and is mostly undertaken by the informal sector, with formal recycling systems capturing less than 5% of wastes generated by the population (Shuker and Cadman 2018). The study also shows that plastic represents a significant proportion of debris extracted from waterways in all towns, ranging from 20% to 38%.

ASEAN countries, including Indonesia, imported recyclables from various countries to be sorted and combined with domestically-collected plastic scrap, and then exported it to China. At this time, these countries imported around 3% of the global trade of plastic wastes (2011 data) and exported around 5% of the worldwide business, denoting a discrepancy in those numbers due to the significant role of intermediate processing or re-exporting (Velis 2014).

Current global recycling rates estimate that only 10% of all plastic has been recycled more than once (Geyer, Jambeck *et al.* 2017). Annually, Indonesia generates ~9.5 million tons of plastic waste, or about 15% of the national waste generated. In 2016, approximately 11% of plastic wastes in Indonesia were recycled.

After China closed the door to plastic waste imports, Indonesia's plastic waste import volume doubled to 320,000 metric tons in 2018 compared to 2017. Based on observations by Ecoton and Nexus3, between 25% and 50% of plastic wastes imported by Indonesian plastic and paper recycling companies were mismanaged (Ismawati Drwiega, Septiono *et al.* 2019). Paper scrap imported by paper companies in East Java was found mixed with plastic scrap and donated or dumped in several villages, including Tropodo and Bangun (GAIA 2019).

WASTE "RECYCLING", DUMPSITES AND WASTE AS FUEL IN EAST JAVA

Nine paper recycling and manufacturing companies in East Java sourced paper scraps that were intended to be used as feedstock to make new sheets of papers for magazines, newspapers, etc. The raw material supplies needed by the industry in East Java Province are 4 million metric tons per year and about 62.5% of it is provided by local trade partners. The rest of the supplies, about 38% or approximately 1.5 million metric tons, is sourced from foreign suppliers, mainly from Australia, Canada, Ireland, Italy, New Zealand, the UK and the US (Ismawati Drwiega, Septiono *et al.* 2019).

In the past, the paper companies imported old newspaper and wastepaper which contained approximately 2-10% plastic scraps. However, in the last 3 years, the proportion of plastic scraps in the paper bales imported from various countries has increased up to 60-70%.

When the containers arrive at the factory, the content is mechanically sorted and washed. The wet paper or cardboard must be separated from contaminants, which are mainly plastic scraps. Washed plastic scraps and residue from pulp and paper factories that cannot be recycled are considered as wastes and are removed from the factory property. These wastes are either purchased by middle-men or small-scale recyclers, or 'donated' to the communities as part of the community development program of the factory. Common destinations for the low-grade plastics are open dumps, tofu factories or chalk/lime processing plants.

Bangun and Tropodo are among the impacted villages that are located near the paper companies. They receive more than 50 metric tons of low-grade plastic every day. As noted by Ecoton,

> *"Bangun isn't the final stop for the plastic waste. As two dump trucks pull into Wahyu's yard, another leaves, stacked with plastics that cannot be recycled because they are soiled, too expensive to recycle, or are simply non-recyclable, like potato chip bags, plastic food packaging, or bubble wrap. They are bound for East Java's local tofu factories in Kelangan Tropodo", (GAIA 2019).*

BANGUN VILLAGE, PUNGGING SUB-DISTRICT, MOJOKERTO REGENCY

Bangun is located in the Mojokerto Regency. It is home to about 10,000 inhabitants and is situated near a large paper manufacturing company. Before the large imports of plastic waste began, communities mainly worked in the agriculture sector, planting seasonal crops such as corn and other types of vegetables.

Figure 3. Location of Mojokerto Regency

Figure 4. One of the unwanted plastic scrap piles in Bangun behind PT Pakerin, a large paper manufacturing company in the Mojokerto Regency. Photo: BaliFokus/Nexus3

Figure 5. A couple in Bangun village collect plastic scraps to sell. The small amount of recyclable plastics are bought by recyclers, low-grade scrap is sold to local factories for fuel. Photo: BaliFokus/Nexus3

Figure 6. Unwanted plastic scrap being dropped at a community site in Bangun. Photo: Ecoton

Figure 7. Unwanted plastic scrap being burned in Bangun. Photo: Fully Syafi/Beritagar

In the last 5 years, new economic activities related to plastic wastes have increased and attracted people from other regencies to come to work in the plastic scavenging business. In most cases, every family owns a pile of plastic waste and every day or two they purchase the unwanted plastics from the paper factory or from the driver for IDR 250,000 (~USD$18) per truck (with a capacity of 4 metric tons), or ask the driver to drop it off in their spots for a tip of IDR 20,000 (~USD$1.40). The piles can be seen in front of every house in the village and more piles can be found in a huge sorting site.

If the plastic waste piles are purchased from the factory directly, sometimes the bales still contain metal wire to bind the bales. Some groups burn the wire and the left-over plastics that are not sold in order to create space for the new piles.

TROPODO VILLAGE, KRIAN SUB-DISTRICT, SIDOARJO REGENCY

Figure 8. Location of Sidoarjo Regency

Tropodo is located in the Sidoarjo Regency with a population of approximately 25,000. There are 50 small-scale tofu makers that utilize unwanted plastic scrap as fuel to create steam to turn the soybean milk into tofu.

Five years ago, most tofu makers used wood to create hot steam. The price of one small truck of firewood was about IDR 1.5 million (~USD$107). When the paper companies started to receive an increased volume of unwanted plastic scrap, tofu makers saw the opportunity to cut their production costs by replacing the firewood with unwanted low-grade plastic scrap for fuel. The price of one small truck of plastic scrap is IDR 250,000 to 350,000 (~USD$18 to $25). By burning the plastic wastes to create steam, tofu makers can cut their production costs by up to 15-20%.

The combustion of mixed plastic scraps takes place all day long, from 6AM to 6PM, releasing thick black smoke. In the morning, people who pass the main road nearby are smothered with smoke-like fog every day. The Primary Health Clinic of Krian Sub-district has recorded an elevated number of patients with respiratory problems from the Tropodo area, especially children. Some tofu makers donate the ashes from plastic burning to corn farmers to be used as fertilizers.

Figure 9. Plastic used as fuel to create steam. Photo: Ecoton

Figure 10. Ashes donated to corn farmers. Photo: Ecoton

Figure 11. Tofu ready to be sold. Photo: BaliFokus/Nexus3

Figure 12. Tofu making process. Photo: BaliFokus/Nexus3

Figure 13. Smoke released from a tofu factory. Photo: BaliFokus/Nexus3

HIGH LEVELS OF TOXIC CHEMICALS BANNED GLOBALLY FOUND IN EGGS FROM TROPODO AND BANGUN SITES

Free-range chicken eggs have been assessed in many previous studies as indicators of environmental contamination with toxic chemicals for a number of reasons. Most toxic chemicals known as persistent organic pollutants (POPs) are lipophilic and accumulate in fatty tissues of organisms.

Eggs have a significant lipid content which accumulates POPs from the hen that lays them. In addition, free-range chickens also pick food from among the soil and dust in the local area, ingesting some soil in the process, and therefore they act as 'active samplers' and their eggs provide an indicator of the POPs environmental contamination levels in that locality. Eggs also represent an important exposure pathway between the soil, the food chain and humans. The use of commercially produced eggs by layer hens under the cover of structures and fed on relatively uncontaminated feed, as indicators of background levels for eggs, provides a basis for comparison of contaminated eggs.

As a food source, eggs can be governed by regulations that specify maximum threshold levels of POPs which can be compared to the Tolerable Daily Intake (TDI) levels intended to protect human health. The TDI can vary between young children and adults or even pregnant women, as some groups of humans are more sensitive to the impacts of POPs than others. The EU limit for dioxins in eggs is 2.5 pg WHO-TEQ g^{-1} fat. The regulatory limit in Indonesia is 2.5 pg WHO-TEQ g^{-1} fat, but includes both dioxins and dioxin-like PCBs (Badan pengawas obat dan makanan Republik Indonesia 2018). There is no current limit for perfluorinated compounds, including PFOS, despite their high toxicity.

LEVELS OF TOXIC CHEMICALS IN EGGS

Table 1 shows the levels of chemicals found in eggs sampled in Tropodo and Bangun, along with a sample from a commercial farm obtained from a supermarket in Bangkok in 2016, which can be used as a comparative background sample for Southeast Asia. The data indicates a variety of toxic substances in eggs from Tropodo and Bangun, including dioxins (PCDD/Fs), PCBs, SCCPs, PBDEs, PFAS substances, and PFOS.

TABLE 1: TOXIC CHEMICALS IN EGGS FROM TROPODO AND BANGUN (ng g^{-1} FAT)

Substance	Tropodo	Bangun	Bangkok super-market control	Indonesia limit	EU standard / limits
Number of eggs in pooled sample	3	3	6		-
Fat content (%)	15	13	11.6		-
PCDD/Fs (pg TEQ g^{-1} fat)	200	10.8	0.1		2.50
DL PCBs (pg TEQ g^{-1} fat)	32	3.1	0.001		-
Total PCDD/F + DL PCBs (pg TEQ g^{-1} fat)	232	13.9	0.1	2.50	5.00
Total PCDD/Fs + DL PCBs - DR CALUX (pg BEQ g^{-1} fat)	560	21	-		-
PBDD/Fs (pg TEQ g^{-1} fat)	< 21.3	< 21.3	< 21.3		-
HCB	5.5	2.7	< 0.2		-
PeCB	1.9	1.1	< 0.4		-
HCBD	< 0.1	< 0.1	< 0.4		-
7 PCB	5.3	15.4	0.22		-
6 PCB	4.4	12.3	0.22		40.00
SCCPs	65	153	-		-
sum HCH	0.8	0.9	2.2		-
sum DDT	10.8	4.3	< LOQ		-
sum of PBDEs	65	91	3.1		-
sum of PFASs (ng g^{-1} of fresh weight)	2.7	26	-		-
L-PFOS (ng g^{-1} of fresh weight)	0.9	15.4	-		-

TABLE 2: DIOXIN (PCDD/Fs) AND DIOXIN-LIKE POLYCHLORINATED BIPHENYLS (DL PCBs) CONGENERS AS MEASURED IN POOLED EGG SAMPLES FROM BANGUN AND TROPODO IN MAS LABORATORY, GERMANY. LEVELS ARE IN pg g^{-1} FAT.

Sample	Bangun (191490001)		Tropodo (191490003)	
Locality	**Bangun**		**Tropodo**	
PCDD/Fs and DL PCBs cong.	**Result**	**LOQ**	**Result**	**LOQ**
2,3,7,8-TCDD	1.60	0.132	35.5	1.67
1,2,3,7,8-PeCDD	3.93	0.264	75.5	3.33
1,2,3,4,7,8-HxCDD	1.44	0.396	18.3	5.00
1,2,3,6,7,8-HxCDD	3.07	0.396	39.5	5.00
1,2,3,7,8,9-HxCDD	1.00	0.396	15.8	5.00
1,2,3,4,6,7,8-HpCDD	4.96	1.980	38.5	25.00
OCDD	13.30	5.940	nd	75.00
2,3,7,8-TCDF	6.74	0.132	82.5	1.67
1,2,3,7,8-PeCDF	5.76	0.264	114.0	3.33
2,3,4,7,8-PeCDF	9.48	0.264	159.0	3.33
1,2,3,4,7,8-HxCDF	3.46	0.396	82.5	5.00
1,2,3,6,7,8-HxCDF	3.47	0.396	80.6	5.00
1,2,3,7,8,9-HxCDF	nd	0.396	nd	5.00
2,3,4,6,7,8-HxCDF	2.47	0.396	50.1	5.00
1,2,3,4,6,7,8-HpCDF	nd	1.980	47.2	25.00
1,2,3,4,7,8,9-HpCDF	nd	1.980	nd	25.00
OCDF	nd	5.940	nd	75.00
PCDD/Fs total	60.68		839.0	
PCDD/Fs in WHO-TEQ2005	10.8		200	
PCB 81	nd	13.2	nd	140
PCB 77	nd	26.4	nd	280
PCB 123	46.5	26.4	nd	280
PCB 118	2250.0	264.0	nd	2800
PCB 114	66.9	26.4	nd	280
PCB 105	838.0	132.0	nd	1400
PCB 126	29.4	6.6	319	70

Sample	Bangun (191490001)		Tropodo (191490003)	
Locality	Bangun		Tropodo	
PCDD/Fs and DL PCBs cong.	Result	LOQ	Result	LOQ
PCB 167	171.0	26.4	nd	280
PCB 156	339.0	26.4	424	280
PCB 157	74.2	26.4	nd	280
PCB 169	nd	13.2	nd	140
PCB 189	44.3	26.4	nd	280
DL PCBs total	**3859.3**		**743.0**	
DL PCBs in WHO-TEQ2005	**3.05**		**31.9**	

nd – not detected at levels above the limit of quantification (LOQ) indicated

Table 1 shows that the level of chlorinated dioxins in Tropodo eggs was 2,000 times the background levels found in supermarket eggs from Southeast Asia. Eggs from Tropodo exceeded the EU regulatory limit by 80-fold. The data also shows significant levels of dioxin-like PCBs which contribute to exceedance of Indonesian and EU limits for eggs as food. Dioxins and dioxin-like PCBs (dl-PCBs) were 39-fold higher than the standard established in EU, and higher than the Indonesian limit by almost 93-fold, for these compounds in eggs. In fact, eggs sampled in Tropodo, in the vicinity of the tofu factory where plastic waste is used as fuel, contained the second highest level of chlorinated dioxins ever measured in eggs from localities in Asia. The highest level of dioxins in eggs from Asia (248 pg TEQ g^{-1} fat) occurred at the Bien Hoa site in Vietnam, a former US Army airbase where the soil is contaminated by historic Agent Orange use. Figure 14 shows that dioxin levels in eggs from Tropodo are the fifth highest levels measured in eggs globally. Annex 2 summarizes the maximum levels of dioxins found in free-range chicken eggs since 2005 in different countries of all continents.

The congener profile for PCDD/Fs and DL PCBs can be seen in Table 2, where measured levels for individual congeners are presented together with levels of quantification (LOQ) for each congener. LOQs for the samples from Tropodo were higher due to high concentrations of dioxins in fat. The congener profiles for PCDD/Fs in both pooled egg samples from Bangun and Tropodo are presented in Figures 14 and 15. While OCDD is the most prevalent congener in the eggs from Bangun, 2,3,4,7,8 PeCDF is the most prevalent congener in the eggs from Tropodo. The eggs from Tropodo had also proportionally higher levels of HxCDF and

HpCDF congeners in comparison with the eggs from Bangun. Dibenzofuran congeners were more prevalent in the egg samples from Tropodo than in those from Bangun.

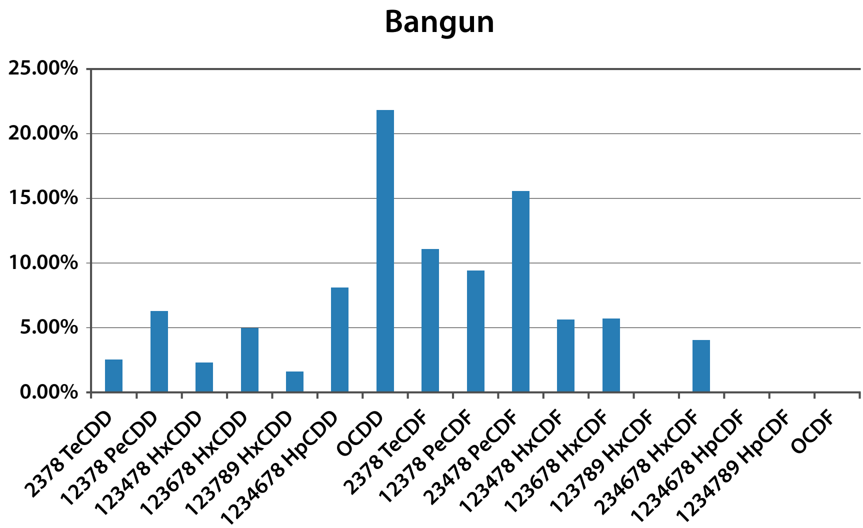


Figure 14. PCDD/Fs congener proportions in pooled free-range chicken eggs from Bangun.

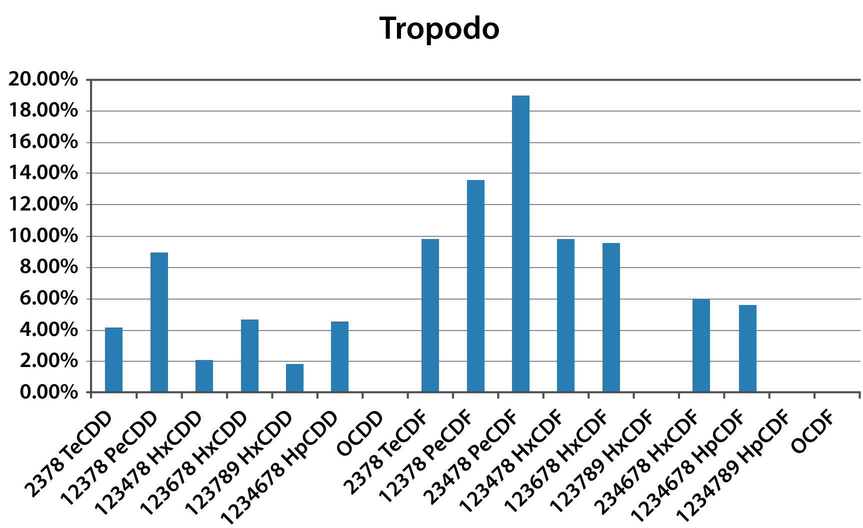


Figure 15. PCDD/Fs congener proportions in pooled free-range chicken eggs from Tropodo.

Figure 16 shows congener profiles for air samples from open burning versus a municipal solid waste incinerator from a study in China. Also congener profiles from previous IPEN egg studies (DiGangi and Petrlik 2005, Petrlik, DiGangi *et al.* 2005, Petrlik, Lobanow *et al.* 2005) were used for comparison and are shown in Figures 17 and 18.

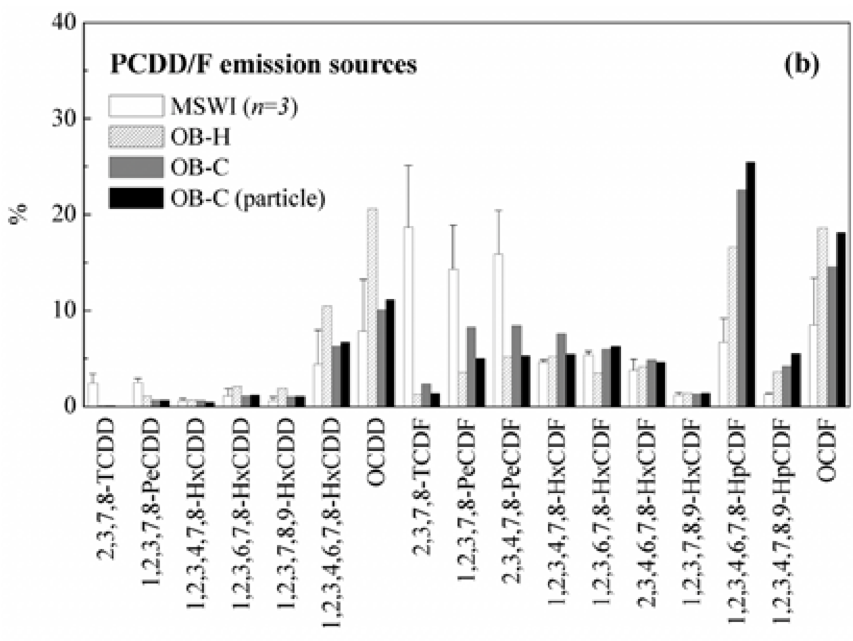


Figure 16: Congener patterns for open burning of waste and municipal solid waste incineration as observed in air samples, expressed as a percentage relative to dioxin concentration (PCDD/Fs). Source: (Xu, Yan et al. 2009)

Although the PCDD/Fs congener profiles in samples from Bangun and Tropodo are not identical with either one of the presented profiles, there are similarities with different types of profiles. The congener profile for the Tropodo sample is closer to profiles from “closed” facilities, e.g. waste incineration facilities or smelters (for example eggs sampled from Helwan, Figure 18) (Petrlik, DiGangi *et al.* 2005, Yu, Jin *et al.* 2006). In contrast, the congener profile for the Bangun sample is closer to those influenced by open air burning of wastes as seen in the sample from Bolshoi Trostenec (Figure 17), which is from an area close to a municipal waste dumpsite in Belarus (Petrlik, Lobanow *et al.* 2005). Access to ash also plays a role in congener profiles as waste incineration ash shows different dioxin congener patterns than air emissions (Oh, Chang *et al.* 2002). This study did not examine ash from either site.

The bioavailability of dioxin congeners in poultry is, "chlorination-dependent ranging from 80% for tetrachlorinated to less than 10% for octachlorinated congeners" according to a study by Stephens *et al.* (Stephens, Petreas *et al.* 1995). Furthermore, Kang *et al.* (2002) reported that the biomagnification factors (BMFs) of PCDD/Fs in wild tufted ducks decreased with an increase in the degree of chlorination. This indicates that the dioxin congener pattern in eggs can be different than the pattern found in the contamination source.

An adult eating just one egg from a free-range chicken foraging in the vicinity of the tofu factory in Tropodo would exceed the European Food Safety Authority (EFSA) tolerable daily intake (TDI) for chlorinated dioxins by 70-fold (EFSA CONTAM 2018). The typical daily egg consumption per person in Indonesia is less than one egg a day (Knoema 2012), but even eating 12 grams of egg a day would exceed the EFSA TDI by more than 20-fold.

The eggs sampled from the Bangun dump site contained 10.8 pg TEQ g^{-1} dioxins and 13.9 pg TEQ g^{-1} dioxins and dioxin-like PCBs. This is more than four times higher than the EU regulatory limit for dioxins and more than five times higher than the Indonesian regulatory limit which includes both dioxins and dioxin-like PCBs. The difference in dioxin levels at the

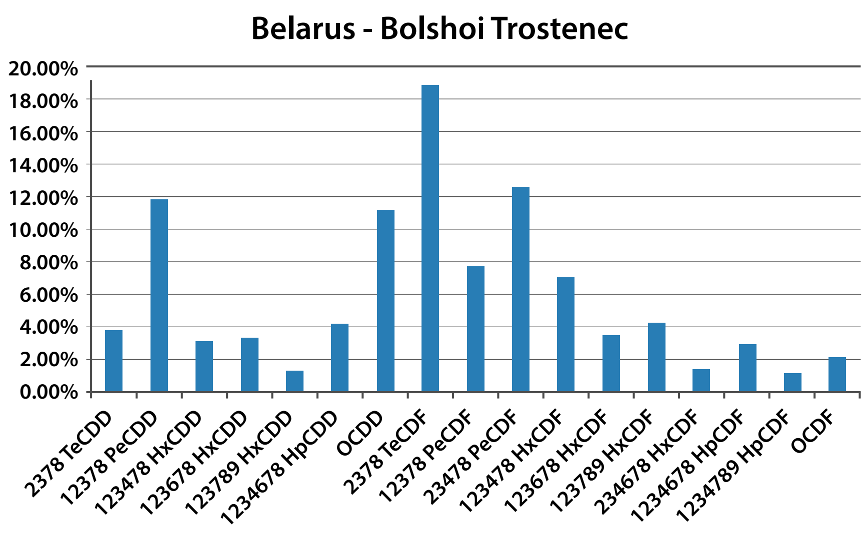


Figure 17: PCDD/Fs congener profile for pooled free-range eggs from the vicinity of a municipal waste dumpsite in Bolshoi Trostenec, Belarus. Source: DiGangi and Petrlik 2005

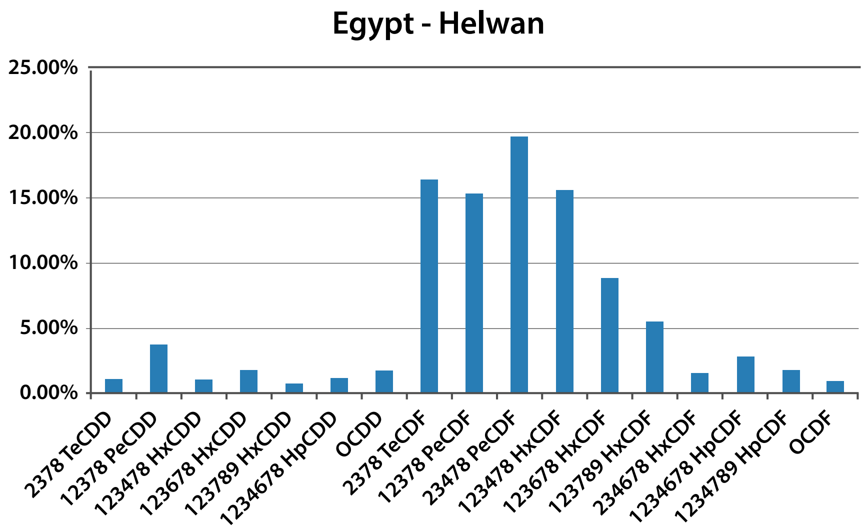


Figure 18: PCDD/Fs congener profile for a pooled free-range eggs sample from Helwan, Egypt. Source: DiGangi and Petrlik 2005

two sites could reflect the constant plastic burning in tofu factories compared to the more variable situation at the Bangun dump site. Note that the chemical content in the tofu itself was not measured, but considering that it is likely that the soil around the factories has become contaminated by airborne emissions, it would be sensible for authorities to test the tofu.

The Tropodo eggs also contained relatively high levels of SCCPs and PBDEs although they were lower than in eggs sampled in Bangun, as chickens there are exposed to plastic and paper waste dumped in the village that may contain both SCCPs and PBDEs. There are no regulatory limits established for these toxic chemicals in eggs.

A 2017 study of 60 plastic children's products from 10 countries found SCCPs in 45% of them (Miller and DiGangi 2017, Miller, DiGangi *et al.* 2017). The same year, governments added SCCPs to the Stockholm Convention for global elimination. SCCPs are toxic to aquatic organisms at low levels, disrupt endocrine function, and are suspected to cause cancer in humans (POP RC 2015).

The most common members of the PBDE family have been listed in the Stockholm Convention for global elimination including PentaBDE (2009), OctaBDE (2009) and DecaBDE (2017). PBDEs have adverse effects on reproductive health as well as developmental and neurotoxic effects (POP RC 2006, POP RC 2007, POP RC 2014). DecaBDE and/or its degradation products may also act as endocrine disruptors (POP RC 2014).

If we compare the data obtained from previous research, the levels of PFOS measured in eggs from the rural Bangun dump site are comparable to levels from industrialized areas of European countries, such as those that are not directly contaminated by production of perfluorinated compounds, e.g. in eggs from Belgium and the Netherlands (D'Hollander W 2011, Zafeiraki, Costopoulou *et al.* 2016). This fact demonstrates the high impact of waste imported to Bangun, which is most likely the source of PFAS contamination. PFOS-related substances have been used in the packaging and paper industries in both food packaging and commercial applications to impart grease, oil and water resistance to paper, paperboard and packaging substrates (KemI 2004). An adult eating just one egg from a free-range chicken foraging in the vicinity of the Bangun dump site would exceed the proposed tolerable weekly intake of PFOS (EFSA CONTAM 2018a) by approximately 1.3-fold.

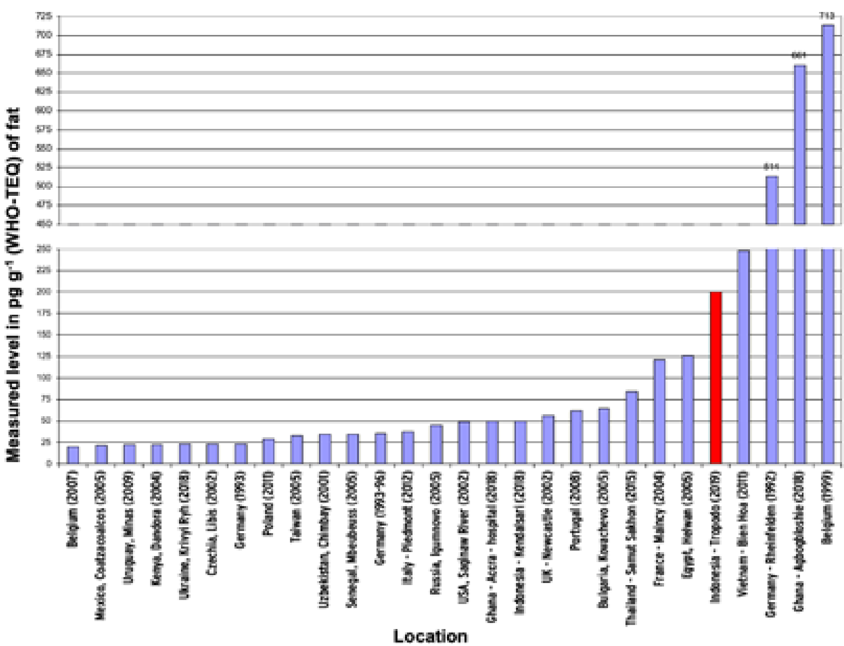


Figure 19: Dioxins measured in free-range chicken eggs from different locations in the world.

BANNED CHEMICALS IN EGGS ARE VERY TOXIC

Eggs from both sampling locations contained dioxins. Both chlorinated and brominated dioxins are known to be extremely toxic. Numerous epidemiologic studies have revealed a variety of human health effects linked to chlorinated dioxin exposure including cardiovascular disease, diabetes, cancer, porphyria, endometriosis, early menopause, alteration of testosterone and thyroid hormones, and altered immune system response among others (White and Birnbaum 2009, Schecter 2012). As noted by Behnisch *et al.*, "Both groups of compounds[1] show similar effects, such as induction of aryl hydrocarbon hydroxylase (AHH)/ EROD activity, and toxicity, such as induction of wasting syndrome, thymic atrophy, and liver toxicity." (Behnisch, Hosoe *et al.* 2003). Chlorinated dioxins are one of the original "dirty dozen" substances regulated by the Stockholm Convention. Brominated dioxins are not yet controlled by the treaty.

Eggs from the rural dump site in Bangun were also contaminated by PFOS and other per- and polyfluoroalkyl substances (PFAS) leaking from wastes at levels comparable to highly industrialized areas in Europe. PFAS is a large class (OECD 2018) of more than 4,500 very persistent fluorinated chemicals (including PFOS) that have been widely used in packaging, textiles and plastics. EFSA has sharply lowered the permitted intake of PFOS from 150 ng/kg body weight/day to 6 ng/kg body weight/week (EFSA CONTAM 2018).

PFOS was listed in the Stockholm Convention in 2009. The Stockholm Convention expert committee concluded that, "PFOS is extremely persistent. It does not hydrolyse, photolyze or biodegrade in any environmental condition tested" (POP RC 2006a). In animal studies PFOS has been shown to cause cancer, neonatal mortality, delays in physical development, and endocrine disruption (Thomford 2002a, Thomford 2002b, Luebker, York *et al.* 2005, Jacquet, Maire *et al.* 2012, Du, Hu *et al.* 2013).

PFOA is another common member of the PFAS family of substances. Governments added PFOA to the Stockholm Convention for global elimination in 2019. Higher maternal levels of PFOS and PFOA are associated with delayed pregnancy, reduced human semen quality and penis size (Fei, McLaughlin *et al.* 2009, Joensen, Bossi *et al.* 2009, Di Nisio, Sabovic *et al.* 2018). In humans, PFOA is associated with high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, pregnancy-induced hypertension, and immune system effects, and it is transferred to the fetus through the placenta and to infants via breast milk (POP RC 2016). PFOA-related compounds such as fluorotelomer alco-

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1 Both, chlorinated and brominated dioxins (PCDD/Fs, PBDD/Fs).

hols, fluoropolymers and fluorotelomer-based polymers must be included in actions designed to eliminate PFOA releases since they can degrade to PFOA.

An investigation of PFAS substances in Indonesia found that they are unregulated and contaminate coastal sediments and breast milk (BaliFokus/Nexus3 Foundation 2019).

CONTROLS OVER PLASTIC WASTE EXPORTS IN THE BASEL CONVENTION

The toxic consequences of plastic waste imports into Indonesia demonstrated in this study provide strong justification for action under the Basel Convention. In May 2019, the Fourteenth Conference of Parties to the Basel Convention (COP14) agreed by consensus to bring most plastic wastes under the control regime of the Basel Convention (BAN 2019, IPEN 2019). The decision takes effect on January 1, 2021, according to decision BC-14/12 of the Basel Convention (Basel Convention 2019) and is expected to have a major impact on global plastic waste flows and production. Indonesia ratified the Basel Convention in 1993 (Basel Convention 2019a).

First, governments created a listing for hazardous plastic waste which is subject to all treaty control procedures. Second, export of mixed or contaminated plastic wastes will now require prior informed consent, granting the importing country the right to refuse the shipment. Only a few narrow exemptions for non-hazardous, non-PVC, clean unmixed and uncontaminated plastic wastes can be exported freely, and only for recycling – not for burning or landfilling (Basel Convention 2019). However, these exemptions include fluorinated polymers made with PFAS substances. The data in this study showing contamination of eggs with PFAS substances indicates that this exemption should be ended. Currently, a Basel Convention Small Intersessional Working Group is examining this issue and will make recommendations to Basel COP15 on the matter.

A second major decision at COP14 addresses actions governments should take on plastics. These decisions can be used to address both production and the numerous toxic chemicals used in plastics. Governments agreed that managing plastic waste begins up front noting the importance of more sustainable production. They also agreed on the importance of reducing single-use plastics and replacing them with environmentally friendly alternatives. Finally, governments agreed that actions on plastics should include removing or reducing the hazardous chemicals that are included in their production and at any subsequent stage of their life cycle.

The Basel Convention decisions at COP14 should have a positive impact on reducing and eliminating uncontrolled plastic waste imports into Indonesia. After 1 January 2021, Indonesia will have the power to refuse mixed or contaminated wastes through the prior informed consent procedure. Burning or landfilling of plastic imported wastes will not be permitted. Indonesia can also consider banning all plastic waste imports, as done previously by China. Enforcement will be a key measure for either option.

Indonesia will also benefit from the entry into force of the Basel Convention Ban Amendment which will happen on 5 December 2019 (Basel Convention 2019b). Indonesia has ratified this amendment which prohibits the member states of the Organization for Economic Cooperation and Development (OECD), the European Union (EU), and Liechtenstein from exporting hazardous wastes as defined by the Convention (Basel Convention 2014) to other countries – primarily developing countries or countries with economies in transition. The Ban Amendment includes most Persistent Organic Pollutants (POPs), most electronic wastes, most obsolete ships, most flammable liquids, and most toxic heavy metals. It will include plastic or paper waste if it is contaminated with a hazardous waste. Indonesia ratified the Ban Amendment in 2005 (Basel Convention 2019c) and played a key role in establishing it within the treaty.

STRENGTHENING THE STOCKHOLM CONVENTION WASTE PROVISIONS

This study demonstrates the presence of POPs substances in chicken eggs that are regulated under the Stockholm Convention such as dioxins, PCBs, PBDEs, SCCPs, and PFOS.

Unintentional production of dioxins and PCBs should be addressed under the treaty by preventing uncontrolled combustion. The Stockholm Convention requires minimization and, where possible, elimination of these substances produced unintentionally. The treaty has identified dioxin sources including uncontrolled burning (illustrated at the Tropodo and Bangun sites) and waste incinerators (Stockholm Convention on POPs 2008, UNEP and Stockholm Convention 2013). Parties to the Convention are obliged to develop an action plan to address these sources and advance toward the minimization and elimination goal, and they are obliged to implement the plan according the Article 5 of the Convention (Stockholm Convention 2010). Open burning as well as waste incineration are not preferable options of waste management according to the Stockholm Convention and its BAT/BEP Guidelines (Stockholm Convention on POPs 2008) in particular. For more information on Stockholm Convention obligations and guidelines, please see Annex 3.

Provisions under the Stockholm Convention may also allow control of POPs present in plastic and paper waste such as SCCPs, PBDEs, PFOS and PFOA, by using stricter limit values to define POPs wastes (known as low POPs content levels). Wastes with levels of these substances over the limit must be destroyed and not exported. However, currently the threshold values are weak, and therefore allow exports of large volumes of POPs in wastes across borders from developed countries (IPEN 2019).

RECOMMENDATIONS

This study links waste mismanagement and uncontrolled movement of plastic waste with contamination of the food chain in Indonesia. Bangun and Tropodo are just two examples of many similar sites in Southeast Asia. Measures to address this issue include:

- Prohibit combustion as a disposal option for plastic waste or as an example of the 'circular economy.' It should not be accepted as a best practice for plastic waste management.
- Prohibit the combustion of plastics as a fuel for industrial operations due to the dioxin and other halogenated pollution generated in emissions and ash.
- Restrict the use of halogen-containing synthetic fuels derived from plastics due to the persistent organic pollutants that would occur in emissions of burning such fuel.
- Remediate sites contaminated with dioxins and other POPs to ensure that human health is protected and that food chain contamination cannot occur.
- Increase monitoring of POPs chemicals in compliance with Stockholm Convention provisions along with other pollutants of concern.
- Update the Indonesian Stockholm Convention National Implementation Plan to evaluate the effectiveness of preventive measures and control of POPs in Indonesia.
- Strictly apply the new provisions of the Basel Convention to block hazardous waste imports and control transboundary movement of plastic wastes or enact a ban on plastic waste imports.
- Introduce stricter, more protective limits for POPs in wastes in the Stockholm Convention.
- Enact a stronger international Beyond 2020 chemicals framework that includes work to reduce and eliminate PFAS as a class.
- Reduce and minimize plastic production and use, and avoid the use of halogenated plastics or the addition of halogenated compounds in plastic production such as bromine, chlorine and fluorine.

ANNEX 1.
SAMPLING METHODOLOGY AND CHEMICAL ANALYSES DESCRIPTION

Pooled samples of 3 egg samples were collected at each of the selected sampling sites in order to obtain more representative samples. Two samples from Indonesia and one pooled sample of commercial eggs (non-free-range) from Bangkok were assessed for polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (dl-PCBs) using the DR CALUX method. These were sent to a Dutch ISO 17025 certified laboratory (BioDetection Systems B.V., Amsterdam) performing the cell-based screening analysis DR CALUX according to the European Standard EC/644/2017. The DR CALUX bioassay method is proven as cost-efficient, semi-quantitative, effect-based toxicity screening analyses for all kinds of stable dioxin-like compounds (PCDD/Fs, dl-PCBs, PBDD/Fs, PBBs, chlorinated and brominated polycyclic aromatic hydrocarbons, N-dioxins).

To allow congener differentiation, all pooled egg samples from Indonesia as well as a pooled eggs sample from a Bangkok supermarket were analyzed for content of individual PCDD/Fs as well as an extended list of PCB congeners by HRGC-HRMS at the accredited laboratories Münster analytical solutions (MAS) Gmbh in Münster, Germany and/or in the State Veterinary Institute in Prague, Czech Republic. All samples were also analyzed for content of non-dioxin-like (indicator) PCBs (iPCBs), DDT and its metabolites, hexachlorocyclohexanes (HCHs), hexachlorobutadiene (HCBD), pentachlorobenzene (PeCB) and hexachlorobenzene (HCB) in a Czech certified laboratory (University of Chemistry and Technology in Prague, Department of Food Chemistry and Analysis).

The eggs from Bangun, Tropodo and a Bangkok supermarket were also analyzed for PBDEs, HBCD and short chain chlorinated paraffins (SCCPs). All of these analyses were conducted in a Czech certified laboratory (Institute of Chemical Technology, Department of Food Chemistry and Analysis). The samples of free-range chicken eggs in this report were sampled during April of 2019. The analyses of eggs from Indonesia were conducted in European laboratories in the period between June and September 2019.

ANNEX 2.
SAMPLE COMPARISON OF REGIONS SINCE 2005

TABLE 3. PCDD/Fs IN FREE-RANGE CHICKEN EGGS SAMPLES FROM DIFFERENT REGIONS – MAXIMUM LEVELS MEASURED IN 2005 – 2018 (IN pg WHO-TEQ g^{-1} OF FAT)

Country, Locality	Region	Year	Level of PCDD/Fs	Fold higher than EU standard	Potential source	Source of information
Ghana, Agbogbloshie	Africa	2018	661	264	e-waste site	Petrlik, Adu-Kumi *et al.* 2019
Ghana, Accra - hospital	Africa	2018	49	20	waste incineration	Petrlik, Adu-Kumi *et al.* 2019
Cameroon, Yaoundé - hospital	Africa	2018	4.6	2	waste incineration; open burning	Petrlik, Adu-Kumi *et al.* 2019
Egypt, Not specified	Africa	2010-2014	4.5	2	metallurgical industry	Khairallah, El-Kabbanya S. *et al.* 2015
Vietnam, Bien Hoa	Asia	2011	248	99	contaminated site (Agent Orange)	Traag, Hoang *et al.* 2012
Indonesia, Tropodo	Asia	2019	200	80	tofu factory using waste as fuel	This study
Thailand, Samut Sakhon	Asia	2015	84	34	e-waste site and open burn-ing	Teebthaisong, Petrlik *et al.* 2018
Indonesia, Kendalsari	Asia	2018	49	20	secondary alu-minum smelter	SVÚ Praha 2018
Taiwan, Chang-Hua County	Asia	2004-2005	15.0	6	ash from metal-lurgical plant	Chen, Huang *et al.* 2010
China, Wuhan	Asia	2014	12.2	5	munici-pal waste incinera-tor	Petrlik, Behnisch *et al.* 2018

Country, Locality	Region	Year	Level of PCDD/Fs	Fold higher than EU standard	Potential source	Source of information
Turkey, Dilovasi	Asia	2008	10.9	4	metallurgical industry	Aslan, Kemal Korucu *et al.* 2010
Indonesia, Bangun	Asia	2019	10.8	4	dumpsite of imported waste	This study
Kazakhstan, Balkhash	Asia	2013	9.8	4	car wrecks; metallurgical industry	Petrlik, Adu-Kumi *et al.* 2019
Kazakhstan, Shabanbai BI	Asia	2014	9.3	4	PCBs oil contamination	Petrlik, Adu-Kumi *et al.* 2019
Poland, Not specified	CEE	2011	29	12	PCP treated wood	Piskorska-Pliszczynska, Strucinski *et al.* 2016
Ukraine, Krivyi Ryh	CEE	2018	23	9	metallurgical industry	Petrlík, Straková *et al.* 2018
Czechia, Pitárne	CEE	2017	15.4	6	PVC recycling plant	SVÚ Praha 2017
Serbia, Grabovac	CEE	2015	11.1	4	chemical contamination	Petrlík and Behnisch 2015
Poland, Malopolska	CEE	2017	9.5	4	air pollution (general)	WĐgiel, ChrzĐszcz *et al.* 2018)
Armenia, Alaverdi	CEE	2018	7.5	3	copper smelter	Petrlík and Straková 2018
Bosnia and Herzegovina, Zenica	CEE	2015	5.6	2	metallurgical industry	Petrlík and Behnisch 2015
Czechia, Lhenice	CEE	2015	5.3	2	PCB contaminated site	Mach 2016)
Belarus, Gatovo	CEE	2014	4.3	2	car shredder	Petrlík, Kalmykov *et al.* 2015
Portugal, Not specified	Europe	2008	61	25	PCP treated wood	Cardo, Castel-Branco *et al.* 2014
Italy, Piedmont	Europe	2012-2013	38	15	metallurgical industry	Squadrone, Brizio *et al.* 2015

Country, Locality	Region	Year	Level of PCDD/Fs	Fold higher than EU standard	Potential source	Source of information
Belgium, Not specified	Europe	2007	20	8	not specified	Van Overmeire, Waegeneers *et al.* 2009
Germany, Teningen	Europe	2014	11.4	5	former PCB capacitors pro-duction (con-taminat-ed site)	Weber, Schwedler *et al.* 2015
Netherlands, Friesland	Europe	2014	9.6	4	not clear	Hoogenboom, ten Dam *et al.* 2014, Hoogen-boom, ten Dam *et al.* 2016
Netherlands, Rijnmond	Europe	2014	9.6	4	industrialized area of the Netherlands	(Hoogenboom, ten Dam *et al.* 2014
Italy, Caserta	Europe	2014-2015	6.2	2	open burning of waste	Lambiase, Serpe *et al.* 2017
Netherlands, Harlingen	Europe	2013	4.8	2	munici-pal waste incinera-tor	Arkenbout 2014
Uruguay, Minas	GRU-LAC	2009	23	9	PCBs burning cement kiln	Reyes 2010, Uruguay 2017
Brazil, Vespasiano - Bello Horizonte	GRU-LAC	2014	7.4	3	fire in cement kiln (used tires burnt)	Augusti, Nunes *et al.* 2015
Peru, Zapallal	GRU-LAC	2010	4.4	2	ash from metal-lurgical work-shops	Swedish EPA 2011
Canada, Not specified	North America	2005-2006	10.6	4	PCP treated wood	Rawn, Sadler *et al.* 2012

ANNEX 3:
WASTE INCINERATION AS A SOURCE OF UNINTENTIONALLY-PRODUCED POPS AND STOCKHOLM CONVENTION OBLIGATIONS AND GUIDELINES

Parties to the Stockholm Convention are obliged to develop an action plan to address sources of unintentionally-produced POPs, and they are obliged to implement the plan according to Article 5 of the Convention (Stockholm Convention 2010). As part of the plan, each Party should develop and maintain a national inventory of sources of unintentionally-produced POPs together with an estimate of releases. Parties should evaluate the effectiveness of national laws and policies that contribute to managing these releases and develop strategies aimed at minimizing these releases. Every five years they should review the success of these strategies in meeting Convention obligations and report the results of this review to the Conference of the Parties.

The Indonesian government has proposed building waste incinerators (Gokkon 2019) to tackle plastic waste in 12 cities (Humas 2019). Several elements of the treaty are highly relevant to decisions regarding construction and operation of waste incinerators. Parties are obliged to promote measures that will reduce the releases of unintentional POPs or eliminate their sources. Parties are also obliged to promote the development of substitute or modified materials, products and processes to prevent the formation and release of unintentionally-produced POPs such as dioxins. Parties are obliged to promote the use of best available techniques (BAT) and best environmental practices (BEP) to control the sources of unintentional POPs identified in its inventory, and Parties are obliged to require the use of BAT to control certain sources (Stockholm Convention 2010).

Parties are given flexibility in defining how BAT will be nationally applied. However, each Party has a formal obligation to define BAT in some way, and it must do so taking into account the guidance provided by the Convention and by the adopted Guidelines. Based on a Party's own definition of BAT, it must promote the use of BAT standards for all dioxin sources listed in its national inventory, and it must require the use of BAT for new facilities in the source categories listed in Part II of Annex C, including incinerators.

The Convention's BAT/BEP Guidelines contain several important elements with high relevance to practical considerations for reducing and eliminating POPs – including from incinerators. These include serious efforts to avoid construction of incinerators by giving priority to alternatives (Stockholm Convention on POPs 2008).

> *"When considering proposals to construct new waste incinerators, priority consideration should be given to alternatives such as activities to minimize the generation of waste, including resource recovery, reuse, recycling, waste separation and promoting products that generate less waste. Priority consideration should also be given to approaches that prevent the formation and release of persistent organic pollutants." (Stockholm Convention on POPs 2008).*

The BAT/BEP Guidelines also clearly state a process that decision-makers should follow when deciding on building and operating incinerators noting that they, "should undertake a comparison of the proposed process, the available alternatives and the applicable legislation using what might be termed a "checklist approach", keeping in mind the overall sustainable development context and taking fully into account environmental, health, safety and socio-economic factors." (Stockholm Convention on POPs 2008).

The Convention recommends the following elements of the approach: reviewing the proposed new facility in the context of sustainable development; identifying possible and available alternatives; undertaking a comparative evaluation of both the proposed and identified possible and available alternatives; and priority considerations which include avoiding formation and release of unintentional POPs.

The treaty notes that when a proposed incinerator is compared with an alternative, "Health, safety and environmental impacts of proposed alternatives should be compared with the corresponding impacts of the originally proposed facility." (Stockholm Convention on POPs 2008).

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