RESULTS BRIEF

PLASTIC WASTE POISONS THE FOOD CHAIN IN KENYA AND TANZANIA

A BRIEF EVALUATION OF THE RESULTS

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SUMMARY OF THE ANALYTICAL RESULTS FOR POPS IN EGGS FROM NAIROBI - MIREMA

An analysis of free-range chicken eggs sampled at a site in Nairobi – Mirema, Kenya, approximately 300 m from a community cooker situated on fenced-in school grounds and using plastic waste for fuel, revealed:

- Significant levels of very hazardous chemicals including dioxins and hexabromocyclododecane (HBCD), which are all regulated globally under the Stockholm Convention.
- The dioxin level in the Mirema eggs was 12 pg TEQ g^{-1} fat, which is almost 5 times the EU limit of 2.5 pg TEQ g^{-1} fat, set as the tolerable level of dioxins (PCDD/Fs) in eggs. The concentration of dioxins in the Mirema eggs is comparable to the levels found in the vicinity of highly contaminated sites near chlorine chemical plants in Russia (Petrlik, Speranskaya *et al.* 2005) or a municipal waste incinerator location in Slovakia (Petrlik, Hegyi *et al.* 2005), and higher than the levels found in the vicinity of a solid waste landfill in Belarus (Petrlik, Lobanov *et al.* 2005).
- Eating half an egg from a sample taken from the vicinity of the community cooker in Nairobi – Mirema would cause a person to exceed the European Food Safety Authority's TDI (tolerable daily intake) for dioxins and dioxin-like PCBs by 2.3-fold. One egg from this locality can contain around 67 pg TEQ of dioxins and dl-PCBs, which is almost equivalent to the total TDI for one person weighing 70 kg. It is worth noting that normally people are not only exposed to dioxins and dl-PCBs from eggs alone, but also from the intake other foods, in particular food containing animal fats.
- The eggs collected in Nairobi – Mirema were also contaminated by the brominated flame retardant hexabromocyclododecane (HBCD), used for example in refrigerator linings. Our analysis found the 4th highest level of this chemical ever measured in chicken eggs from African countries, more than two times higher than at the Guiyu e-waste site in China (Zeng, Luo *et al.* 2016). The levels of another group of banned brominated flame retardants, polybrominated diphenyl ethers (PBDEs), however, were not very high.
- All measured POPs in this pooled eggs sample were found at higher levels than in pooled egg samples taken from a supermarket in Accra and/or other supermarkets taken as background samples for comparison.

SUMMARY OF THE ANALYTICAL RESULTS FOR POPS IN EGGS FROM PUGU KINYAMWEZI

An analysis of free-range chicken eggs sampled from five households located next to a large municipal solid waste dumpsite on the south-western edge of Dar es Salaam, Tanzania, revealed:

- Significant levels of very hazardous chemicals including dioxins, both chlorinated (PCDD/Fs) and brominated (PBDD/Fs), polychlorinated biphenyls (PCBs), and short-chain chlorinated paraffins (SCCPs), which are all regulated globally under the Stockholm Convention.
- The fifth-highest level of dioxins in eggs from Africa ever measured was found in a sample collected at Pugu Kinyamwezi.
- The dioxin level in the Pugu Kinyamwezi eggs was 26 pg TEQ g^{-1} fat, so two times higher in comparison with the eggs from Nairobi – Mirema, and higher than levels found in the vicinity of polluted sites near chemical plants in Mexico (Petrlik, Bejarano *et al.* 2005) or in Kerala, India (Petrlik, Jayakumar *et al.* 2005). The concentration of dioxins in the Pugu Kinyamwezi eggs is comparable to the levels found in the vicinity of a chlorine chemical plant in the Czech Republic (Greenpeace CZ 2002), or at a site in Poland contaminated from wood treated with pentachlorophenol (Piskorska-Pliszczynska, Strucinski *et al.* 2016).
- Eating half an egg from the sample taken from the vicinity of a dumpsite in Pugu Kinyamwezi, Tanzania, would exceed the EFSA's TDI for dioxins and dioxin-like PCBs by 7.5-fold. One egg from this locality can contain around 220 pg TEQ of dioxins and dl-PCBs, which is almost equivalent to the total TDI for 13 persons weighing 70 kg each.
- PBDD/Fs contributed to the overall dioxin toxicity expressed in TEQ levels by one tenth, which is a substantial amount, resulting most likely from the burning of plastics from electronic waste containing brominated flame retardants. That can create these highly toxic chemicals, which have been measured at very high levels in eggs from an e-waste scrap yard in Agbogbloshie, Ghana, as well (Hogarh, Petrlik *et al.* 2019).
- Eggs collected in the neighborhood of the Pugu Kinyamwezi dumpsite were highly contaminated by SCCPs, which are used as additives in a variety of plastics. Our analysis showed the 3rd highest level of this chemical ever measured in chicken eggs from African countries, almost 10 times higher than in the reference sample of eggs from a supermarket in Accra.

- All measured POPs in these egg samples were higher than in the pooled egg sample from the supermarket in Accra and/or other supermarkets taken as background samples for comparison.

WHY DID WE USE FREE-RANGE CHICKEN EGGS FOR MAPPING FOOD-CHAIN CONTAMINATION WITH POPS?

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 the fatty tissues of organisms.

Eggs have a significant lipid content, where POPs from the hen that lays them accumulate. In addition, free-range chickens also pick at food from among the soil and dust in the local area, ingesting some soil in the process, and therefore 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 and for dioxins and dioxin-like PCBs it is 5.0 pg WHO-TEQ g^{-1} fat. There is no current limit for brominated flame retardants or perfluorinated compounds, including PFOS, despite their high toxicity.

LEVELS OF POPS IN EGGS

Table 1 shows the levels of chemicals found in eggs sampled in the Nairobi – Mirema and Pugu Kinyamwezi sites in comparison with background (reference) levels in eggs obtained from a supermarket in Accra originating from chicken kept indoors on large chicken farms. The free-range chicken eggs from Nairobi – Mirema and Pugu Kinyamwezi demonstrate specific levels of contamination of the food chain, so they can indicate the overall contamination of locally produced food originating from animals, including milk or meat from animals potentially foraging freely in the

studied areas. The data indicates a variety of toxic substances present in eggs from the Nairobi – Mirema and Pugu Kinyamwezi sites, including chlorinated dioxins (PCDD/Fs), PCBs, brominated dioxins (PBDD/Fs), SCCPs, PBDEs, HBCD, PFAS substances, and PFOS.

TABLE 1: TOXIC CHEMICALS IN EGGS FROM NAIROBI - MIREMA, KENYA, PUGU KINYAMWEZI, TANZANIA, AND ACCRA - SUPERMARKET, GHANA, USED FOR COMPARISON AS A BACKGROUND LEVEL FOR THE AFRICAN EGG SAMPLES (NG g^{-1} FAT IF NOT INDICATED OTHERWISE)

Locality	Nairobi - Mirema	Pugu Kinyamwezi	Accra Supermarket	EU standard / limits
Sample ID (eggs)	KE_001	TZ-PU-KI_ EGG	ACC-M-E	
Date of sampling	01/2020	01/2020	11/2018	
Number of eggs in pooled sample	5	9	6	
Fat content (%)	14.0	18.0	8.8	
PCDD/Fs (pg TEQ g^{-1} fat)	12	26	0.39	2.50
DL PCBs (pg TEQ g^{-1} fat)	2.1	9.5	0.17	-
Total PCDD/F + DL PCBs (pg TEQ g^{-1} fat)	14	35	0.56	5.00
PBDD/Fs (pg TEQ g^{-1} fat)	NA	3.0	< LOQ	-
SCCPs	102	599	62	-
Sum of HBCD	287	30	< LOQ	-
Sum of PBDEs	24	50	11.2	-
Sum of N-BFRs	3.6	< LOQ	< LOQ	-
Sum of PFASs (ng g^{-1} fw)	1.5	4.7	NA	-
L-PFOS (ng g^{-1} fw)	0.6	2.3	NA	-

NA = not analyzed; < LOQ = below the level of quantification of the used analytical method (mostly meaning a negligible level)

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 testoster-

one 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. The eggs from Nairobi – Mirema were not analyzed for brominated dioxins due to the financial limitations of our study.

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).

Hexabromocyclododecane (HBCD) is highly toxic to aquatic organisms and has negative effects on reproduction, development, and behavior in mammals, including transgenerational effects (POP RC 2007b).

HBCD has also found its use in packaging material, video cassette recorder housings, and electronic equipment. HBCD was listed in the Stockholm Convention for global elimination with a five-year specific exemption for use in building insulation that expired in 2019.

Short-chain chlorinated paraffins (SCCPs) are a group of POPs added by governments to the Stockholm Convention for global elimination in 2017. SCCPs are toxic to aquatic organisms at low levels, disrupt endocrine function and are suspected to cause cancer in humans (POP RC 2015). SCCPs are other additives in plastics that might also be expected at sites affected by wastes. 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).

ANNEX: COMPARISON WITH OLDER STUDY FROM AFRICAN DUMPSITES

Free-range chicken eggs were also sampled in the vicinity of two African dumpsites in 2004 and 2005, and the results of the analyses for PCDD/Fs, dl-PCBs and HCB were published in separate reports in March and

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

April of 2005 (DiGangi and Petrlik 2005, Petrlik, Diouf *et al.* 2005, Petrlik, Kamande *et al.* 2005).

The levels of dioxins and dl-PCBs measured in eggs from two African sites in Dandora, Kenya, and Mbeubeuss, Senegal, were either comparable (Dandora) or higher (Mbeubeuss) to what we have measured in eggs from the sites in this study.

When we compared the site from Nairobi, Kenya, included in this study, where a community cooker burning waste as fuel is a potential contamination source, with the sample from the Dandora landfill taken in 2004, we could see many differences - in the total level of PCDD/Fs and dl-PCBs (27 pg TEQ g^{-1} fat in eggs from Dandora and 14 pg TEQ g^{-1} fat in eggs from Nairobi – Mirema), in the balance between PCDD/Fs and dl-PCBs, as well as in the balance between PCDD and PCDFs. In addition to this, the dioxin pattern was also different (see graph in Figure 1).

The sample from Dandora taken in 2004 has much more in common with the egg samples from the Pugu Kinyamwezi dumpsite in Tanzania included in this study, although the total level of PCDD/Fs and dl-PCBs is higher in the eggs from Pugu Kinyamwezi at 36 pg TEQ g^{-1} fat. Both the sample from Dandora taken in 2004 and the recent sample from Pugu Kinyamwezi have the same balance between PCDD and PCDF congeners (81:19), and the same PCDD/Fs and dl-PCBs proportion of TEQ (73:27).

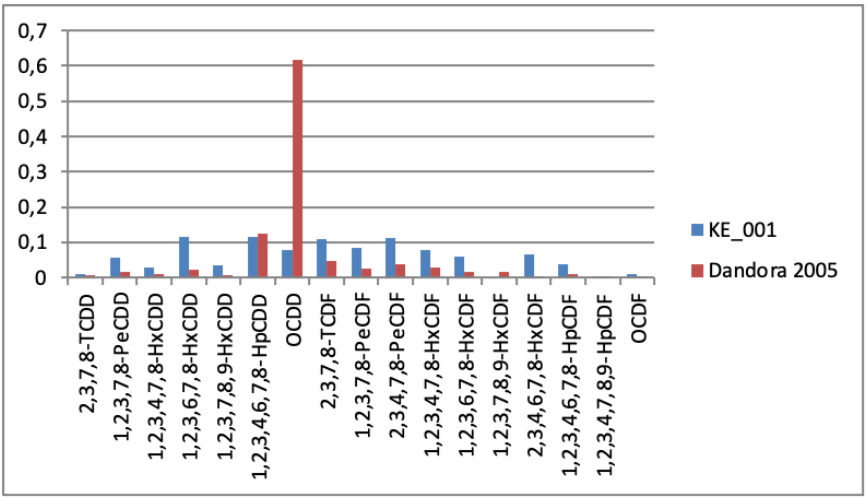

Figure 1: PCDD/F congener patterns in samples from Nairobi – Mirema from 2020 and from the Dandora dumpsite from 2004.

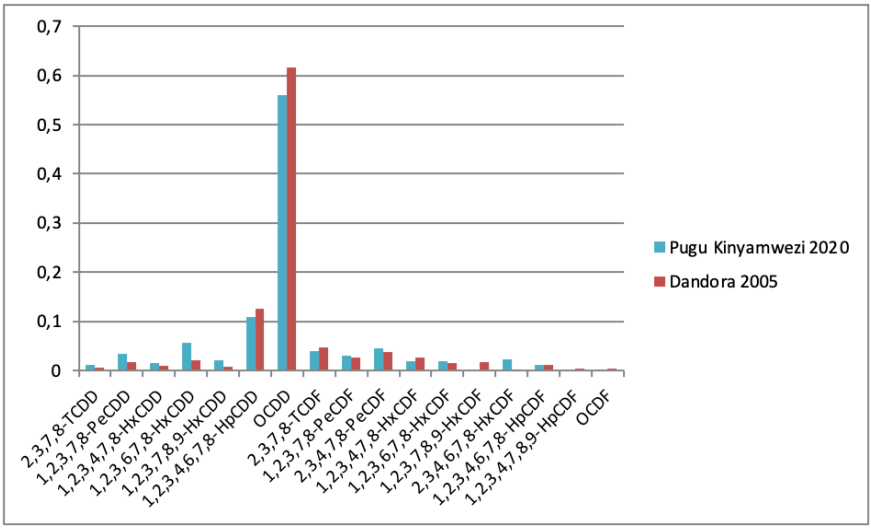

Figure 2: PCDD/F congener patterns in samples from Pugu Kinyamwezi from 2020 and from the Dandora dumpsite from 2004.

Their dioxin congener patterns are also very close to each other (see graph in Figure 2). Both samples were taken at dumpsites with large quantities of plastic waste where open burning occurs quite often. The influence on the dioxin levels from such practices in Dandora were also proven by passive air sampling. At the Dandora site "mean concentrations of 1041 pg sample" were measured during a pilot passive air sampling project in Africa in 2005 – 2006 (Přibylová and Klánová 2013).

However, the level of dioxins in the eggs from Nairobi – Mirema, exceeding the EU limit value by more than fourfold, shows that the burning of waste in community cookers is not a safe way of dealing with plastic waste.

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