UN environment programme

Regional Report

Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the African Region

ISBN: 978-92-807-4149-0

Job number: DTI/2639/GA

Disclaimer

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory or city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Mention of a commercial company or product in this document does not imply endorsement by the United Nations Environment Programme or the authors. The use of information from this document for publicity or advertising is not permitted. Trademark names and symbols are used in an editorial fashion with no intention on infringement of trademark or copyright laws.

The views expressed in this publication are those of the authors and do not necessarily reflect the views of the United Nations Environment Programme. We regret any errors or omissions that may have been unwittingly made.

Suggested citation: United Nations Environment Programme (2024). *Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the African Region*. Geneva

DOI: https://doi.org/10.59117/20.500.11822/45420

URL: https://wedocs.unep.org/20.500.11822/45420

ACKNOWLEDGEMENTS

This report was coordinated by the United Nations Environment Programme (UNEP), in the framework of the project title "Continuing regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the African Region"; Project GEF ID 4886.

The Chemicals and Health Branch of UNEP is acknowledged for assistance and preparation of maps as well as coordination of input from the national teams in the Africa region.

UNEP appreciates the information provided by project countries to section 4.1.3 Core matrix human milk, and to the Section 7 Sustainability Plans. These two sections are based on the information included in the national reports submitted by project country.

Internal review at UNEP was done by Victor Hugo Estellano Schulze, Haosong Jiao, and Tapiwa Nxele.

The worldwide implementation of the Global Monitoring Plan is made possible thanks to the substantial contributions by the Global Environment Facility (GEF) to support POPs monitoring activities in regions implemented by UNEP.

This document has been prepared by:

Dr Heidelore Fiedler, Örebro University, Sweden under contract by Basel Convention Coordinating Center Stockholm Regional Center Latin America and the Caribbean (BCCC-SCRC).

All original graphics and tables were prepared by Heidelore Fiedler unless otherwise specified.

Layout and graphic design modifications: Murat Özoğlu and Lowil Fred Espada.

UNEP, Chemicals and Health Branch, Geneva, Switzerland. 110 pp.

ABBREVIATIONS

CEE	Central and Eastern Europe
DDT	Dichlorodiphenyltrichloroethane
GEF	Global Environment Facility
GMP	Global monitoring plan
GRULAC	Group of Latin America and the Caribbean
HCH	Hexachlorocyclohexane
HBB	Hexabromobiphenyl
HBCD	Hexabromocyclododecane
PAS	Passive air sampler(s)
PBDE	Polybrominated diphenylether(s)
PCB	Polychlorinated biphenyl(s)
PCDD	Polychlorinated dibenzodioxins
PCDF	Polychlorinated dibenzofurans
PFAS	Perfluororoalkane substances
PFHxS	Perfluorohexanesulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluorooctanesulfonic acid
PUF	Polyurethane foam
TEF	Toxicity equivalency factor
TEQ	Toxic equivalent
UN	United Nations
UNEP	United Nations Environment Programme
WBC	World Bank classification (of income groups)
WEOG	Western European and Other Groups
WHO	World Health Organization

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES IN APPENDIX

SECTION 1

Introduction

Photo: ©Unsplash / Sergey Pesterev

1. INTRODUCTION

Persistent organic pollutants (POPs) are characterized by certain toxic properties which include resistance to degradation in the environment, bioaccumulation across food chains and long-range transportation though air, water currents or migratory species (United Nations Environment Programme [UNEP] and Secretariat of the Stockholm Convention 2017). There are gender and age-differentiated windows of susceptibility and exposure to these harmful chemicals. Men and women, and children differ in their physiological susceptibility to the effects of exposure to hazardous chemicals, and different social roles related to gender, age and socioeconomic status can affect exposure to POPs (UNEP 2019a). For example, pregnancy, and lactation are periods of susceptibility where the transfer of POPs can occur (Secretariat of the Strategic Approach to International Chemicals Management 2018).

This report addresses activities and results in support of the global monitoring plan (GMP) as stipulated by the Stockholm Convention on Persistent Organic Pollutants (POPs) and coordinated by the United Nations Environment Programme (UNEP). The report covers the period of the UNEP/GEF GMP2 project implemented for fifteen countries in the African region (UNEP 2015a). The report covers the time between 2016 and 2021.

Activities related to the two rounds of interlaboratory assessments, are referred to in a separate report (UNEP 2023a).

1.1. Compounds to Be Monitored

The UNEP/GEF GMP2 projects from the onset included the POPs listed until 2013 (see Table 1, upper part). At the mid-term workshops in 2017, it was agreed with the participating countries and the expert laboratories to expand the spectrum to include all POPs listed at the time. In addition, agreement was reached to also include perfluorohexanesulfonic acid (PFHxS), which was recommended for listing by the POPs review committee (POPRC) in 2019 (Secretariat of the Stockholm Convention 2019a) and listed at the tenth meeting of the Conference of the Parties in 2022 (Secretariat of the Stockholm Convention 2022).

Table 1: Recommended analytes (UNEP 2021)

COP	POPs or POPs group	Recommended analytes
Initial POPs	Aldrin	Aldrin
	Chlordane	cis- and trans-chlordane; and cis- and trans-nonachlor, oxychlordane
	Dichlorodiphenyltrichloroethane (DDT)	4,4'-DDT, 2,4'-DDT and 4,4'-DDE, 2,4'-DDE, 4,4'-DDD, 2,4'-DDD
	Dieldrin	Dieldrin
	Endrin	Endrin
	Hexachlorobenzene	HCB
	Heptachlor	Heptachlor and heptachlorepoxide
	Mirex	Mirex
	PCB	ΣPCB_6 (6 congeners): 28, 52, 101, 138, 153, and 180
		PCB with TEFs (12 congeners): 77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189
	PCDD/PCDF	2,3,7,8-substituted PCD/PCDF (17 congeners)
	Toxaphene	Congeners P26, P50, P62
COP-4	Chlordecone	Chlordecone
	alpha-hexachlorocylcohexane	α–HCH
	beta-hexachlorocylcohexane	β–HCH
	Lindane	γ–HCH
	Hexabromobiphenyl	PBB 153
	Pentachlorobenzene	PeCBz
	Tetra- and pentabromodiphenyl ether *	PBDE 47, 99, 153, 154, 175/183 (co-eluting), Optional: PBDE 17, 28, 100
	Hexa- and heptabromodiphenyl ether **	
	Perfluorooctane sulfonic acid	PFOS (linear and branched PFOS, ∑PFOS) for air, precursor compounds: FOSA, NMeFOSA, NEtFOSA, NMeFOSE, NEtFOSE
COP-5	Endosulfan	α-, β-endosulfan; and endosulfan sulfate
COP-6	Hexabromocyclododecane	α-HBCD, β-HBCD, γ-HBCD
COP-7	Hexachlorobutadiene	HCBD
	Pentachlorophenol	[PCP, PCA]
	Polychlorinated naphthalenes (PCN)	[PCN]
COP-8	Short-chain chlorinated paraffins (SCCP) (C_{10}-C_{13}) alkanes	[SCCP]
	Decabromodiphenyl ether	PBDE 209
COP-9	Dicofol	Dicofol
	Perfluorooctanoic acid	PFOA
COP-10	Perfluorohexanesulfonic acid	PFHxS

* commercial pentabromodiphenyl ether, c-penta BDE

** commercial octabromodiphenyl ether, c-octa BDE

Note: For substance groups in square brackets, no decision has been made as to the specific compound to be analyzed.

1.2. Matrices to Be Sampled

Passive air samplers (PAS) have been developed as simple and cost-effective and PAS equipped with polyurethane foam (PUF) disks (Shoeib and Harner 2002; Herkert, Martinez, and Hornbuckle 2016) or XAD resins (Wania *et al.* 2003) have been widely applied to measure and assess atmospheric concentrations of POPs, due to their capacity to retain POPs at low cost and ease of handling. The sorbing matrix (PUF) is usually installed in protective chamber, which can be either formed like a dome or a cylinder (Shoeib and Harner 2002). This protective chamber used to protect the sorbent from the deposition of the large particle, sunlight, precipitation, and help to reduce the impact of wind speed on the sampling rate.

Among the core matrices to evaluate changes in POPs concentrations over time, human milk and human blood were recommended to assess human exposure. In the UNEP-coordinated projects, human milk was chosen to be analyzed for all POPs listed in the annexes of the Convention. The biomonitoring component of the GMP has been put in place by the United Nations Environment Programme (UNEP) in coordination with the World Health Organization (WHO) (UNEP/POPS/COP.6/28). Due to inherent persistence and bioaccumulation of POPs, the biomonitoring samples should be collected from primiparae, *i.e.*, mothers having their first child.

In order to promote reliability and comparability of results, samples were collected by the participating countries following a comprehensive protocol originally developed by WHO (WHO 2007) and modified by UNEP to allow analysis for all POPs in this project (UNEP 2017a). Participating countries were encouraged to adhere as closely as possible to the protocol, which provides guidance on the number and type of samples, selection of donors, collection, storage and pooling of samples, and shipping of samples to the laboratory contracted by UNEP. For each sample, national approval was obtained before sampling, following the general ethical guidelines for studies involving human subjects by the WHO (WHO 2011). The identity of the mothers was not disclosed. In brief, one national pool as a representative sample should be prepared by collecting 50 mL of breast milk from 50 mothers for up to 50 million citizens. The most important criterion is that the donating mother should be *primiparae*; all other criteria were less important (UNEP 2017a).

The GMP defined water as a core matrix to evaluate changes over time caused by Party action to eliminate POPs according to the goals of the Stockholm Convention (Fiedler *et al.* 2019; Fiedler *et al.* 2020a) for PFOS and PFOA; not for the other POPs. The GMP guidance document (latest version UNEP 2021), the GMP guidance document already included PFHxS. The aim of the UNEP-coordinated GMP2 projects was to test the suitability of the guidance document established for water sampling (Weiss *et al*. 2015) and investigate the levels of PFOS, PFOA and PFHxS in surface water samples collected from developing countries in Africa, Asia-Pacific, and GRULAC.

To summarize, the matrices for POPs analysis include the following core matrices:

1	Ambient air:	for all POPs (including PFOS precursors and PBDE 17 and PBDE 28)
2	Human milk:	All POPs
3	Water:	PFOS, PFOA and PFHxS

This report covers the core matrices only and does not present other matrices albeit analyzed by the expert laboratories and following general guidance produced under the UNEP/GEF GMP2 projects (UNEP 2017b). The sampling strategies followed national priorities to collect 'samples of national interest' but also had a strong capacity building component since the sampling strategy was built on having mirror samples; *i.e.* the same sample analyzed in an expert laboratory and in a national laboratory. For information, the national reports produced by the participating countries should be consulted.

SECTION 2

Characteristics of the Participating Countries

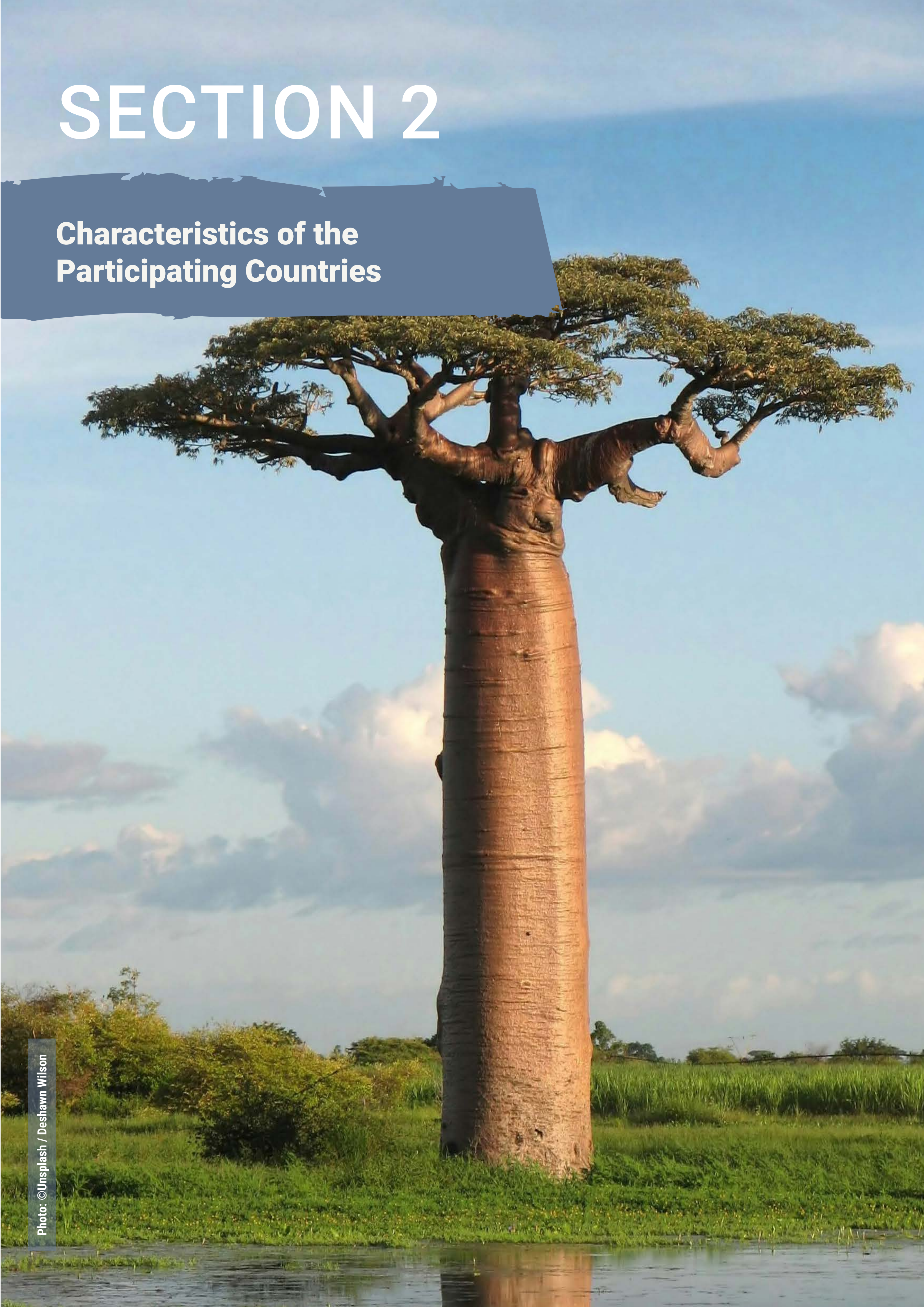


Photo: ©Unsplash / Deshawn Wilson

2. CHARACTERISTICS OF THE PARTICIPATING COUNTRIES

2.1. Global Development Indicators of Participating Countries

For the characterization of the economic situation in a country, the World Bank Classification (WBC) is used by defining the four income groups (L=low, LM=lower-middle, UM=upper-middle, H=high) as the gross national income (GNI) per capita in US$ according to the Atlas methodology (World Bank n.d. a). From Table 2, it can be seen that three countries moved up (MUS from UM to H, SEN and TZA from L to LM). This leaves five low-income countries in the Africa project (COD, ETH, MLI, TGO, and UGA).

The countries in the Africa project differ largely as to population and population density, which is defined as population density per square kilometer of land area (population/km²). All countries remained with the same PD_Code although many countries had an increase in population density. Within the 15 countries in Africa, two were least densely populated countries, MLI and ZMB ((PD<25, having less than 25 inhabitants *per* km²) whereas MUS was densely populated PD_330-2000, 5, (having between 330 and 2 000 inhabitants per km²). For exact numbers as provided by the World Bank, see column PopDen in Table 2 (World Bank n.d. b).

2.2. Assessment and Visualization of Results

All data were maintained in Microsoft Office 365 Excel®; statistical evaluations were made using R packages with R-Studio. The Kruskal-Wallis H test was used to determine if there are statistically significant differences between the independent variables and dependent variables. Post-hoc analysis was performed using the pairwise Wilcoxon test. Adjustment of the p-value was made using the Benjamini-Hochberg method. Significance level was set to p=0.05.

Table 2: WBC classifications of the Africa countries PD for reference year: left=pop/km², right=PD_Code

		WBC classification			GNI per year			Population density code (PD_Code)			PopDen (pop/km²)		
Country name	**ISO3**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
Congo DR	COD	L	L	L	1 030	1 080	1 110	PD_25-90	PD_25-91	PD_25-92	36	37	38
Egypt	EGY	LM	LM	LM	10 800	11 350	11 820	PD_90-200	PD_90-200	PD_90-200	97	99	101
Ethiopia	ETH	L	L	L	2 010	2 140	2 300	PD_90-200	PD_90-200	PD_90-200	106	109	99
Ghana	GHA	LM	LM	LM	4 860	5 200	5 540	PD_90-200	PD_90-200	PD_90-200	128	131	134
Kenya	KEN	LM	LM	LM	4 130	4 380	4 570	PD_25-90	PD_25-90	PD_25-90	88	90	92
Morocco	MAR	LM	LM	LM	7 170	7 480	7 700	PD_25-90	PD_25-90	PD_25-90	80	81	82
Mali	MLI	L	L	L	2 170	2 270	2 330	PD<25	PD<25	PD<25	15	16	16
Mauritius	MUS	UM	UM	H	23 540	25 460	26 790	PD_330-2000	PD_330-2000	PD_330-2000	623	623	624
Nigeria	NGA	LM	LM	LM	5 030	5 040	5 180	PD_200-330	PD_200-330	PD_200-330	210	215	221
Senegal	SEN	L	LM	LM	3 110	3 300	3 410	PD_25-90	PD_25-90	PD_25-90	80	82	85
Togo	TGO	L	L	L	2 010	2 120	2 220	PD_90-200	PD_90-200	PD_90-200	142	145	149
Tunisia	TUN	LM	LM	LM	10 910	11 290	11 410	PD_25-90	PD_25-90	PD_25-90	74	74	75
Tanzania	TZA	L	L	LM	2 470	2 620	2 810	PD_25-90	PD_25-90	PD_25-90	62	64	65
Uganda	UGA	L	L	L	2 030	2 110	2 220	PD_200-330	PD_200-330	PD_200-330	205	213	221
Zambia	ZMB	LM	LM	LM	3 330	3 550	3 550	PD<25	PD<25	PD<25	23	23	24

SECTION 3

National Activities with Respect to Sampling and POPs Analysis

Photo: ©Unsplash / CDC

3. NATIONAL ACTIVITIES WITH RESPECT TO SAMPLING AND POPS ANALYSIS

3.1. Sampling

For the sampling at national level, standard operational procedure (SOP) documents were developed and made available in English, Spanish and French for the core matrices air using passive samplers (UNEP 2017c), water (UNEP 2017d), and human milk (UNEP 2017a). A fourth SOP was developed for the national samples (UNEP 2017b), which are not included in this report but can be found in the national reports for this project.

3.1.1. Core Matrix Air with PAS/PUF

Similar to the UNEP/GEF GMP1 projects (Bogdal *et al*. 2013; Fiedler *et al*. 2013), in these UNEP/GEF GMP2 projects, passive air samplers (PAS) consisting of two bowls as protective chamber and equipped with pre-cleaned polyurethane foam (PUF) disks were used. Up to six pairs of PAS were exposed at one site in each country, each PAS was equipped with one pre-cleaned PUF to capture a specified group of POPs. The sampling sites should not have direct POPs impact. RECETOX equipped all participating countries with passive air samplers and preconditioned PUFs as shown below:

- PUFs 1-4, 9-10: dichloromethane to capture OCPs, PCB, HCBD and brominated POPs
- PUFs 5-8: toluene to capture dl-POPs
- PUFs 11-12: methanol to capture PFAS

Per site, a maximum of 12 PAS were set up whereby each PUF from PAS with odd numbers were shipped to the expert laboratories and PUFs from even-numbered PAS should be analyzed in a national laboratory where capacity existed. As a general rule, each PUF should be exposed for one season, *i.e.*, three months, and be analyzed for the respective POPs group (UNEP 2017b; UNEP 2021) For dl-POPs and toxaphene, since analysis is complex and expensive and concentrations were expected to be low, four PUFs should be combined for one annual sample. The set-up of the PAS/PUFs at a sampling site is detailed in Table 3.

All countries had at least the samplers (and analyses) highlighted with green background (= odd numbers for expert back-up lab analysis). PAS 7 and PAS 8 are special cases and were exposed only when there was a national dioxin laboratory. In such cases, the expert laboratory and the national laboratory both analysed the PUFs on the quarterly basis.

PUFs were shipped with express mail to the expert laboratories, E&H VU universiteit and MTM Research Centre, at defined frequencies; either after each sampling round; however, most countries shipped the PUFs once or twice per year.

The set-up of the PAS/PUFs at a sampling site is detailed in Table 3.

Photo: © Mali, Ministère de l'Environnement de l'Assainissement et du Développement Durable

Table 3: Assignment of samplers, PUFs, and analytes according to laboratory per country

PAS	PUF*	Destination Laboratory	Group of chemicals for analysis	# of analyses per year
PAS 1	I, II, III, IV	Basic POPs pesticides in expert back-up laboratory	aldrin, dieldrin, endrin, chlordane, DDT, alpha, beta, and gamma-HCHs, heptachlor, mirex, HCB, pentachloro-benzene, endosulfan, toxaphene	4
PAS 2	I, II, III, IV	Basic POPs in national POPs laboratory	aldrin, dieldrin, endrin, chlordane, DDT, alpha, beta, and gamma-HCHs, heptachlor, mirex, HCB, pentachloro-benzene, endosulfan, toxaphene	4
PAS 3	I, II, III, IV	Indicator PCB in expert back-up laboratory	6 indicator PCB	4
PAS 4	I, II, III, IV	Indicator PCB in national POPs laboratory	6 indicator PCB	4
PAS 5	I, II, III, IV	Dioxin-like POPs in expert back-up laboratory (combined into one extract as annual average)	17 PCDD/PCDF, 12 dl-PCB	1
PAS 6	I, II, III, IV	Dioxin-like POPs in national dioxin laboratory (combined into one extract as annual average)	17 PCDD/PCDF, 12 dl-PCB	1
PAS 7	I, II, III, IV	Dioxin-like POPs in expert back-up laboratory (each exposure to generate one seasonal data point; total of 4 per year and country)	17 PCDD/PCDF, 12 dl-PCB	4
PAS 8	I, II, III, IV	Dioxin-like POPs in national laboratory (each exposure to generate one seasonal data point; total of 4 per year and country)	17 PCDD/PCDF, 12 dl-PCB	4
PAS 9	I, II, III, IV	PBDE in expert laboratory	8 PBDE, HBCD, HBB	4
PAS 10	I, II, III, IV	PBDE in national laboratory	8 PBDE, HBCD, HBB	4
PAS 11	I, II, III, IV	PFOS in expert laboratory	3 PFAS	4
PAS 12	I, II, III, IV	For PFOS in national laboratory	3 PFAS	4

*Roman numbers (I, II, III, and IV) represent the sampling seasons

Note: Exposure periods were designated as follows

-Seasonal: 3 months with I=Jan-Mar, II=Apr-Jun, III=Jul-Sep, IV=Oct-Dec

-Annual: 4 PUFs from each 3-months exposure combined into one extract for analysis, maximum of 4 PUFs (with one PUF for each season).

Photo: ©Mongolia / Mongolian Academy of Sciences

All countries from the Africa project participated in the air monitoring with PAS/PUFs. The identification of the sampling sites is provided in Appendix in Table S 2.

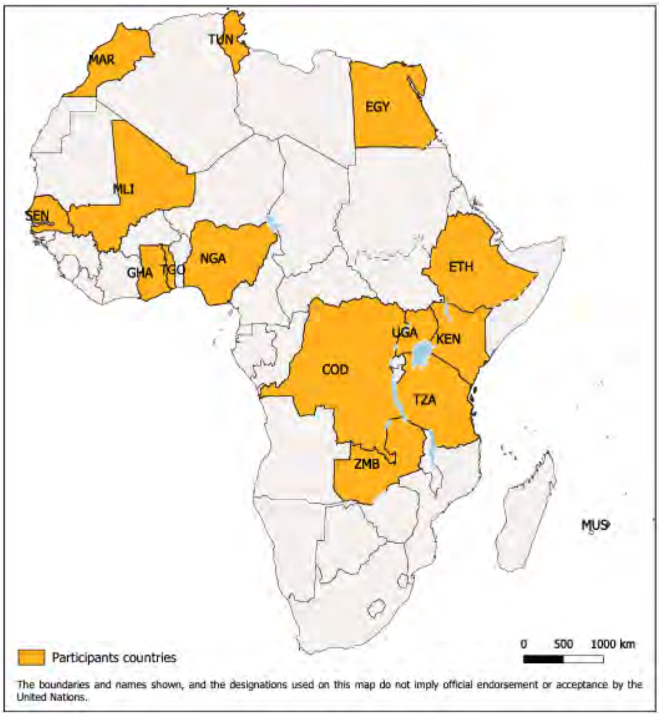


Figure 1: Geographical sketch of countries participating in the UNEP/GMP2 Africa project (graphics, courtesy of Chemicals and Health Branch, Industry and Economy Division of UNEP)

Photographic impressions of the air sampling sies with the PAS exposed are shown from to to.

Sampling site for air with PAS/PUF: Egypt, © Ministry of Environment

Sampling site for air with PAS/PUF: Ethiopia, © Ethiopian Environment and Forest Research Institute

Sampling site for air with PAS/PUF: Ghana, © Environmental Protection Agency

Sampling site for air with PAS/PUF: Kenya, © University of Nairobi

Sampling site for air with PAS/PUF: Mali, © Ministère de l'Environnement, de l'Assainissement et du Développement Durable

Sampling site for air with PAS/PUF: Mauritius, © Ministry of Environment, Solid Waste Management and Climate Change

Sampling site for air with PAS/PUF: Morocco, © National Laboratory for Studies and Pollution Monitoring

Sampling site for air with PAS/PUF: Nigeria, © Federal Ministry of Environment

Sampling site for air with PAS/PUF: Senegal, © Direction de l'Environnement et des Etablissements Classés

Sampling site for air with PAS/PUF: Tanzania, © Vice President's Office, Division of Environment

Sampling site for air with PAS/PUF: Togo, © Direction des Laboratoires/ Laboratoire de Contrôle Qualité et de Normalisation

Sampling site for air with PAS/PUF: Tunisia, © International Centre of Technology Environnemet

Sampling site for air with PAS/PUF: Uganda, © Directorate of Government Analytical Laboratory (DGAL)

Sampling site for air with PAS/PUF: Zambia, © Environmental Management Agency

3.1.2. Core Matrix Air with Active Sampler

Three sites equipped with active air samplers (AAS) were chosen for the Africa project. These were located in Ghana, Kenya, and Mauritius.

Sampling site for air with AAS: Kenya, © University of Nairobi

Sampling site for air with AAS: Mauritius, © Ministry of Environment, Solid Waste Management and Climate Change

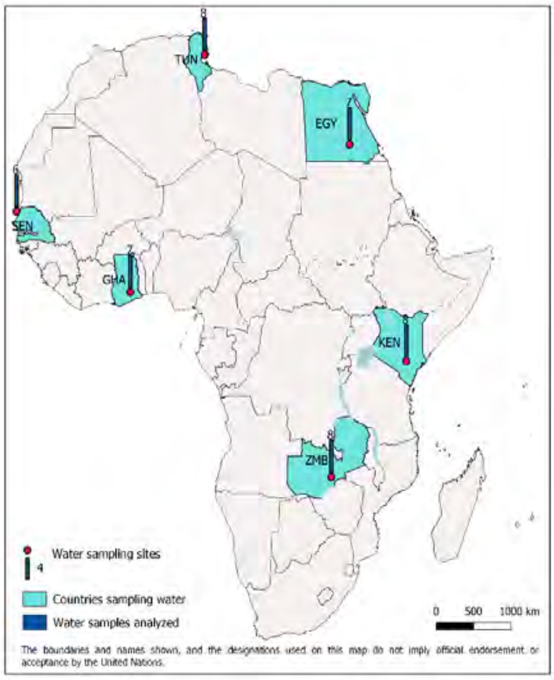


Figure 2: Geographical sketch of water sampling locations under UNEP/GMP2 Africa project

3.1.3. Core Matrix Water

PFAS were not among the initial twelve POPs at the onset of the Stockholm Convention in 2001 (entry into force in 2004) but were listed through the POPs review process. PFOS, its salts and perfluorooctanesulfonyl fluoride (PFOSF) have been listed into annex B of the Stockholm Convention in 2009 (Secretariat of the Stockholm Convention 2009) with an amendment in 2019 (Secretariat of the Stockholm Convention 2009); PFOA, its salts and PFOA-related compounds have been listed in Annex A with specific exemptions in 2019 (UNEP 2019b). PFHxS, its salts and PFHxS-related compounds were listed in Annex A without specific exemptions in 2022 (Secretariat of the Stockholm Convention 2022). With the listing of PFOS in 2009, water has been chosen as a core matrix (Weiss *et al*. 2015). So far, water is a core matrix in the GMP for the perfluorinated compounds only; not for any of the brominated or chlorinated POPs (UNEP 2021).

Surface water samples were collected by staff from local laboratories or institutions from developing countries participating in the water sampling activity of the UNEP/GMP2 projects. Across the projects, a total of 22 countries participated; of these six countries from the African region were chosen to participate. The identification of the sampling sites is provided in Appendix in Table S3,

The graphical sketch of the water sampling sites is shown in Figure 2.

All water samples were collected according to the protocol for the sampling of water as a core matrix in the UNEP/GEF GMP2 projects (UNEP 2017d). To ensure integrity of the samples and to minimize contamination, each country had received nine 1-L high-density polyethylene (HDPE) bottles from Örebro University; it was attempted to have eight samples from each country plus one blank. The protocol prescribes to have an area- and time-integrative sampling location since sampling occurred only 4-times *per* year. Water samples were taken as surface water samples at a recommended depth of about 1 m from either the mouth of a large river, an estuary or bay in each country (for details of sampling locations, see Table S 3. One location for each country was chosen. Samples were taken at the end of each quarter of the year, classified into four intervals using the Roman numbers I, II, III, and IV, respectively. In total 144 water samples were analyzed; the African countries contributed with 44 samples, which corresponds to 92 % realization of the planned activities (6 countries with four samples per year during two years; thus, a total of eight samples per country).

In addition, Nigeria sent one sample and Uganda sent five water samples for PFAS analysis. Both countries sent these samples as national samples since they were not included in the "water sampling network". The water samples received by the expert laboratory were as shown in Table 34. Photographic impressions of the water sampling sites are shown below.

Sampling site for water: Egypt, © Ministry of Environment

Sampling site for water: Ghana, © Environmental Protection Agency

Sampling site for water: Kenya, © University of Nairobi

Sampling site for water: Senegal, © Direction de l'Environnement et des Etablissements Classés

Sampling site for water: Tunisia, © International Centre of Technology Environnemet

Sampling site for water: Zambia, © Environmental Management Agency

3.1.4. Core Matrix Human Milk

Human milk samples have been collected as national pools and sent for analysis. The human milk sampling survey was conducted following a protocol originally developed by WHO (2007), adapted for the regional projects in the SOP by UNEP (2017a). The procedure and criteria are also contained in the GMP guidance document (UNEP 2021) with the objective to be representative of the country. Most important, donor mothers should be primipara and collected between three and twelve weeks after delivery.

Other recommended parameters included

- Mother should be under 30 years of age (the national coordinator might consult national health statistics for possible advice on setting the maximum age)
- Both mother and child should be apparently healthy, including normal pregnancy.
- Mother should be breastfeeding one child only (*i.e.*, no twins).
- Mother should have resided in the represented area (country) for at least the previous ten years.
- Mother should not reside in local areas where emissions of POPs are known or suspected to result in elevated concentrations of POPs in the local population.
- Mother should be available for sample collection within 3 to 8 weeks of delivery.

To avoid contamination of the sample, the State Institute for Chemical and Veterinary Analysis of Food (CVUA) in Freiburg, Germany, as the reference laboratory in this project sent 100 mL pre-cleaned glass bottles to each participating country to collect the breast milk from individual mothers. In addition, a 2 L pre-cleaned glass bottle was provided to prepare the national pool. For the national pool, 25 mL human milk (if available) from each mother was placed into glass bottle, kept in a fridge or freezer until shipment to the central laboratory in Freiburg. Further, all countries sent their samples, either as a national pool or individual samples to CVUA, for analysis of brominated and chlorinated POPs. CVUA subsequently sent an aliquot of 10 mL to MTM Research Center, Örebro University, Sweden, for analysis of perfluorinated compounds. The results are reported *per* national pool or national sub-pool in the case of Niue and Germany.

The recommendations included in the guidance document as regards the criteria for selecting donor mothers as well as the procedure for the chemical analysis are not repeated in the country sections. Details may be found in the national reports of the participating country.

Egypt

Human milk samples from primipara mothers were collected; and a national pool was created and sent to the expert laboratories. Individual human milk samples were sent to national laboratory insert name for POPs analysis as appropriate.

Policy makers and stakeholders were informed of the potential risks of POPs at national level; POPs monitoring results are used for national policy review and control actions towards sustainable monitoring and sound management of POPs.

Ghana

The human milk sampling was coordinated by two institutions, specifically Ghana Atomic Energy Commission and Environmental Protection Agency. Individual milk samples were analyzed locally, and the pooled samples were sent to Freiburg, Germany, for analysis of brominated and chlorinated POPs and Örebro University, Sweden, for perfluorinated substances.

The survey was conducted in the southern, the middle and the northern zones of Ghana. In each zone, one health facility was selected in an urban and rural communities for the collection of the mothers' milk as follows:

- Southern zone: La General Hospital for urban and Ada Hospital for rural communities
- Middle zone: Kwadaso (urban) and Jachie Pramso (rural) hospitals, and
- Northern zone: Tamale (urban) and Tolon (rural) hospitals.

Ethical clearance was obtained from the Ghana Health Services Ethical Review Committee after meeting all the ethical requirements for the sampling of human breast milk before the commencement of the survey. A total of three hundred (n=300) nursing mothers, one hundred from each zone (Southern, Middle, and Northern zones) were used in the survey. Incomplete what was the final outcome

Kenya

The national protocol met all national ethical requirements for human subjects, including informed consent of donors and confidentiality, and in addition quality assurance and control of POPs analyses. Other topics to be considered in these guidelines were: criteria and selection of donors, number of samples, sampling method, sample handling, preparation of pooled sample, model donor questionnaire and informed consent form, transport and storage, analysis of pooled and individual samples and estimated timeline and budget.

The following activities were initially undertaken before sampling started:

1. consultative meetings with representatives from the Ministry of Health and Ministry of Environment (both national and provincial)
2. Inception meetings and on-site training on milk sampling techniques, interviews, filling of the questionnaires etc. (Community health facilitators, research assistents) from selected areas.
3. Issuing of the covering letter from the Ministry of Health before sampling

Interviews of potential donors took place at post-natal or well-baby clinics. The selection and visiting the clinics was done prior to collection of samples to acquaint oneself with the staff and facilities and made the necessary arrangements before the selection of donors. Training was also done for those who assisted in milk sampling. The criteria for selection of donors were strictly adhered to, as stipulated in the protocol and only those mothers who met the criteria were.

Collection of samples was conducted at health clinics providing postnatal services, but some arrangements were made to visit the mothers at their homes especially those who could not get enough milk at the time, but this was also done under supervision of health personnel from the clinic.

A minimum of 50 individual samples for the survey were collected between three to eight weeks after delivery. Completion of the questionnaire was done at the time of sample collection, where individual interviews were conducted, and the willing donors signed the Informed Consent Form.

At least 50 mL of milk was collected by hand expression directly to the collecting jars. Sample collection jars were labelled with the donor's individual identification and area code but not the name of the mother. All samples were stored in freezers during the collection period and then transported to the designated laboratory at the Department of Public Health, Pharmacology and Toxicology, University of Nairobi, where they were kept deep frozen at -20 °C while awaiting shipment and analysis.

Both individual and pooled samples were prepared in the analytical laboratory at PHPT laboratory by thawing the frozen samples (50 mL) at room temperature and shaken intensely before removing aliquots as follows:

From 16 individual samples: 25 mL was taken into a 500 mL bottle (Bottle A, 400 mL)

From 34 individual samples: 25 mL was taken into a 1000 ml bottle (Bottle B, 850 mL)

Bottles A and B were sent to CVUA for POPs analysis accompanied by the completed summary of information from the questionnaire. The remaining 25 mL from the 50 50 mL samples were stored in a freezer until analysis for basic POPs in the national laboratory.

Mali

The breast milk sampling activity was carried out by the team of the National Directorate of Health (DNS) which ensured the coordination under the leadership of a breast milk coordinator in collaboration with the competent services and resource persons (doctors, nurses and health personnel of the Ministry of Health and technicians of the Central Veterinary Laboratory).

To facilitate the collection of data, close collaboration was established between the various departments of the Ministries of Agriculture, Livestock, Environment and

Health and the chief physicians of the reference health centers. In the same vein, a memorandum signed by the Minister of Health was used to ensure the proper involvement of health personnel in the various health districts targeted by the study.

Correspondence was sent to the Chief Doctors of the referral health centers to ensure the proper involvement of health personnel and to pre-select primipara women who met the selection criteria in partnership with the master midwives. Individual interviews were conducted to obtain the necessary information from the questionnaire and to ensure that the questionnaire was completed in its entirety. The study procedures were well explained, in particular the donor's right to withdraw from the study without prejudice. In addition, donors were required to give written consent on a standard form: Informed Consent Form. Based on this consent, the initial interview is conducted by the collection staff for each eligible woman, a milk sample is collected and stored, following the inclusion and exclusion criteria and in compliance with the prior consent.

Selection of donors: On the basis of this consent, the initial interview was carried out by the collection staff for each eligible woman, a milk sample was collected and stored, following the inclusion and exclusion criteria and in compliance with the prior consent.

Sampling was conducted between 3 and 8 weeks (21 days to 2 months) after birth. After obtaining prior consent from the donors, individual interviews were conducted to obtain the remaining necessary information from the questionnaire to ensure that the questionnaire was completed in full. Routine hand and chest hygiene and rinsing with copious amounts of clean water were followed without the use of soap to avoid contamination of samples. Once hand hygiene was assured, breastfeeding practice was well established, an individual 50 mL sample was then taken by manual extraction after breastfeeding or while the mother rested on the other breast, to take advantage of the mother's decompression reflex.

Individual milk samples were homogenized by heating to 38 °C and shaking for 10 minutes. Afterwards, they were pooled into two bottles of 500 mL and 1000 mL to package the pooled samples as follows:

- 500 mL bottle: 25 mL of milk from each of the 16 donors was pooled to obtain 400 mL of milk.
- 1000 mL bottle: 25 mL of milk from the other 34 donors were pooled to obtain 850 mL of milk.

Table 4: Table of collection of breast milk samples in Bamako, Mali

CSREF	Number of Donors	Collected Volume by CSREF in mL
CSRéf Commune I Bamako	20	1 000
CSRéf Commune III Bamako	20	1 000
CSRéf Commune I BKO	20	1 000
TOTAL	**60**	**3 000**

Coolers were used to transport the samples from the health centers to the laboratory. Once at the laboratory, they were immediately removed from the coolers and placed in a freezer at -20 °C, until they were shipped to the reference laboratory in Freiburg.

Mauritius

Human milk was collected from 22 February 2018 to 18 March 2018 from urban, rural and coastal regions namely Plaine Verte, Sainte Croix, Terre Rouge, Triolet, Grand Gaube, Bois Pignolet, Notre Dame, Crève Coeur, Saint Pierre, Dagotière, Quartier Militaire, L'Esperance, Bramsthan, Caroline, Flacq, Poste de Flacq, Brisée Verdière, Quatre Sœurs, Bon Accueil, Mare d'Australia, Bois d'Oiseaux, L'Escalier, Black River, Palma, Quatre Bornes, La Gaulette, Tamarin, Beaux Songes, Trois Boutiques, Mahebourg, Souillac, Grand Bois, Bois Chéri, Chamouny and Chemin Grenier. Mothers included in the survey were aged between 19 and 30 years with a mean age of 25 years.

According to the Statistics Mauritius, as at 31st December 2020, the population of the Republic of Mauritius was 1 266 030 inhabitants. 49 individual samples were collected from different regions of the country. It was expected that the number of samples collected for analysis would provide statistically reliable data and would give a sufficient statistical base to allow scientifically valid assessments of changes in levels of POPs over time

For participant recruitment, sensitizing campaigns were held at health clinics providing prenatal and postnatal services. Collection of samples was conducted at the mothers' home by community midwives and community health nursing officers. Mothers were generally explained on the background and purpose of the survey. Informed consent forms were completed at the time of sampling.

Criteria for selecting participants followed the recommendation since the SOP (UNEP 2017a) and was donor mothers had between 3 to 8 weeks (21 days to 2 months) after delivery. A total of 50 mL of milk was manually collected from each participant, after feeding or while the infant was nursing on the other breast. The sample was collected directly into the collecting jar with a protected screw cap provided by CVUA, Freiburg, Germany. The samples were labelled with a unique identification code and were kept in the freezer at -20 °C in the Area Health Centres. The samples were sent to the Central Health Laboratory, Victoria Hospital, in frozen state for the preparation of the pooled sample.

The remaining individual milk samples were kept in the freezer at -20 °C in the Biochemistry Department, Central Health Laboratory and transferred to the GAD for analysis. The extraction of POPs from the milk samples was performed in accordance with the protocol provided by the VU, expert laboratory recruited by UNEP Chemicals and Health Branch during on-site training from 18 to 22 September 2017.

Morocco

The Ibn Sina University Hospital of Rabat covers two establishments, namely the Souissi Maternity Hospital and the National Center for Reproductive Health, where nearly 20 000 births are performed each year. The Souissi Maternity Hospital has been proposed as a site for the collection of breast milk. For this purpose, a team of specialized nurses was put in place for the smooth running of the sampling campaign. The period of these samples was spread from January 2017 until the end of October 2017 and were accompanied by surveys of young mothers, which were the subject of collection of samples of "breast milk".

An authorization from the ethics committee was issued by the competent authority at the Ministry of Health to proceed with the milk collection campaigns from women as donor mothers. The mothers used breast pumps to collect the milk into 50 mL pre-cleaned glass containers (Pyrex glass containers with a screw top). For each sample, the name of the donor mother and the date of collection was noted.

In accordance with the UNEP SOP, 59 individual milk samples were collected, homogenized and then approximately 25 mL of milk from each participant was placed into a 2 000-mL bottle to make a pooled national sample of 1 300 mL. The pool was kept in a freezer at -20 °C until it was sent to the reference laboratory (in frozen form) in Germany for analysis. The remaining samples were analyzed nationally.

Nigeria

The human milk survey was conducted in line with the WHO/UNEP Human Milk Survey Protocol (UNEP 2017a).

In a first step, the national protocol and questionnaires for data collection on donor mothers were developed, in line with national circumstances. The following was included:

- Identification of target communities and public health centres;
- Prior to consultations and processing of ethical clearance at FCT Health Research Ethics Committee, dated 2 January 2018, with the validity period from 9 January 2018 to 8 January 2019;
- Advocacies in identified rural/suburban communities;
- Correspondence and visits to a number of primary healthcare centres (PHCs), maternities and general hospitals in Abuja and its environments;
- Administration of questionnaire and selection of volunteer donors among identified primipara mothers, in line with sampling protocol;

Human milk sampling activities were coordinated by Federal Ministry of Environment (FMEnv), through PCU, with active participation of Federal Ministry of Health representatives, medical staff at surveyed healthcare facilities and community leaders.

Collection of samples was handled by female members of the GMP team, while PCU ensured proper documentation, labelling and preservation of collected samples.

After administering and analysing the questionnaires, a list of volunteers was established, based on the criteria designed to reduce variability in individual samples due to physiological and environmental factors which may impact on the levels of POPs in human milk.

Human milk samples were collected using either manual or pump expressions (based on donors' choice) into pre-cleaned 50 mL amber bottles and temporarily stocked in cool box, for sample integrity and ease of transportation to the refrigerating system in PCU office.

A total of 68 samples were collected, stabilised/sterilised with 0.1 % potassium dichromate and refrigerated. The following Table 5 is the record of healthcare facilities visited, dates and number of samples collected.

Table 5: Nigeria: Healthcare facilities visited, dates and number of samples collected

#	Healthcare Facility	Date of Visit	Number of Samples Collected
1	Primary Health Care Center Gwagwa	29-30 August-2018; 12 and 19 September 2018	6
2	Primary Health Care Center Jiwa	30 September 2018	2
3	Primary Health Care Center Dutse Makaranta	3 August 2018 13, 14, and 20 September 2018	13
4	General Hospital Nyanya	3, 6, 7, 10, and 14 September 2018	7
5	General Hospital Kuje	3, 10, and 17 September 2018	5
6	Primary Health Care Center Lugbe	4, 11, and 18 September 2018	14
7	Primary Health Care Center Karmo	12, 17-19 September 2018	20
8	Primary Health Center Kwali	13 September 2018	1
	Total		68

Senegal

This study was made possible thanks to the close collaboration between the Ministry of Health and the regional and district chief medical officers (MCDs and MCRs). A memorandum signed by the Minister of Health ensured the involvement of health personnel in the various localities targeted by the study. Correspondence sent to these MCDs and MCRs made it possible to pre-select primipara women who met the selection criteria in partnership with the master midwives.

This survey was conducted by the Poison Control Center in the Dakar region through health facilities such as Nabil Choucair, Roi Baudouin, Dominique de Pikine, Polyclinique de Dakar, Gaspard Camara and the health posts Parcelles assainies and Guédiawaye. These facilities were chosen for their level of attendance and their gynecological and pediatric activities, factors that offered opportunities and facilities for obtaining breast milk samples. A total of 50 individual samples were collected from July to September 2017 and the number of mothers selected per site depended on strict adherence to the selection criteria.

In Senegal, HIV testing is included in prenatal checkups, so the HIV status of the donor is known from her medical records. However, donors who tested positive for HIV were not excluded from this study; any milk sample found to be contaminated or suspected of being contaminated with HIV had to be processed by heating at 62.5 °C for 30 minutes.

The donor questionnaire was used as the basis for recording the data obtained from women participating in the study. Once breastfeeding is well established, sampling is conducted between 3 and 8 weeks (21 days to 2 months) after birth. At the time of collection, individual interviews were conducted to obtain the remaining information and to ensure that the questionnaire is completed in full. 50 mL of milk was collected by manual extraction after breastfeeding or while the mother was resting on the other breast, to take advantage of the mother's decompression reflex. In some cases, a breast pump was provided to facilitate milk extraction. The sample was then collected directly into the container provided by the Poison Control Center team and the milk samples were stored in a refrigerator at +4 °C for up to 72 hours. A document summarizing the information about the mothers who provided samples for this study was prepared by Epi info and submitted to GEMS/Food, but always in the strictest confidence. This document was sent with the pooled samples to GEMS by DHL.

Each sample was labeled with a unique identification code, placed in a cooler and sent to the FMPOS Toxicology and Hydrology Laboratory. Small tablets of potassium dichromate ($K_2Cr_2O_7$) were added to the bottles to sterilize the milk and maintain the integrity of the fat during transport. Samples were immediately removed from the coolers and placed in the freezer at -20 °C until shipment. Frozen samples were packed in dry ice and shipped to the receiving laboratory in Germany by express mail.

The remaining individual samples were sent to and kept at the Ceres-Locustox laboratory in Dakar.

Tanzania

The survey was undertaken across five regions. Regional medical officers were involved in the selection of suitable health facilities for the survey. The following health facilities were purposely selected: Mount Meru Regional Referral Hospital (Arusha), Makongoro Health Centre (Mwanza), Mkoani Regional Referral Hospital (Pwani), Makole Health Centre and Chamwino Dispensary (Dodoma) and Mbeya Regional Referral Hospital (Mbeya). Inclusion of some of these health centres, as opposed to originally planned sites was due to the fact that clinics are usually conducted at these health facilities as identified in each specific region. Health Care Workers, mostly nurses helped in selection suitable candidates (based on existing data at the facility) for participation in accordance with selection and exclusion criteria.

The survey was conducted in accordance with standard Guidelines issued by UNEP. A total of 55 mother's milk samples were collected from five different locations, in accordance with UNEP criteria, to select one sample in every one million people. Currently, Tanzania has 54.4 million population. Individual samples will be analyzed in-country for some of the POPs while the pooled/composite sample was sent to WHO/UNEP reference laboratories in Germany for quality assurance and analysis of complex POPs.

Tunisia

For reasons of feasibility and timeliness, we chose maternal and child protection centers (PMI) and basic health care centers (CSSB) as the place to recruit participants for the survey. Indeed, such structures exist in all regions and most of them provide post-natal consultations. It is during these consultations that the mothers who will participate in the survey will be selected.

This report details the methodology recommended for conducting the survey (criteria for selecting donor mothers, sampling plan, operational aspects, ethical considerations, etc.), as well as the forms for:

- Survey briefing note;
- The consent form;
- The questionnaire to be administered to participating mothers;
- The technical brochure on breastfeeding.

The setting of the number of milk samples to 52 for the whole country requires the use of a non-probability sampling technique (empirical method or by reasoned choice).

Thus, it will be limited to the regions of Grand Tunis, Sousse, Nabeul, Gafsa, Tataouine, Kébili, Béjà and Le Kef supposed to be representative of the different socio-economic and demographic contexts encountered in the country.

The sampling of the biological matrix "breast milk" requires the approval of the national ethics committee of the Pasteur Institute of Tunis, for that an ethics file was elaborated by the national coordinator of the survey in accordance with the procedures in force.

The approval was granted to the DHMPE for the execution of this investigation after providing all the necessary documents and holding a meeting to provide the clarifications requested by the members of the biomedical ethics committee on the subject.

Uganda

Fifty samples were collected from five traditional regions countrywide in accordance with the approved national protocol. The milk samples were collected from each regional hospital to represent the country as per the following sampling plan below:

Table 7: Sampling plan for human milk in Uganda

Number	Traditional Region	Regional Hospital	No. of Samples
1	Central	Mulago	10
2	Eastern	Mbale	5
3	Eastern	Jinja	5
4	Northern	Gulu	10
5	South-Western	Kabarole	10
6	Southern	Mbarara	10
Total			**50**

A mother deemed to be a suitable donor for the breast milk sample when the following criteria were met: first child, mother's age less than 30 years, no known previous exposure to POPs. The child's age was 3 – 4 weeks. Mothers with multiple children (twins or more) were excluded. From each mother, 50 mL of milk was collected by hand expression after a feeding or while infant was nursing on the other breast. In some cases, a human milk pump was used to obtain the milk.

Pre-natal visits were arranged and conducted countrywide in the six regional referral hospitals to interview potential donors using questionnaires. These were studied and the submitted information enabled us to establish and identify the suitable donors thereafter.

Preparation of a pooled maternal milk sample was done according to the 2007 WHO protocol and the UNEP 2012 protocol (WHO 2007; UNEP 2012). Ethical consideration and confidentiality were assured including the aspect of obtaining informed consent of the donors. Post-natal (milk collection) visits were thereafter conducted in the six regional referral hospitals to obtain the necessary milk samples. Handling of milk samples right from collection, transportation, storage and disposal complied with national and institutional biosafety rules and measures including standard operating procedures (SOPs) for medical laboratories.

Table 6: Chosen regions and numbers of samples for human milk sampling in Tunisia

Regions	Grand Tunis	Sousse	Nabeul	Gafsa	Tataouine	Kébili	Béja	Le Kef	Total
Quota	14	08	06	06	04	04	05	05	**52**

From each donor mother, 25 mL were taken from the 50 mL sample, stored frozen at -20 °C at the Directorate of Government Analytical Laboratories (DGAL). These were later analyzed for basic POPs by DGAL. The remaining 25 mL placed into a 2 L glass bottle to create the national pool (1 250 mL consisting of 50 x 25 mL), packaged and sent per express mail to the contracted laboratory CVUA (Freiburg, Germany) for analysis.

Zambia

The human milk sampling was conducted in all the ten provinces of Zambia through selected health centers of the Districts of the provinces based on the detailed research protocol. The ten provinces are: Lusaka, Central, Eastern, Copperbelt, Northwestern, Western, Southern, Luapula, Northern and Muchinga. In all the provinces, provincial headquarters were purposefully targeted for the study. The health centers with the highest deliveries within the provincial headquarters were considered in the study.

The participants were breast feeding mothers who fulfilled a predetermined criterion given in the protocol, the inclusion and exclusion criteria was used to select the study participants within the selected Health Centers as prescribed in the research protocol.

Samples were collected and a pooled sample was generated and shipped for analysis to CVUA in Freiburg, Germany, following the clearance for material transfer agreement.

3.2. Results Generated by National Laboratories

Sampling strategies and results for the national samples are described in the national reports developed for this project.

The results are presented according to alphabetical order of the country name and address the analysis of the core matrices only. Within each section, the matrices follow the same sequence as shown for the results of the expert laboratories with the POPs in the same sequence as well.

3.2.1. Egypt

The laboratory in Egypt, Central Laboratory of Residue Analysis of Pesticides and Heavy Metal in Food (QCAP), analyzed the human milk sample and found the following results for PCB_6.

Table 8: Egypt: Results for indicator PCB in PUFs exposed in 2018. Concentrations in ng/PUF

PCB 28	PCB 52	PCB 101	PCB 138	PCB 153	PCB 180	PCB6
1.16	0.22	0.18	9.05	10.38	6.98	27.97

3.2.2. Ghana

POPs in Ambient Air

The PUFs were cut into small pieces, transferred to a Soxhlet apparatus and extracted with 200 mL dichloromethane for 8 h. The eluate was evaporated to 1 mL using rotary evaporator. Analytes were then fractionated over silica column (1.8 g, 1.5%), fraction 1 containing PCB with 14 mL hexane and fraction 2 containing OCPs with 10 mL hexane:diethylether (85:15, v/v). The eluates were evaporated to 1 mL, were picked in isooctane into GC vials for instrumental analysis.

A gas chromatograph model CP-3800 (Varian) with auto sampler and coupled to an electron capture detector (ECD) of activity 15 mCi was used for the analysis. 1.0 µL of extract was injected. The operating conditions were capillary column: VF-5ms, 30 m x 0.25 mm x 0.25 µm, temperature programme: 70 °C (2 min) to 180 °C (1 min) at 25 °C/min to 300 ⁰C at 5 °C/min, Injection temperature: 270 °C, detector temperature: 300 °C, carrier gas: nitrogen at 1.0 mL/min, make up gas: nitrogen at 29 mL/min. None of the OCPs or PCB could be quantified; all values were below the detection limit.

POPs in Human Milk Samples

Subsamples of human breastmilk samples were taken and analyzed at the Pesticide Residue Laboratory of Ghana Standards Authority as a mirror study for the whole pool but also for disaggregate samples and obtain more insight into the distribution of concentrations within the pool.

Ten individual mothers milk samples were analyzed for pesticide residues and polychlorinated biphenyls (PCB). A QuEChERS method was used for the extraction of PCB (Luzardo *et al*. 2013; Asamoah *et al*. 2018). 5 mL from each homogenized human milk sample was transferred into a cleaned 50 mL PP bottle, 10 mL of acetonitrile was added and vortexed for one minute. A mixture of 4 g anhydrous magnesium sulphate, 1 g of sodium chloride, 1 g of trisodium citrate dehydrate and 0.5 g of disodium hydrogen citrate sesquihydrate were added and vortexed to avoid agglomeration of the salts. The mixture was then centrifuged at 3000 rpm for 5 min. The organic layer was collected and reduced to dryness under nitrogen stream and the fat weight measured gravimetrically. Clean up was done by adding 6 mL of acetonitrile into the concentrate and then transferred into an already cleaned 15 mL PP centrifuge bottle containing 150 mg primary secondary amine (PSA), 900 mg of magnesium sulphate and 150 mg of C-18. The PP centrifuge tube with its content was closed and vortexed for 30 s and centrifuged for 5 min at 3000 rpm. 4 mL of the cleaned-up sample was transferred to a clean glass tube, and 40 μl of 5% formic acid in acetonitrile was added to adjust pH. It was then evaporated to dryness under a gentle stream of nitrogen. The extract in the glass tube was reconstituted in 1 mL of ethyl acetate and 2040 μl of 1% Polyethylene glycol in ethyl acetate (v/v). The extract was transferred into 2 mL GC vial for analysis.

The samples were analyzed using a gas chromatograph coupled to a triple quadrupole MS (GC-MS/MS, Agilent Technologies 7890B 7000C GC–MS/MS) with autosampler 80 and helium as the carrier gas. Injection temperature was 280 °C, splitless mode and 2.0 μl injection volume. The ion source was EI mode, source temperature of 3000 °C and MSD transfer line of 325 °C. The column type HP-5 ms (30 m × 0.25 mm × 0.25 μm) was used with column flow of 1.25 mL/min. The column temperature was first set as 70 °C and held for 2 min, ramped to 150 °C at 25 °C/min and then to 200 °C at 3 °C/min and then finally to 280 °C and held at 3 min. The solvent delay time was 4 min and a total time of 35 min (Asamoah *et al.* 2018).

3.2.3. Mali

Le laboratoire de Toxicologie et de contrôle de qualité environnementale du Laboratoire Central Vétérinaire a réalisé les analyses des PUFs pour doser deux groupes de POPs (les PCB et les OCPs). The results for OCPs and indicator PCB are presented in the following tables; all samples were exposed in Bamako, Mail (expressed as ng/PUF).

Table 9: Mali: Results for indicator PCB in PUFs exposed in 2017. Concentrations in ng/PUF

Code sample	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)
PCB 28	2.7	3.7	4.4	2.5
PCB 52	2.6	2.8	3.5	2.1
PCB 101	1.5	2.5	2.6	1.8
PCB 138	2.9	2.4	3.4	3.3
PCB 153	2.6	4.2	5.5	4.7
PCB 180	1.9	2.2	3.6	3.1
Sum PCB_6	14.2	17.8	23.0	17.5

Table 10: Mali: Results for indicator PCB in PUFs exposed in 2018. Concentrations in ng/PUF

Code sample	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)
PCB 28	3.2	4.1	2.9	2.3
PCB 52	2.5	3.4	4.6	3.2
PCB 101	2.6	3.7	6.5	4.5
PCB 138	3.5	3.1	3.6	2.9
PCB 153	4.5	4.4	4.6	3.6
PCB 180	2.7	2.9	2.2	1.7
PCB6	19.0	21.6	24.4	18.2

Au regard des résultats ainsi présentés dans les tableaux 7 et 8 les niveaux des marqueurs PCB pendant les deux ans d'échantillonnage de l'air ambiant à Bamako au Mali (2017 et 2018) indiquent que les marqueurs PCB étaient présents dans l'air ambiant au-dessus des limites de quantification dans les échantillons de PUFs du Mali.

Four HCH isomers have been analyzed HCH: α -HCH, β-HCH, γ-HCH or lindane, and δ-HCH. Whereby δ -HCH is not listed as a POP, all the values during both years were below the limit of detection.

Table 11: Mali: Concentration of HCHs in 2017. Concentrations in ng/PUF

Code sample	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)
alpha-HCH	2.7	1.3	3.2	2.3
beta-HCH	<LOQ	<LOQ	<LOQ	<LOQ
gamma-HCH	3.9	6.3	14.6	27.5
Sum HCH3	6.6	7.6	17.8	29.5

Table 12: Mali: Concentration of HCHs in 2018. Concentrations in ng/PUF

Code sample	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)
alpha-HCH	5.1	0.8	5.7	6.3
beta-HCH	<LOQ	<LOQ	<LOQ	<LOQ
gamma-HCH	7.2	7.4	11.3	18.2
Sum HCHs	12.3	8.2	17.0	24.5

Only alpha-HCH and gamma-HCH presented values with gamma-HCH showing the higher levels.

Table 13: Mali: drins in 2017. Concentrations in ng/PUF

Code sample	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)
Aldrin	1.1	0.6	0.9	0.3
Dieldrin	11.2	9.1	10.3	12.7
Endrin	0.2	0.4	0.1	0.2
Sum drins	12.5	10.1	11.3	13.2

Table 14: Mali: drins in 2018. Concentrations in ng/PUF

Code sample	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)
Aldrin	1.5	0.8	0.7	2.3
Dieldrin	24.1	19.2	18.0	5.9
Endrin	7.2	7.4	11.3	0.79
Sum drins	32.8	27.4	30.0	8.99

Durant la période couvrant les deux ans 2017 et 2018, des concentrations mesurables des pesticides organochlorés drins (Aldrine, Dieldrine et Endrine) ont été reportées pendant toutes les huit (08) périodes d'échantillonnage. Les teneurs rencontrées au cours des trois premières saisons sont situées autour du même niveau comparativement à la faible teneur enregistrée au cours de la dernière saison pour ce qui concerne l'année 2018.

Table 15: Mali: endosulfan in 2017. Concentrations in ng/PUF

Code sample	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)
α-Endosulfane	22	26	41	36
β-Endosulfane	18	13.6	22	15.6
Endosulfane sulfate	5	4.4	2.3	8.2
Endosulfans	45	44	65.3	59.8

Table 16: Mali: endosulfan in PUFs in 2018. Concentrations in ng/PUF

Code sample	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)
α-Endosulfane	19.8	30.8	65.7	26.3
β-Endosulfane	14.2	17.5	23.3	12.5
Endosulfane sulfate	7.6	6.4	9.4	8.1
Endosulfans	41.6	54.7	98.4	46.9

Les concentrations en pesticides organochlorés du groupe des endosulfanes commencent à présenter des niveaux importants dans l'air ambiant du site de Bamako (Mali). L'Endosulfane α a présenté la teneur la plus élevée et l'endosulfane sulfate la plus faible teneur. Selon la période d'échantillonnage les teneurs obtenues au cours de la saison III sont les plus élevées au cours des deux ans.

Table 17: Mali: DDT in PUFs in 2017

Code sample	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)	ML-04 (2017-I)
op'-DDT	76.2	57.6	34.5	26
pp'-DDT	92.3	65.4	48.9	31.5
op'-DDD	32	36	19.89	12.7
pp'-DDD	34	24	28.2	13.3
op'-DDE	67	74	43	23
pp'-DDE	52.1	56.9	32	95
Total DDTs	353.6	313.9	206.49	201.5

Les concentrations en pesticides organochlorés du groupe des DDTs ont été les plus élevées dans l'air ambiant du site de Bamako (Mali). Le métabolite pp'-DDE a présenté la teneur la plus élevée suivi du pp'-DDT et le pp'DDD la plus faible teneur. Il n'y a pas eu de variation des teneurs obtenues selon la période d'échantillonnage les deux ans.

Table 18: Mali: DDT in PUFs in 2018

Code sample	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)	ML-04 (2018-I)
op'-DDT	87.6	69.2	51.7	72.7
pp'-DDT	100.4	55.9	66.2	61.3
op'-DDD	37.1	42	27.18	38.9
pp'-DDD	46.4	37.3	41.4	42.5
op'-DDE	78.5	67.4	52.5	49.23
pp'-DDE	55.52	49.58	38.76	26.8
Total DDTs	405.52	321.18	277.74	291.43

3.2.4. Senegal

The national laboratory at CERES has the standardized analytical methods to analyse POPs in these matrices Subsequently, aldrin, dieldrin, endrin, and lindane were analysied but could not be quantified at concentrations below 1 µg/PUF

3.2.5. Tunisia

Principe du protocole : l'extraction et la purification ont été réalisées selon le protocole N°2 « procédure de l'analyse des pesticides organochlorés (OCPs) et des polychlorobiphényle (PCB) dans les matrices environnemental et humain pour mettre en œuvre le plan de surveillance global dans le cadre de la convention de Stockholm ».

Afin d'extraire les pesticides des PUFs, il faut les couper en petits morceaux et procéder à l'extraction en utilisant l'extracteur par liquide pressurisé Accelerated solvent extraction (ASE). et le dichlorométhane comme solvant d'extraction, puis procéder à leur purification à travers différentes colonnes.

Automated extraction was used such as pressurized or accelerated solvent extraction. Les cellules sont préalablement nettoyées au détergent, puis rincées à l'eau et à l'acétone avant de subir un cycle d'extraction ASE. Les étapes sont les suivantes. For purification Al2O3 or silica gel columns were used.

Chromatographie en phase gazeuse GC (AGILENT 7890) coupled to an ECD (µECD), chromatographic column HP-5 (5% polaire) de longueur 60 mètres. The analyses were performed in the laboratory of CITET.

Chlordecone, hexachlorobenzene, hexachlorobutadiene, mirex, and pentachlorobenzene could not be quantified in any PUF.

None of the six indicator PCB could be quantified in any of the PUFs in 2017 or 2018

Table 19: Tunisia PAS/PUFs: OCPs in 2017. Concentrations in ng/PUF

Sample ID →	TUN-2(2017-I)	TUN-2(2017-II)	TUN-2(2017-III)	TUN-2(2017-IV)
Exposure period →	du 02/01/2017au 03/04/2017	Le 03/04/2017 au 03/07/2017	du 03/07/2017 au 02/10/2017	Le 02/10/2017 au 02/01/2018
Unit →	ng/PUF	ng/PUF	ng/PUF	ng/PUFl
Drins				
Aldrin	18,957	8,705	<0,830	1,565
Dieldrin	<0,508	<0,508	<0,508	<0,508
Endrin	13,656	18,992	9,372	<6,399
limite inferieur (LB)	32,613	27,697	9,372	1,565
limite supérieure (UB)	33,121	28,205	10,710	8,472
Chlordanes				
α-Chlordane	2,240	<0,760	<0,760	<0,760
γ-Chlordane	<0,650	1,361	7,655	<0,650
Oxychlordane	NA	NA	NA	NA
cis-Nonachlor	NA	NA	NA	NA
Trans-Nonachlor	NA	NA	NA	NA
Sum Chlordanes	2,240	1,361	7,655	0
Heptachlor				
Heptachlor	<25,88	<25,88	<25,88	<25,88
cis-Heptachlorepoxide	<0,760	<0,760	7,655	<0,760
trans-Heptachlorepoxide	NA	NA	NA	NA
Sum Heptachlors	--	--	7,655	--
DDTs				
o,p'-DDT	NA	NA	NA	NA
p,p'-DDT	59,127	<37,757	<37,757	<37,757
o,p'-DDD	NA	NA	NA	NA
p,p'-DDD	38,974	64,327	17,977	<14,308
o,p'-DDE	NA	NA	NA	NA
p,p'-DDE	<0,508	<0,508	<0,508	<0,508
Sum 6DDTs	98,101	64,327	17,977	--
HCHs				
α-HCH	52,244	12,663	99,999	24,058
β -HCH	57,650	24,811	10,467	22,640
γ-HCH	113,930	23,207	67,457	18,333
Sum 3HCHs	223,824	60,681	177,923	65,031
Endosulfane				
α-Endosulfan	2,240	<0,650	<0,650	<0,650
β-Endosulfan	16,605	21,829	46,989	24,001
Endosulfan sulfate	19,376	68,122	3,586	<2,00
Sum Endosulfans	38,221	89,951	50,575	24,001

Table 20: Tunisia PAS/PUFs: OCPs in 2018. Concentrations in ng/PUF

Code de l'échantillon :	TUN-2(2018-I)	TUN-2(2018-II)	TUN-2(2018-III)	TUN-2(2018-IV)
Date d'échantillonnage :	du 02/01/2018au 02/04/2018	Le 02/04/2018 au 02/07/2018	du 02/07/2018 au 01/10/2018	Le 01/10/2018 au 31/12/2018
Date d'exécution :	ng/PUF	ng/PUF	ng/PUF	ng/PUF
Drins				
Aldrin	2,710	27,372	5,786	5,324
Dieldrin	<0,508	<0,508	<0,508	<0,508
Endrin	<6,399	<6,399	<6,399	<6,399
Sum Drins limite inferieur (LB)	2,710	27,372	5,786	5,324
Sum Drins limite supérieure (UB)	9,617	34,279	12,693	12,231
Chlordanes				
α-Chlordane	<0,760	1,904	<0,760	<0,760
β-Chlordane	<0,650	22,570	8,672	<0,650
Oxychlordane	NA	NA	NA	NA
cis-Nonachlor	NA	NA	NA	NA
trans-Nonachlor	NA	NA	NA	NA
Sum Chlordanes	0,00	24,474	8.672	0,00
Heptachlor				
Heptachlor	<25,88	29,509	26,487	<25,88
cis-Heptachlorepoxide	<0,760	22,570	8,672	<0,760
trans-Heptachlorepoxide	NA	NA	NA	NA
Sum Heptachlors	--	52,079	35,159	--
DDTs				
o,p'-DDT	NA	NA	NA	NA
p,p'-DDT	<37,757	<37,757	<37,757	<37,757
o,p'-DDD	NA	NA	NA	NA
p,p'-DDD	<14,308	25,566	20,077	<14,308
o,p'-DDE	NA	NA	NA	NA
p,p'-DDE	<0,508	<0,508	<0,508	<0,508
Sum 6DDTs	--	25,566	20,077	--
HCHs				
α-HCH	4,125	3,874	3,054	3,673
β -HCH	<1,14	7,385	1,215	7,689
γ-HCH	73,384	38,617	48,049	54,907
limite inferieur (LB)	77,509	49,876	52,318	66,269
limite supérieure (UB)	78,649	49,876	52,318	66,269
Endosulfans				
α-Endosulfan	<0,650	3,805	<0,650	0,588
β-Endosulfan	<1,078	0,426	24,536	5,646
Endosulfan sulfate	<2,000	8,680	7,476	<2,000
limite inferieur (LB)	0,00	12,911	32,012	6,234
limite supérieure (UB)	3,728	12,911	32,662	8,234
Mirex	<3,74	<3,74	<3,74	<3,74

3.2.6. Uganda

OCPs and PCB in Air

The analytes in the PUFs were extracted using Soxhlet extraction in accordance to the "Protocol 2: Protocol for the Analysis of Polychlorinated Biphenyls (PCB) and Organochlorine Pesticides (OCP) in Human Milk, Air and Human Serum provided by UNEP."

Sample preparation started by cutting the PUF sample into little pieces with clean scissors. The PUF sample was transferred straight to the Soxhlet apparatus (without thimble) and then soaked with some dichloromethane. Soxhlet extraction was performed with dichloromethane for 16 h including a blank and internal standard. 1 mL of iso-octane and boiling granules were added to the flask to facilitate gentle boiling. The extracts were then concentrated to 1 mL after adding 10 mL of iso-octane as a keeper using the rotary evaporator and subsequently under a gentle stream of nitrogen.

Sample Clean-up and purification: Sample purification of the air extracts consisted of 2 steps. First, the extracts were purified over an alumina (Al_2O_3) column and then fractionated. The sample extracts were quantitatively transferred to alumina columns after adjusting the volumes to 100 mL with n-hexane. They were eluted over 15 g of 8 % deactivated alumina with 1 cm Na_2SO_4 using 60 mL hexane for PCB only followed by 170 mL to capture the OCPs. The eluates obtained were evaporated to 1 mL with rotary evaporator and under nitrogen.

The second step involved fractionation over a deactivated silica column. 6 mL hexane were added to condition the silica columns, then the sample extracts from above were added whilst placing collection tubes (20 mL) beneath to obtain fraction 1. 14 mL hexane were added to obtain this fraction. Once it has gone through, 10 mL hexane: di-ethyl ether (85:15, v/v) mixture were added to collect fraction 2. Fraction 1 contained all PCB and non-polar pesticides (some OCPs: HCB, p,p'-DDE) and the rest of OCPs (polar pesticides) were in fraction 2.

This was followed by addition of 1 mL iso-octane to both tubes and concentration of the extracts to 500 µL on a heating block (max 40 °C) under a nitrogen flow. The extracts were then transferred into GC vials. End-point detection was done with GC-MS/MS using a multi-level calibration curve prepared from dilution of PCB/OCP stock solutions.

Table 21: Uganda: OCP in PUFs

EXPERT LABORATORY RESULTS						
Year of Exposure →	2017		2018			2019
Season →	I (I,II,III)	IV	I	II	III	I
Exposure Duration →	(Jan - Oct 2017)	(Oct 2017 - Jan 2018)	(Jan - Apr 2018)	(Apr - Jul 2018)	(Jul 2018-Feb 2019)	(Feb - May 2019)
OCPS	ng/PUF		ng/PUF		ng/PUF	
Sum HCHs	0.59	0.37	1.5	0.63	0.54	0.97
Sum Heptachlors	1.96	0.56	1.54	1.81	0.49	0.57
Sum Endosulfans	4.5	2	0	0	0	0
Sum Drins	7.83	1.5	3.6	4.6	2.9	1.1
Sum Chlordanes	3.47	1.41	1.78	1.78	1.79	0
Sum Nonachlors	0	0	0	0	0	0
Sum DDTs	55.67	12.34	19.46	24.65	22.55	5.73
Pentachlorobenzene	0.3	0.77	0.56	0.47	0.54	0.49
Hexachlorobenzene	2	2.6	2.6	2.2	1.1	0.72
Mirex	0.13	0.14	0.12	0.12	0	0
NATIONAL LABORATORY MIRROR RESULTS						
Year of Exposure →	2017		2018			2019
Season →	I (I,II,III)	IV	I	II	III	I
Exposure Duration →	(Jan - Oct 2017)	(Oct 2017 - Jan 2018)	(Jan - Apr 2018)	(Apr - Jul 2018)	(Jul 2018-Feb 2019)	(Feb - May 2019)
OCPs	ng/PUF		ng/PUF		ng/PUF	
Sum HCHs	0	0	75.71	94.23	16.89	60.43
Sum Heptachlors	0	23.50	9.03	9.75	4.65	5.10
Sum Endosulfans	0	0	55.02	49.75	26.80	33.38
Sum Drins	16	0	15.45	32.04	7.73	42.79
Sum Chlordanes	0	0	101.51	152.32	17.85	212.04
Sum Nonachlors	0	0	0	7.32	34.39	0
Sum DDTs	290.55	201	0.75	190.52	398.86	302.60
Pentachlorobenzene	0	0	0	0	0	0
Hexachlorobenzene	35	56	1.18	1.02	0.47	1.37
Mirex	0	0	21.50	177	140	462.21

Table 22: Uganda: PCB in Air

EXPERT LABORATORY RESULTS						
Year of Exposure →	2017		2018			2019
Season →	I (I,II,III)	IV	I	II	III	I
Analyte →	ng/PUF					
PCB 28	0.77	1.4	1.7	1.8	0.62	<0.28
PCB 52	1.2	1.1	1.1	1.2	0.61	0.38
PCB 101	1.1	0.9	1.1	1.1	0.92	0.32
PCB 138	0.59	0.56	0.65	0.59	0.79	<0.28
PCB 153	0.51	0.1	0.52	0.51	0.6	0.36
PCB 180	0.28	0.29	<0.28	<0.28	<0.28	<0.28
Sum of PCB6 (UB)	4.45	4.35	5.35	5.48	3.82	1.90
Sum of PCB6 (LB)	4.17	4.35	5.07	5.20	3.54	1.06
NATIONAL LABORATORY MIRROR RESULTS						
Year of Exposure →	2017		2018			2019
Season →	I (I,II,III)	IV	I	II	III	I
Concentration →	ng/PUF					
PCB 28	N/A	N/A	N/A	N/A	N/A	N/A
PCB 52	3.47	22.55	9.45	3.47	6.90	15.27
PCB 101	<0.01	10.50	<0.01	<0.01	<0.01	<0.01
PCB 138	<0.01	5.45	0.07	<0.01	<0.01	<0.01
PCB 153	<0.01	7.50	0.06	<0.01	<0.01	<0.01
PCB 180	0.12	25.50	0.20	0.12	0.04	<0.01
Sum of PCB6 (LB)	3.59	71.50	9.79	3.59	6.94	15.27

Polychlorinated biphenyls (PCB) in breast milk

The Table 22 details the breast milk PCB results obtained for the national pooled sample. All the PCB; indicator, mono- and non- ortho were detected in relatively low concentrations.

Table 23: Uganda: Sum of 6 indicators PCB in human milk national pool

S/No	ndl -PCB	UGA-DGAL ng/g fat	CVUA ng/g fat
1	PCB 28	<0.1	0.26
2	PCB 52	<0.03	0.095
3	PCB 101	0.008	0.11
4	PCB 138	1.812	0.63
5	PCB 153	0.527	0.85
6	PCB 180	0.170	0.53
Sum 6PCB (upper bound)		2.647	2.46
Sum 6PCB (lower bound)		2.517	2.46


Photo: © Uganda, Directorate of Government Analytical Laboratory

SECTION 4

Results from Expert Laboratories

4. RESULTS FROM EXPERT LABORATORIES

Chemical analysis of all samples collected in the African region were analyzed by so-called 'expert laboratories' with the following assignments according to POPs group and matrix:

- E&H VU Vrije Universiteit in Amsterdam, the Netherlands (formerly IVM): Air and national samples: Organochlorine pesticides (OCP), indicator PCB (PCB_6), PBDE, [HBB, HBCD]
- MTM Research Centre, Örebro University in Örebro, Sweden: Air, water, human milk [PFOS, PFOA, PFHxS]
- CVUA Freiburg, Germany: Human milk: OCP, PCB_6, toxaphene, [PBDE, HBCD, HBB, PCN and SCCP]

Groups of POPs in [square brackets] were not analyzed in the GMP1 projects. Note: the group of the OCP contains some pesticides that were listed as 'new' POPs such as endosulfan, HCH isomers (although voluntarily already included in the GMP1, chlordecone, pentachlorobenzene, hexachlorobutadiene (HCBD). For these and the POPs printed in brackets, no comparative data were available when examining the results of the GMP2 projects across all projects.

The list of POPs above includes more POPs than had been proposed in the approved project document (UNEP 2015b).

4.1. Chemical Analysis and Reporting of Results

Generic protocols for the analysis of POPs had been developed in a previous GEF project for OCPs and indicator PCB (PCB_6) (UNEP 2014a), PBDE (UNEP 2014b), and PFAS (UNEP 2015c). They were used in this GMP2 project. In brief, brominated and chlorinated POPs were analyzed using GC/MS instrumentation whereby dl-POPs were detected with HRMS as sector-field instruments. PFAS were analyzed using LC/MSMS.

POPs were determined as the mass concentration (ng or pg) extracted from the PUFs. For certain groups of POPs, such as dl-POPs or toxaphene, it was recommended to combine four PUFs to an annual sample. For comparison of results, all data were normalized to one PUF and a 3-month exposure time.

For the sums of OCPs, the mass concentrations were added and no 'equivalents' used. Concentrations for OCPs, PCB_6, and BFRs in air were reported in ng/PUF and in nanogram per gram lipid (ng/g lipid) for human milk.

For dl-POPs, all values of the 29 compounds were calculated as toxic equivalents (TEQ) using the 2005 WHO TEF scheme (van den Berg *et al*. 2006). The 17 PCDD/PCDF, consisting of 7 PCDD and 10 PCDF, are referred to as TEQ_DF and the 12 dl-PCB as TEQ_PCB. Concentrations for dl-POPs were reported in picogram per PUF (pg TEQ/PUF) for PAS/PUF air samples, and picogram lipid (pg/g lipid) for human milk.

In order to compare, results should be reported according to number of PUFs (and exposed periods); thus, when four PUFs were combined, the amount should be divided by a factor of 4 to receive the amount *per* PUF. For HBCD, first a screening using GC/MS should be performed and only samples, where HBCD was quantifiable in the GC/MS screening will undergo isomer-specific analysis using LC/MS.

Concentrations for PFAS were reported in picogram per PUF (pg/PUF) in air, pg/g fresh weight (f.w.) in human milk, and nanogram per liter (ng/L) for water.

Since no conversion to volume was made, temperature, windspeed, precipitation or characteristics of the PUFs (density) were not considered.

4.2. Ambient Air

4.2.1. Chlorinated POPs

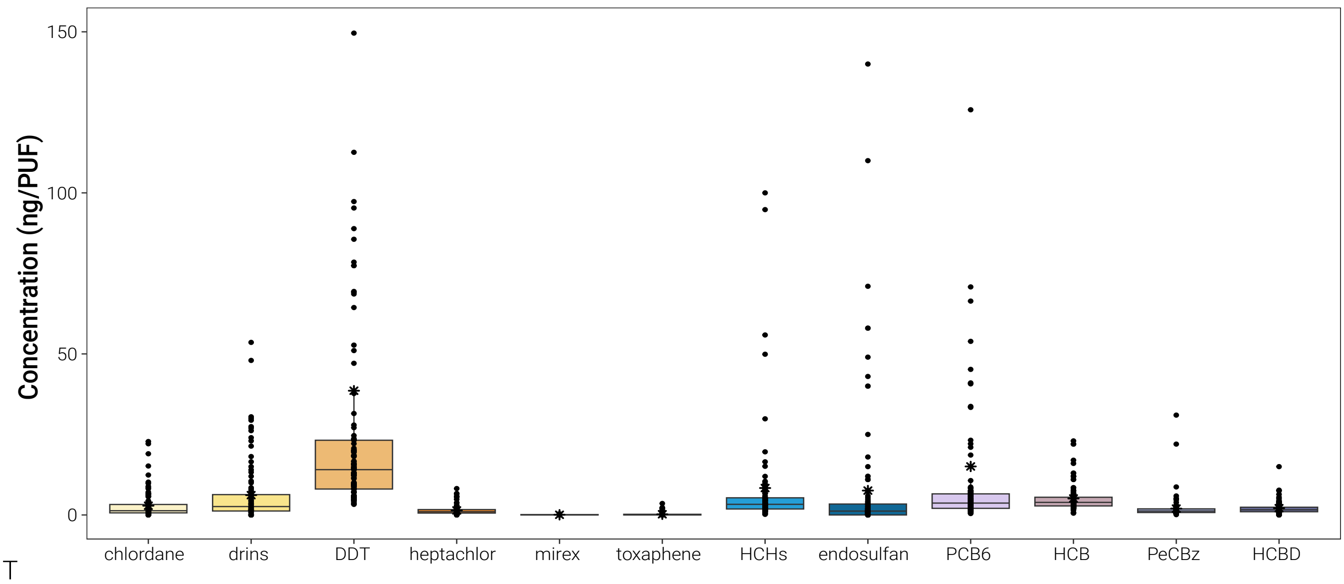
Data are available from 113 datasets as shown in Table 24; the summary of results per group of chlorinated POPs (as sums of isomers or congeners) are shown in Table 25. Graphical sketches provide the summary and comparison of results of chemical analyses for chlorinated POPs (Cl-POPs) as Figure 3. All data refer to 1 PUF and 3 month of exposure time and are given in ng/PUF.

The highest mean and median values were found for DDTs with a large difference between the mean (38.8 ng/PUF) value and the median value (14.1 ng/PUF). Similar median values were found in COD, MLI, and TZA; however, COD had many more outliers towards high values. From Table 25 it can be seen that for mirex, the median value was zero. It is striking that highest median values are found for different country chlordanes were highest in ZMB, drins in KEN, heptachlors in ETH and TZA, α-endosulfan in GHA, HCHs in TZA, PCB_6 in COD, HCB in MAR and TUN (Figure 8).

The concentrations of chlorinated POPs in each sample per country are shown in Figure 5.

Table 24: Number of PUFs per country and year, analyzed for Cl-POPs

Country	2017 (N=47)	2018 (N=55)	2019 (N=11)	Overall (N=113)
COD	2	4	2	8
EGY	4	4		8
ETH	3	4	1	8
GHA	4	4		8
KEN	4	4		8
MLI	4	4		8
MUS	4	4		8
MAR	3	3		6
NGA	1	4	3	8
SEN	4	4		8
TZA		1	4	5
TGO	4	4		8
TUN	4	4		8
UGA	2	3	1	6
ZMB	4	4		8



T

Figure 3: PAS/PUF: Box plots for chlorinated POPs in PAS/PUFs: summary across all samples (n=113); y-axis zoomed to 150 ng/PUF

Box 1. For all the box and whiskers plots in this report:

The whiskers represent the minimum and maximum concentrations without the outliers. The lower border of the box represents the first quartile (25%), the line inside the box the median and the upper border is the third quartile (75%). The asterisk represents the mean concentration. The dots outside the whiskers are outliers, which were defined as all concentrations greater or smaller the interquartile range multiplied by 1.5

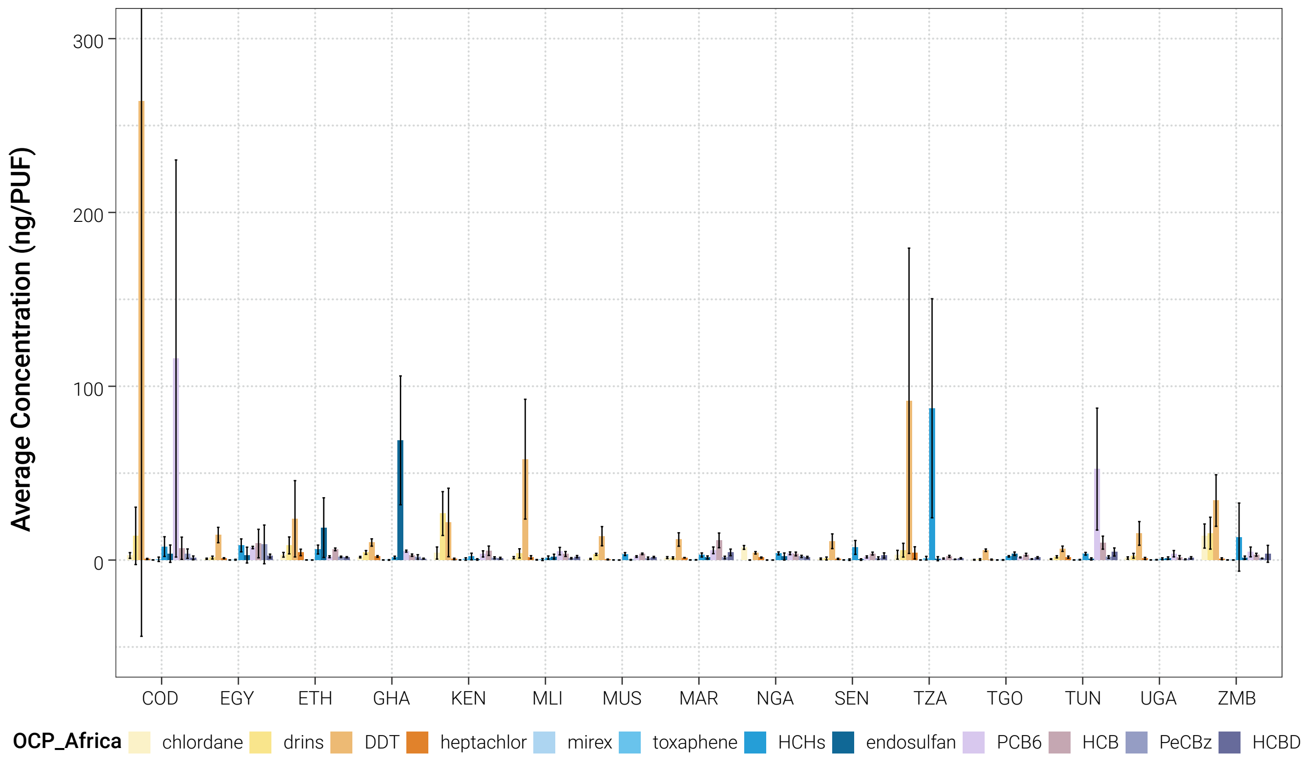


Figure 4: PAS/PUF: Mean values and SD for chlorinated POPs in PAS/PUF (n=113)

Photo: ©Pexels / Keith Lobo

Table 25: PAS/PUF: Chlorinated POPs: Mean (with standard deviation, SD), median, minimum and maximum values (ng/PUF)

	Central tendencies	COD (N=8)	EGY (N=8)	ETH (N=8)	GHA (N=8)	KEN (N=8)	MLI (N=8)	MUS (N=8)	MAR (N=6)
chlordane	Mean (SD)	2.64 (1.64)	0.744 (0.356)	3.03 (1.34)	1.68 (0.421)	4.04 (3.48)	1.39 (0.596)	0.636 (0.324)	1.41 (0.564)
	Median [Min, Max]	2.76 [0.460, 5.70]	0.800 [0.0800, 1.14]	3.48 [0.630, 4.40]	1.83 [0.980, 2.09]	3.28 [1.32, 12.4]	1.37 [0.740, 2.13]	0.595 [0, 0.970]	1.15 [0.930, 2.23]
drins	Mean (SD)	13.9 (16.5)	1.44 (0.826)	8.42 (4.87)	4.38 (1.08)	26.7 (12.6)	3.85 (2.64)	3.27 (0.599)	1.26 (0.584)
	Median [Min, Max]	6.62 [2.22, 48.0]	1.62 [0, 2.41]	7.42 [2.65, 16.5]	4.37 [3.10, 6.01]	25.5 [12.0, 53.6]	3.35 [1.23, 7.42]	3.30 [2.37, 4.30]	1.30 [0.540, 2.18]
DDT	Mean (SD)	264 (308)	14.4 (4.42)	23.8 (21.9)	10.1 (2.10)	21.6 (19.7)	58.1 (34.5)	13.7 (5.51)	11.8 (3.86)
	Median [Min, Max]	114 [64.4, 895]	14.9 [9.26, 20.1]	16.9 [11.6, 77.4]	9.46 [7.96, 12.9]	14.3 [9.01, 69.4]	54.5 [23.2, 97.3]	14.3 [5.85, 23.4]	11.2 [8.08, 18.4]
heptachlor	Mean (SD)	0.624 (0.335)	1.05 (0.292)	4.39 (1.88)	2.08 (0.467)	0.633 (0.453)	1.63 (0.891)	0.326 (0.244)	1.35 (0.112)
	Median [Min, Max]	0.725 [0, 0.960]	1.01 [0.740, 1.57]	4.69 [1.00, 6.68]	2.12 [1.30, 2.78]	0.745 [0.120, 1.39]	1.45 [0.490, 3.00]	0.430 [0, 0.590]	1.37 [1.20, 1.48]
mirex	Mean (SD)	0.071 (0.0768)	0.0400 (0.056)	0.054 (0.0585)	0.040 (0.0555)	0.084 (0.0787)	0.156 (0.143)	0.056 (0.0609)	0.062 (0.0682)
	Median [Min, Max]	0.0650 [0, 0.160]	0 [0, 0.130]	0.0450 [0, 0.130]	0 [0, 0.120]	0.105 [0, 0.220]	0.185 [0, 0.370]	0.0450 [0, 0.120]	0.0550 [0, 0.140]
toxaphene	Mean (SD)	0.446 (1.26)	0.196 (0.250)	0.021 (0.0601)	0.0738 (0.152)	0.613 (0.701)	0.308 (0.583)	0 (0)	0.112 (0.123)
	Median [Min, Max]	0 [0, 3.57]	0.105 [0, 0.670]	0 [0, 0.170]	0 [0, 0.420]	0.430 [0, 2.14]	0.0800 [0, 1.70]	0 [0, 0]	0.105 [0, 0.240]
HCHs	Mean (SD)	7.75 (5.68)	8.46 (3.71)	6.07 (2.56)	1.50 (0.726)	2.05 (1.92)	1.41 (0.935)	3.45 (0.824)	2.93 (1.16)
	Median [Min, Max]	5.39 [1.20, 19.6]	8.10 [4.50, 16.5]	6.73 [2.16, 9.30]	1.27 [0.940, 3.20]	1.34 [1.20, 6.77]	1.48 [0.310, 2.61]	3.19 [2.55, 5.20]	2.57 [1.97, 4.82]
endosulfan	Mean (SD)	3.68 (4.98)	2.87 (4.54)	18.7 (17.2)	68.9 (37.0)	0.350 (0.408)	1.99 (1.40)	0.140 (0.199)	1.52 (0.864)
	Median [Min, Max]	1.45 [0, 12.0]	0.220 [0, 12.0]	13.0 [4.10, 58.0]	53.5 [40.0, 140]	0.175 [0, 0.920]	1.25 [0.740, 4.20]	0 [0, 0.440]	1.55 [0, 2.60]
PCB_6	Mean (SD)	116 (114)	7.23 (0.681)	1.93 (0.538)	5.13 (0.568)	3.55 (1.77)	5.14 (2.15)	2.03 (0.455)	5.60 (1.92)
	Median [Min, Max]	49.6 [21.0, 290]	7.16 [6.52, 8.67]	1.88 [1.15, 2.75]	5.05 [4.46, 5.97]	2.81 [2.19, 7.56]	4.75 [3.00, 8.27]	2.12 [1.39, 2.50]	5.40 [3.28, 8.37]
HCB	Mean (SD)	6.79 (6.41)	9.51 (8.21)	6.16 (0.765)	2.83 (0.658)	5.38 (2.70)	3.50 (1.40)	3.58 (0.450)	11.3 (4.23)
	Median [Min, Max]	4.40 [2.80, 22.0]	6.15 [3.40, 23.0]	6.15 [5.00, 7.40]	2.55 [2.20, 3.90]	4.40 [3.90, 12.0]	3.10 [2.00, 6.40]	3.55 [2.70, 4.10]	11.5 [4.00, 17.0]
PeCBz	Mean (SD)	3.69 (2.71)	9.01 (11.1)	1.84 (0.400)	1.81 (1.27)	1.28 (0.584)	1.01 (0.392)	1.08 (0.653)	1.45 (0.766)
	Median [Min, Max]	3.35 [1.10, 8.70]	3.45 [1.80, 31.0]	1.90 [1.20, 2.40]	1.50 [0.610, 4.70]	1.15 [0.920, 2.70]	0.890 [0.710, 1.90]	0.965 [0.380, 2.30]	1.30 [0.470, 2.80]
HCBD	Mean (SD)	1.27 (1.09)	2.32 (1.09)	1.65 (0.316)	0.823 (0.267)	1.10 (0.499)	1.98 (0.625)	1.71 (0.398)	4.42 (1.89)
	Median [Min, Max]	1.04 [0, 2.80]	2.10 [0.860, 3.90]	1.70 [1.00, 2.10]	0.800 [0.440, 1.30]	1.30 [0, 1.50]	2.20 [1.00, 2.60]	1.65 [1.20, 2.40]	3.85 [2.20, 7.60]

Table 25 cont'd

	Central tendencies	NGA (N=8)	SEN (N=8)	TZA (N=5)	TGO (N=8)	TUN (N=8)	UGA (N=6)	ZMB (N=8)	Overall (N=113)
chlordane	Mean (SD)	7.27 (1.07)	0.703 (0.470)	3.06 (2.55)	0.176 (0.211)	0.565 (0.210)	1.17 (0.670)	13.8 (6.94)	2.87 (4.12)
	Median [Min, Max]	6.86 [6.02, 8.86]	0.685 [0, 1.46]	3.03 [0, 6.70]	0.0900 [0, 0.510]	0.575 [0.330, 0.930]	1.28 [0, 1.78]	12.7 [5.70, 22.8]	1.32 [0, 22.8]
drins	Mean (SD)	0 (0)	0.900 (0.847)	5.69 (3.97)	0.324 (0.465)	1.86 (0.619)	2.48 (1.39)	15.5 (9.18)	6.16 (9.46)
	Median [Min, Max]	0 [0, 0]	0.915 [0, 2.10]	6.30 [1.58, 10.4]	0 [0, 1.10]	1.75 [1.40, 3.30]	2.06 [1.10, 4.60]	15.7 [4.20, 27.4]	2.61 [0, 53.6]
DDT	Mean (SD)	4.17 (0.684)	10.8 (4.24)	91.6 (87.8)	5.63 (0.719)	6.52 (1.53)	15.3 (6.81)	34.3 (14.8)	38.6 (103)
	Median [Min, Max]	4.24 [3.29, 5.23]	11.5 [4.89, 16.7]	85.6 [15.5, 229]	5.66 [4.72, 6.97]	6.54 [4.62, 9.42]	15.4 [5.73, 24.7]	32.8 [15.9, 52.7]	14.1 [3.29, 895]
heptachlor	Mean (SD)	1.44 (0.318)	0.684 (0.354)	4.14 (3.50)	0.266 (0.300)	1.68 (0.623)	0.911 (0.616)	0.749 (0.541)	1.40 (1.48)
	Median [Min, Max]	1.41 [1.10, 1.83]	0.775 [0.170, 1.03]	4.85 [0, 8.20]	0.150 [0, 0.850]	1.76 [0.520, 2.45]	0.652 [0.245, 1.81]	0.800 [0.120, 1.51]	1.00 [0, 8.20]
mirex	Mean (SD)	0 (0)	0.0563 (0.0605)	0.0240 (0.0537)	0.0438 (0.061)	0.0388 (0.054)	0.0706 (0.064)	0.0700 (0.077)	0.0583 (0.0743)
	Median [Min, Max]	0 [0, 0]	0.0500 [0, 0.120]	0 [0, 0.120]	0 [0, 0.130]	0 [0, 0.110]	0.0817 [0, 0.140]	0.0600 [0, 0.180]	0 [0, 0.370]
toxaphene	Mean (SD)	0 (0)	0.231 (0.441)	1.08 (1.05)	0.0788 (0.165)	0.194 (0.160)	0.169 (0.138)	0.0275 (0.0778)	0.218 (0.528)
	Median [Min, Max]	0 [0, 0]	0.0850 [0, 1.30]	0.700 [0, 2.30]	0 [0, 0.460]	0.200 [0, 0.510]	0.215 [0, 0.317]	0 [0, 0.220]	0 [0, 3.57]
HCHs	Mean (SD)	3.84 (0.851)	7.27 (3.98)	87.3 (63.0)	2.14 (0.397)	3.63 (0.777)	0.738 (0.552)	13.2 (19.6)	8.36 (21.8)
	Median [Min, Max]	3.75 [2.40, 5.08]	7.02 [3.07, 15.1]	94.8 [12.0, 180]	2.16 [1.67, 2.90]	3.45 [2.70, 5.10]	0.670 [0.197, 1.60]	3.81 [1.65, 55.9]	3.30 [0.197, 180]
endosulfan	Mean (SD)	2.04 (2.02)	0.303 (0.425)	0.780 (1.16)	3.64 (0.990)	0.651 (0.606)	1.08 (0.753)	1.34 (0.956)	7.57 (20.4)
	Median [Min, Max]	1.75 [0, 5.90]	0 [0, 0.900]	0 [0, 2.60]	3.50 [2.10, 5.30]	0.705 [0, 1.50]	1.30 [0, 2.00]	1.10 [0, 2.60]	1.20 [0, 140]
PCB_6	Mean (SD)	3.89 (0.780)	1.81 (0.585)	0.850 (0.333)	1.53 (0.242)	52.4 (35.1)	3.66 (1.81)	4.68 (2.81)	15.1 (42.8)
	Median [Min, Max]	3.94 [2.87, 4.76]	1.87 [0.830, 2.49]	1.02 [0.440, 1.13]	1.46 [1.31, 2.08]	40.9 [18.6, 126]	4.44 [1.06, 5.20]	3.94 [1.97, 10.7]	3.69 [0.440, 290]
HCB	Mean (SD)	3.51 (1.06)	3.74 (0.828)	2.12 (0.589)	3.13 (0.778)	10.0 (3.74)	1.56 (1.01)	3.09 (0.825)	5.11 (4.19)
	Median [Min, Max]	3.70 [2.30, 4.70]	3.70 [2.70, 5.00]	1.90 [1.50, 3.00]	3.00 [2.20, 4.40]	9.85 [5.20, 16.0]	1.46 [0.550, 2.60]	3.10 [2.00, 4.30]	3.90 [0.550, 23.0]
PeCBz	Mean (SD)	2.09 (0.640)	1.11 (0.745)	0.436 (0.116)	0.594 (0.159)	1.73 (0.765)	0.443 (0.233)	0.931 (0.177)	1.97 (3.60)
	Median [Min, Max]	1.80 [1.40, 3.00]	0.850 [0.380, 2.70]	0.510 [0.290, 0.530]	0.630 [0.380, 0.770]	1.55 [0.860, 2.90]	0.480 [0.100, 0.770]	0.920 [0.700, 1.30]	1.20 [0.100, 31.0]
HCBD	Mean (SD)	1.65 (0.478)	2.64 (1.51)	1.02 (0.329)	1.45 (0.500)	4.65 (2.32)	1.28 (0.652)	3.60 (4.87)	2.11 (1.93)
	Median [Min, Max]	1.70 [1.00, 2.30]	2.90 [0, 4.40]	0.870 [0.800, 1.60]	1.35 [0.840, 2.40]	4.05 [1.50, 7.70]	1.40 [0.500, 2.20]	2.30 [0, 15.0]	1.60 [0, 15.0]

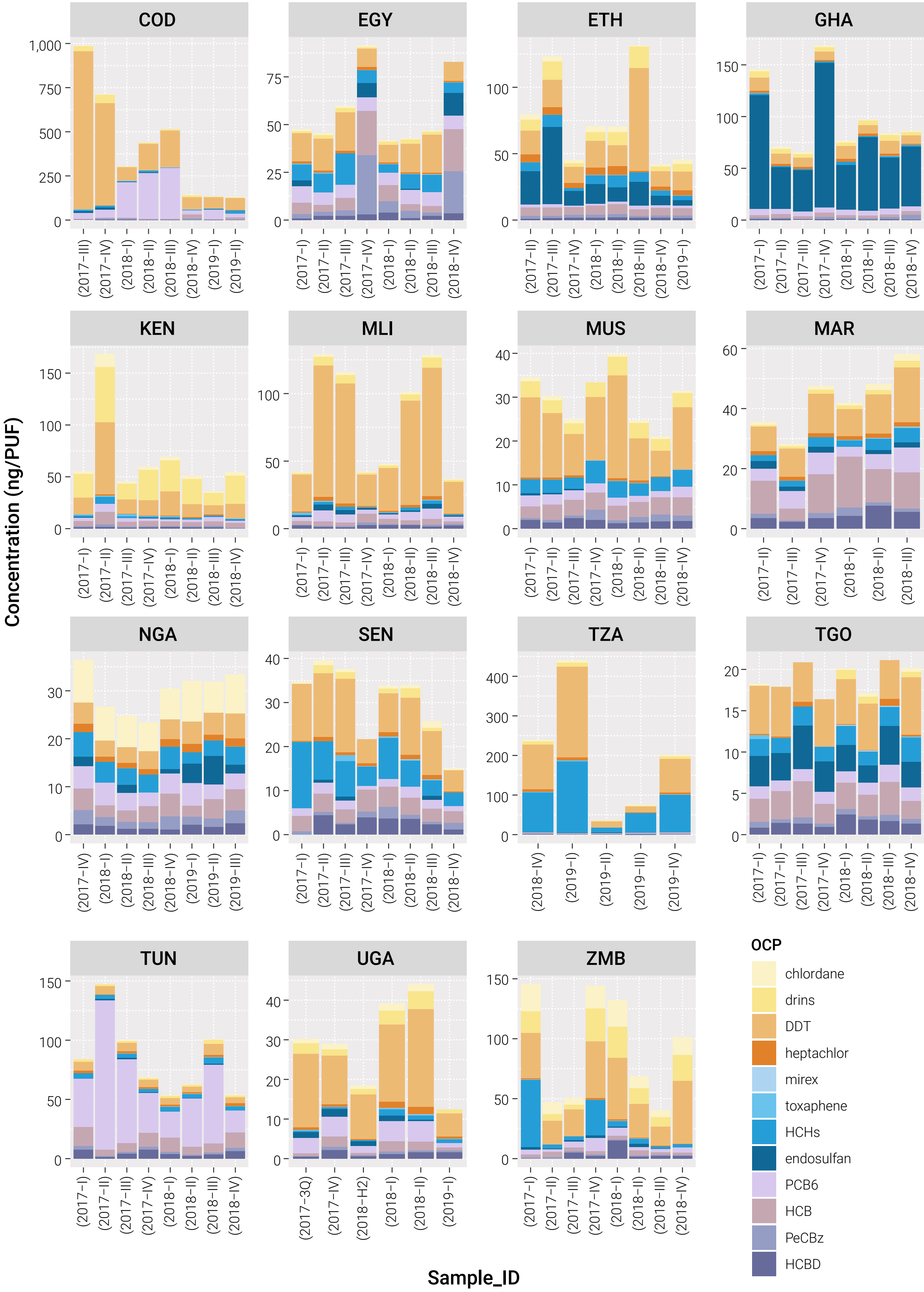


Figure 5: PAS/PUF: Stacked bar graphs for chlorinated POPs by country and sample (n=113)

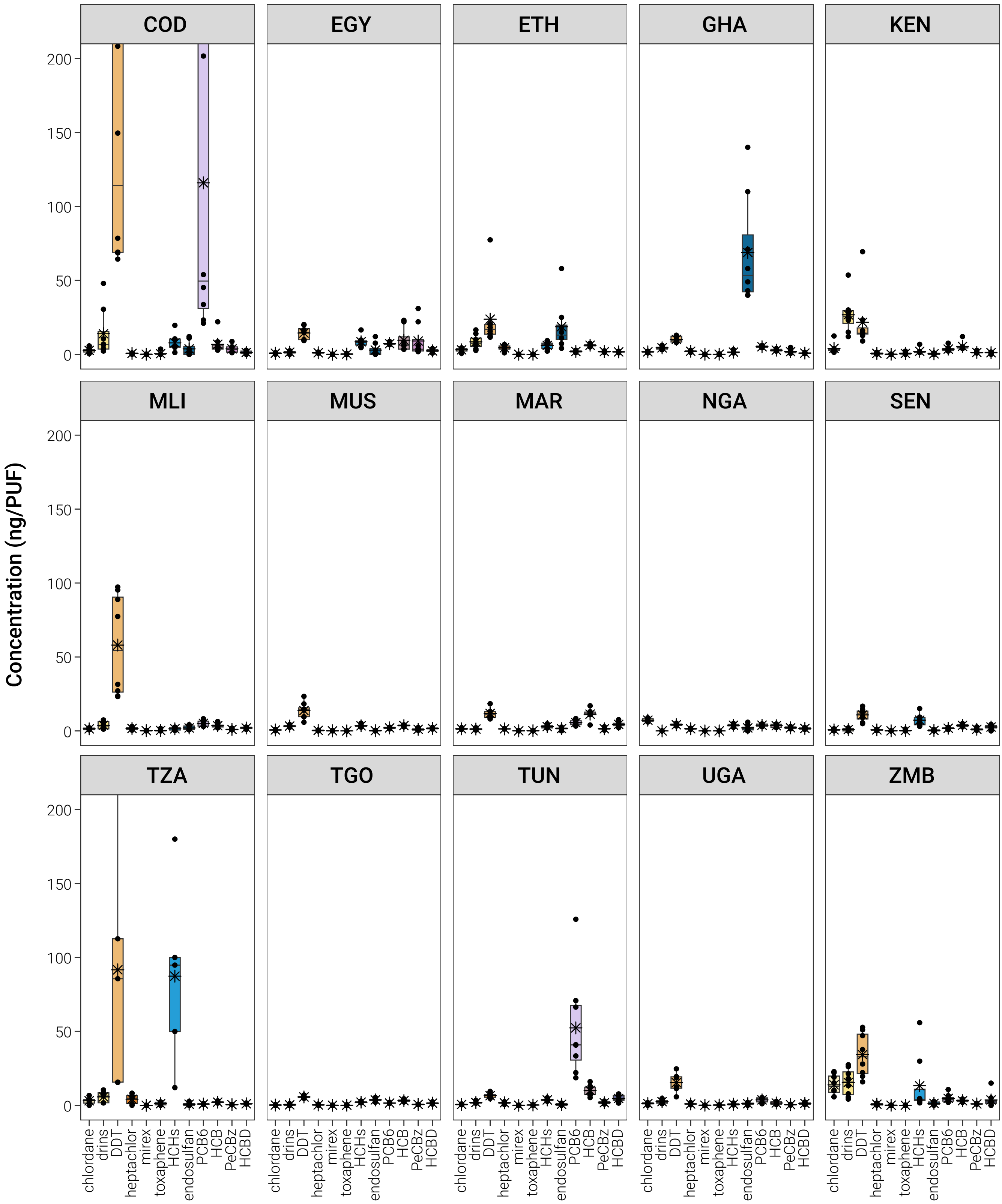


Figure 6: PAS/PUF: Unscaled boxplots for chlorinated POPs in air per country (n=113). Concentrations in ng/PUF. Note: y-axis zoomed to 40 ng/PUF

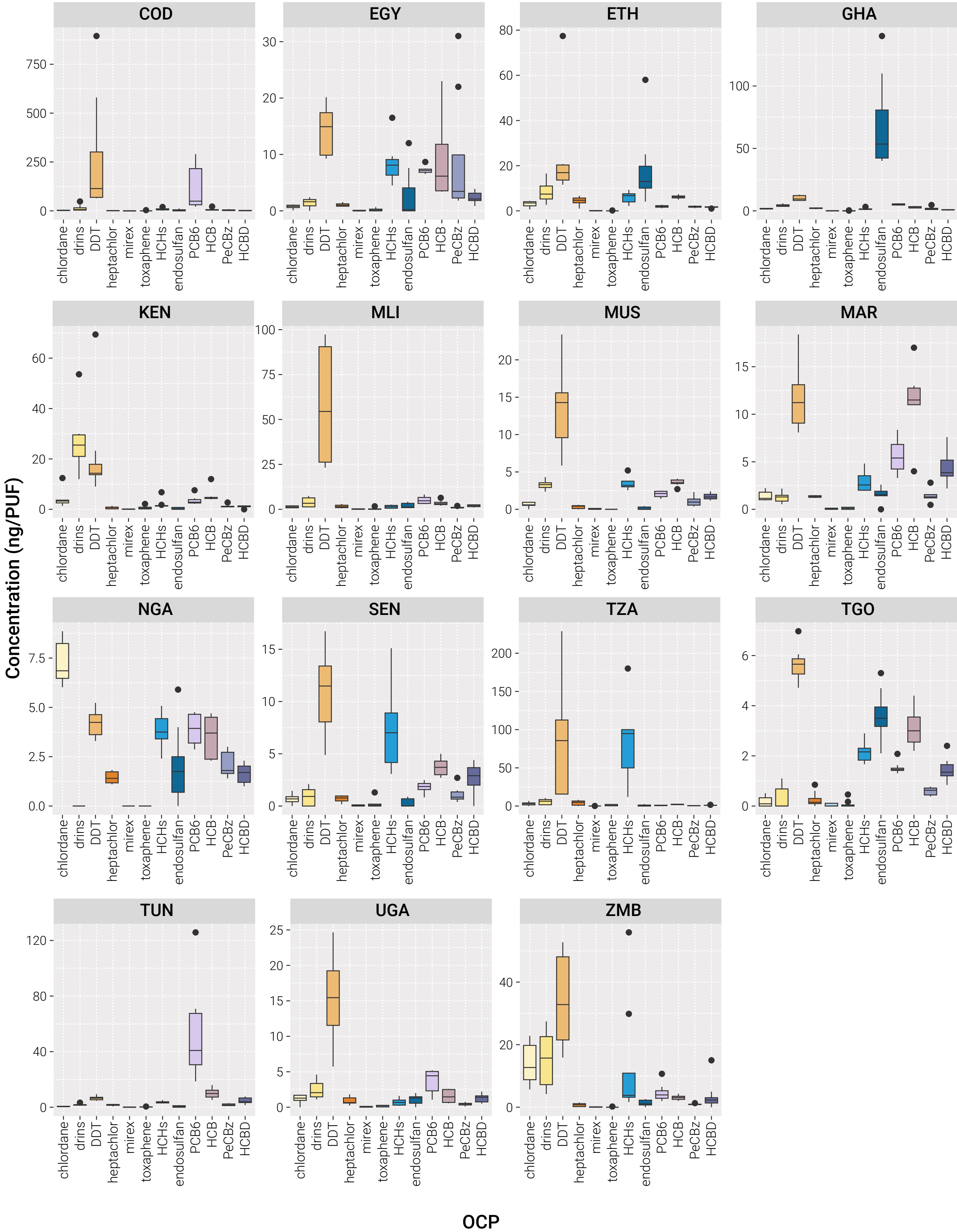


Figure 7: PAS/PUF: Scaled boxplots for sums of chlorinated POPs by country (n=113)

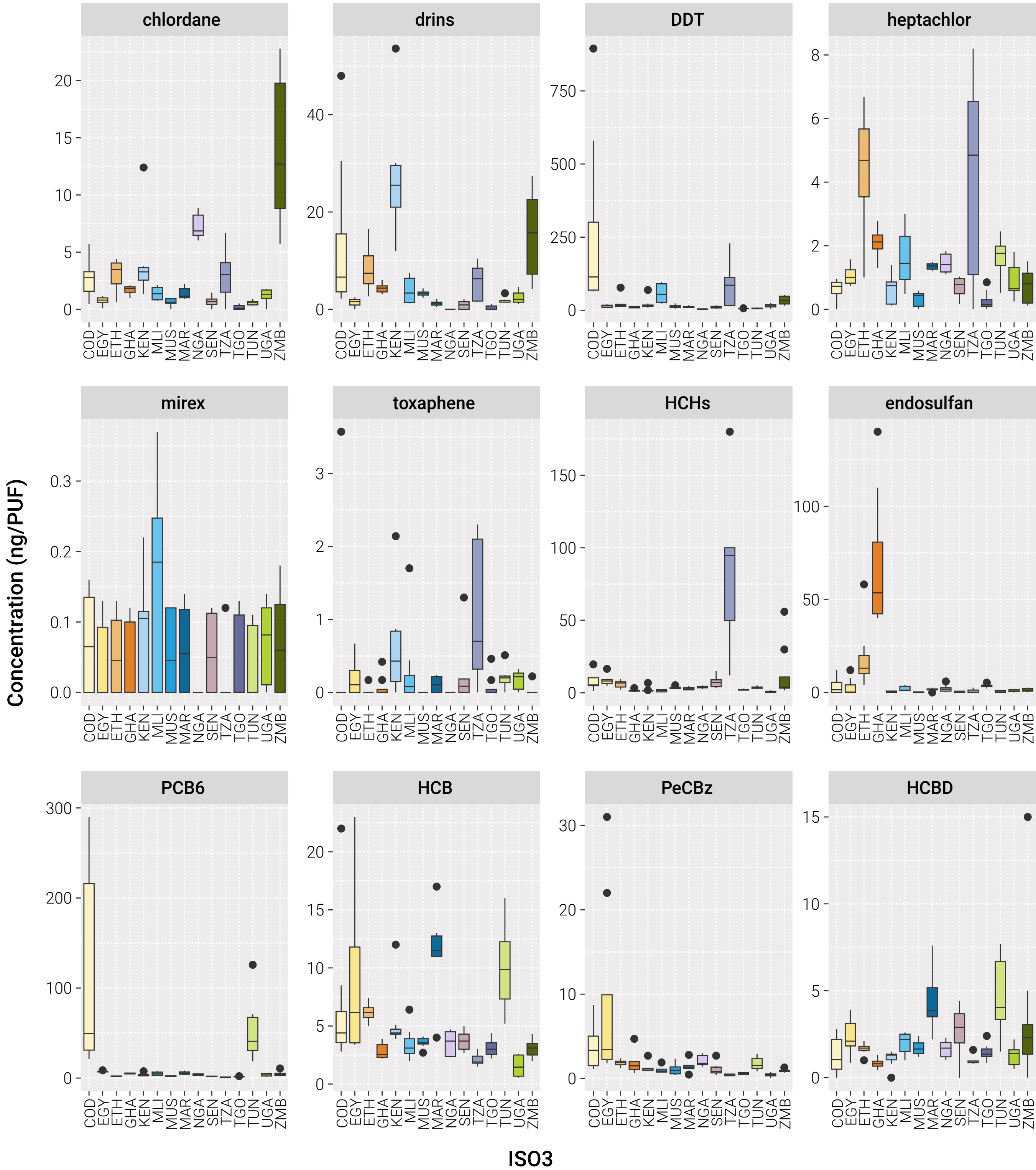


Figure 8: PAS/PUF: Scaled boxplots for country by chlorinated POPs (n=113)

4.2.2. Dioxin-like POPs

In total, 89 samples have been analyzed for dl-POPs (Table 26). The results of the PUF extracts are detailed in Table S 5.

Table 27 provides the mean, median, minimum and maximum values for each country. The values refer to pg TEQ per number of PUFs that had been extracted together. For some countries, *i.e.,* those that indicated to have national dioxin analytical capacities, single individual PUFs were analyzed by the expert laboratory. Other countries, with no dioxin analytical capacity, the seasonal PUFs were combined to an annual sample. For assessment and to compare the results, all samples were normalized to 1 PUF and 1 quarter of year, *i.e.,* 3-month exposure time. Graphical sketches provide the summary and comparison of results of chemical analyses for dl-POPs, shown as TEQs for PCDD and PCDF combined (TEQ_DF) and dl-PCB (TEQ_PCB). Results are from quarterly, annual samples (indicated by "A" resulting from combinations of 4 PUFs. "H" indicates that 6 months have been covered by the exposures. All data refer to 1 PUF and 3 months of exposure time and are given in pg TEQ/PUF.

An overview of results for dl-POPs (as TEQ/PUF) is shown in Figure 9

Across all samples, the highest median values for TEQ_DF were found in Mali (45.0 pg/PUF) and Egypt (44.1 pg/PUF); also, Ghana and DR Congo had comparatively high values. Values below the overall median value of 4.07 pg TEQ/PUF were found in ETH, MUS, MAR, SEN, TZA, TGO, TUN, and ZMB. The overall median value for TEQ_PCB (2.17 pg TEQ/PUF). The highest TEQ_PCB was found in EGY (11.3 pg TEQ/PUF) followed by GHA (6.29 pg TEQ/PUF), COD (6.09 pg TEQ/PUF, and MLI (5.54 pg TQ/PUF). Lowest values were associated with samples from ETH, MUS, MARA, SEN, TZA, and TGO (Figure 9). Stacked bar graphs show the contribution of the partial TEQs by sample (Figure 10). For each country, the results are displayed in Figure 12, Figure 12, Figure 13, and Figure 14. The mean values with standard deviations are shown in Figure 11.

Tunisia and Zambia were the only countries that had TEQ_PCB > TEQ_DF Figure 13. The statistical assessment showed that the amounts of TEQ_DF and TEQ_PCB were significantly different between countries ($p<2.2\times10^{-16}$). Also, the pairwise assessment gave p-values <<0.05 with a few exceptions such as, *e.g.*, for Congo DR or Egypt with Ghana, Mali or Nigeria (p-values >>0.05).

The mean values and standard deviations for each country are shown in Figure 11.

Table 26: Number of PUFs per country and year, analyzed for dl-POPs

Country	2017 (N=61)	2018 (N=23)	2019 (N=5)	Overall (N=89)
COD	4	1	1	6
EGY	5	5		10
ETH	4	1		5
GHA	5	1		6
KEN	5	1		6
MLI	5	1		6
MUS	5	1		6
MAR	4	1		5
NGA	1	1	1	3
SEN	5	1		6
TZA		1	3	4
TGO	5	1		6
TUN	5	5		10
UGA	3	1		4
ZMB	5	1		6

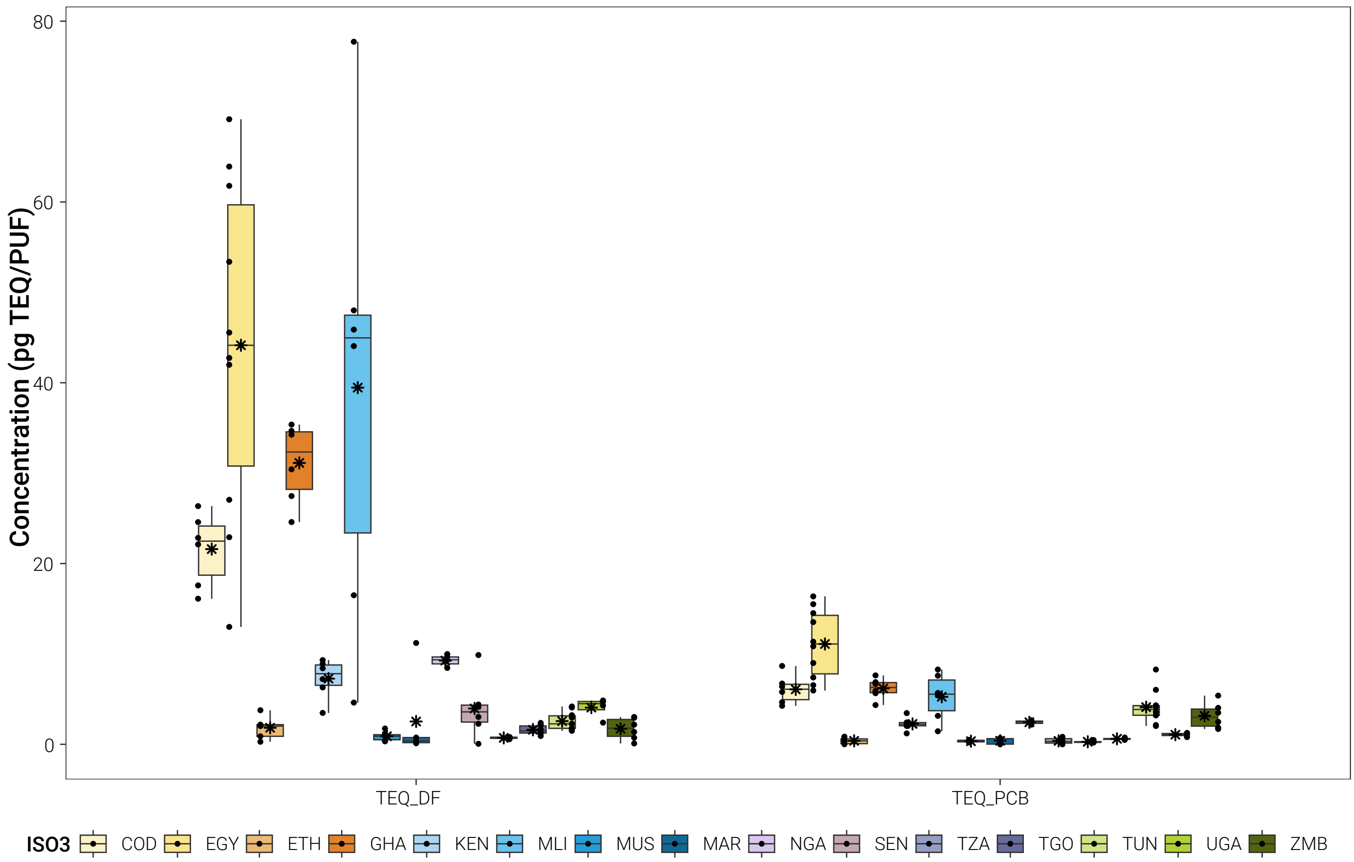


Figure 9: PAS/PUF: Box whisker plots for dl-POPs by country displayed for 2 TEQ (n=89). Values normalized to 1 PUF and 3 months exposure

Table 27: dl-POPs in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (pg TEQ/PUF and 3 months)

	Central tendencies	COD (N=6)	EGY (N=10)	ETH (N=5)	GHA (N=6)	KEN (N=6)	MLI (N=6)	MUS (N=6)	MAR (N=5)
TEQ_DF	Mean (SD)	21.6 (3.99)	44.1 (18.7)	1.83 (1.34)	31.1 (4.41)	7.27 (2.17)	39.5 (25.8)	0.893 (0.521)	2.53 (4.86)
	Median [Min, Max]	22.5 [16.1, 26.4]	44.1 [13.0, 69.2]	2.02 [0.283, 3.77]	32.3 [24.6, 35.4]	7.81 [3.47, 9.32]	45.0 [4.62, 77.7]	0.893 [0.329, 1.75]	0.365 [0.115, 11.2]
TEQ_PCB	Mean (SD)	6.08 (1.59)	11.1 (3.80)	0.382 (0.351)	6.18 (1.15)	2.26 (0.727)	5.26 (2.60)	0.344 (0.115)	0.391 (0.342)
	Median [Min, Max]	6.09 [4.26, 8.67]	11.1 [5.95, 16.4]	0.383 [0.011, 0.843]	6.29 [4.34, 7.62]	2.21 [1.21, 3.46]	5.54 [1.44, 8.27]	0.307 [0.216, 0.487]	0.614 [0.014, 0.691]

	Central tendencies	NGA (N=3)	SEN (N=6)	TZA (N=4)	TGO (N=6)	TUN (N=10)	UGA (N=4)	ZMB (N=6)	Overall (N=89)
TEQ_DF	Mean (SD)	9.26 (0.767)	3.96 (3.29)	0.713 (0.105)	1.60 (0.566)	2.57 (0.990)	4.06 (1.13)	1.72 (1.20)	13.3 (18.3)
	Median [Min, Max]	9.35 [8.45, 9.98]	3.59 [0.0552, 9.88]	0.736 [0.575, 0.806]	1.48 [0.918, 2.37]	2.26 [1.49, 4.18]	4.50 [2.40, 4.85]	1.77 [0.0929, 3.02]	4.07 [0.0552, 77.7]
TEQ_PCB	Mean (SD)	2.44 (0.247)	0.377 (0.334)	0.282 (0.127)	0.611 (0.0937)	4.11 (1.86)	1.07 (0.200)	3.16 (1.42)	3.53 (3.78)
	Median [Min, Max]	2.47 [2.17, 2.66]	0.315 [0.000374, 0.825]	0.227 [0.201, 0.471]	0.625 [0.491, 0.754]	3.86 [2.03, 8.27]	1.10 [0.802, 1.26]	2.99 [1.69, 5.39]	2.17 [0.000374, 16.4]

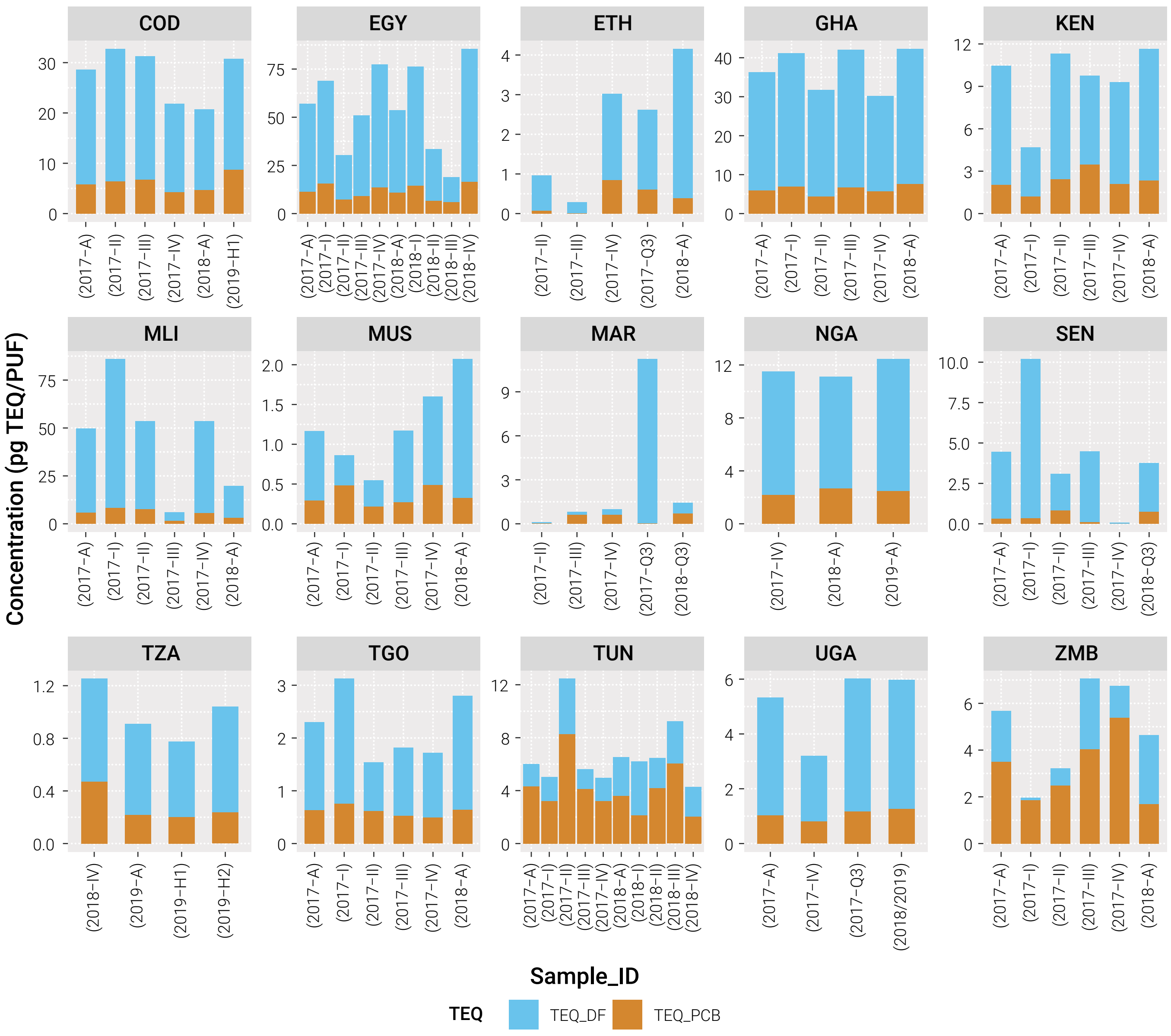


Figure 10: PAS/PUF: Stacked bar graphs for dl-POPs as 2 TEQ by country and sample (n=89)

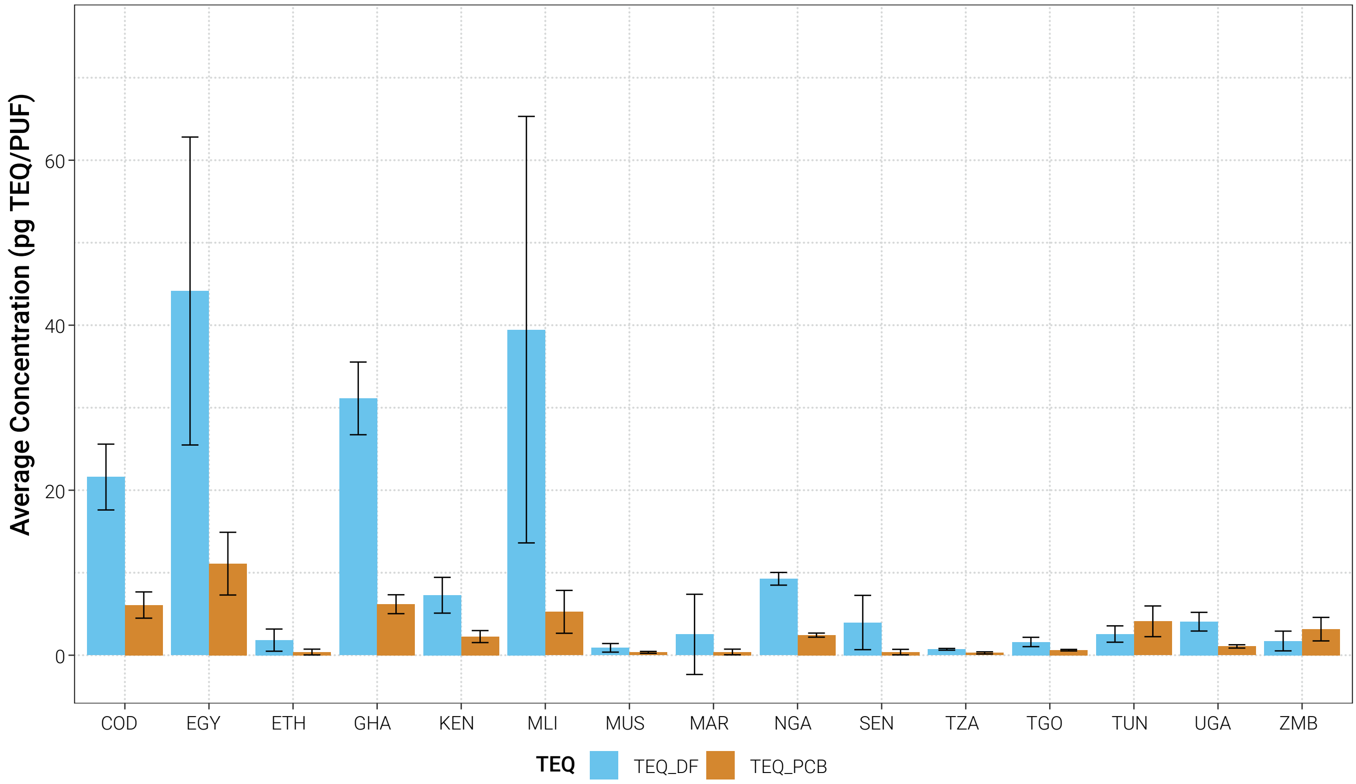


Figure 11: PAS/PUF: Mean values and SD for dl-POPs (as partial TEQ) for countries (n=89)

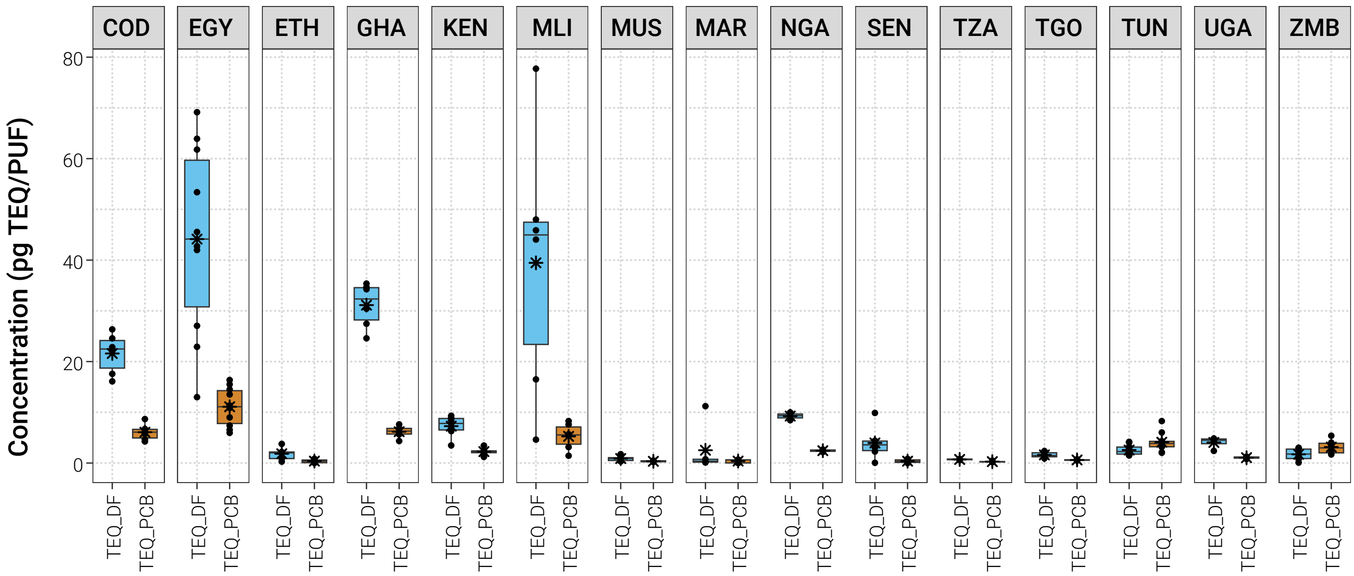


Figure 12: PAS/PUF: Box whisker plots unscaled for dl-POPs (for 2 TEQ) per country (n=89). Values normalized to 1 PUF and 3 months exposure

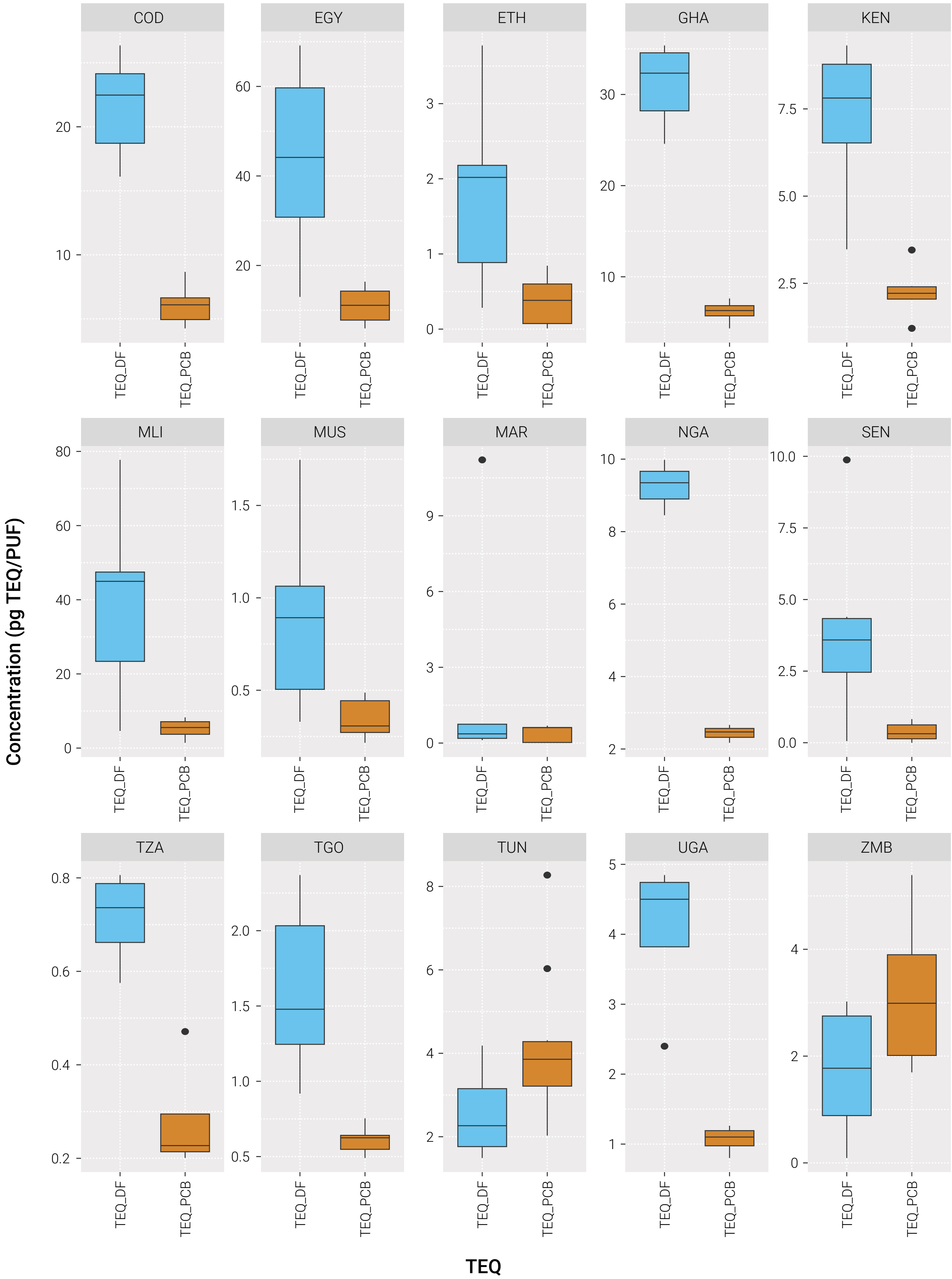


Figure 13: PAS/PUF: Scaled boxplots for concentrations of 2 TEQs by country (n=89)

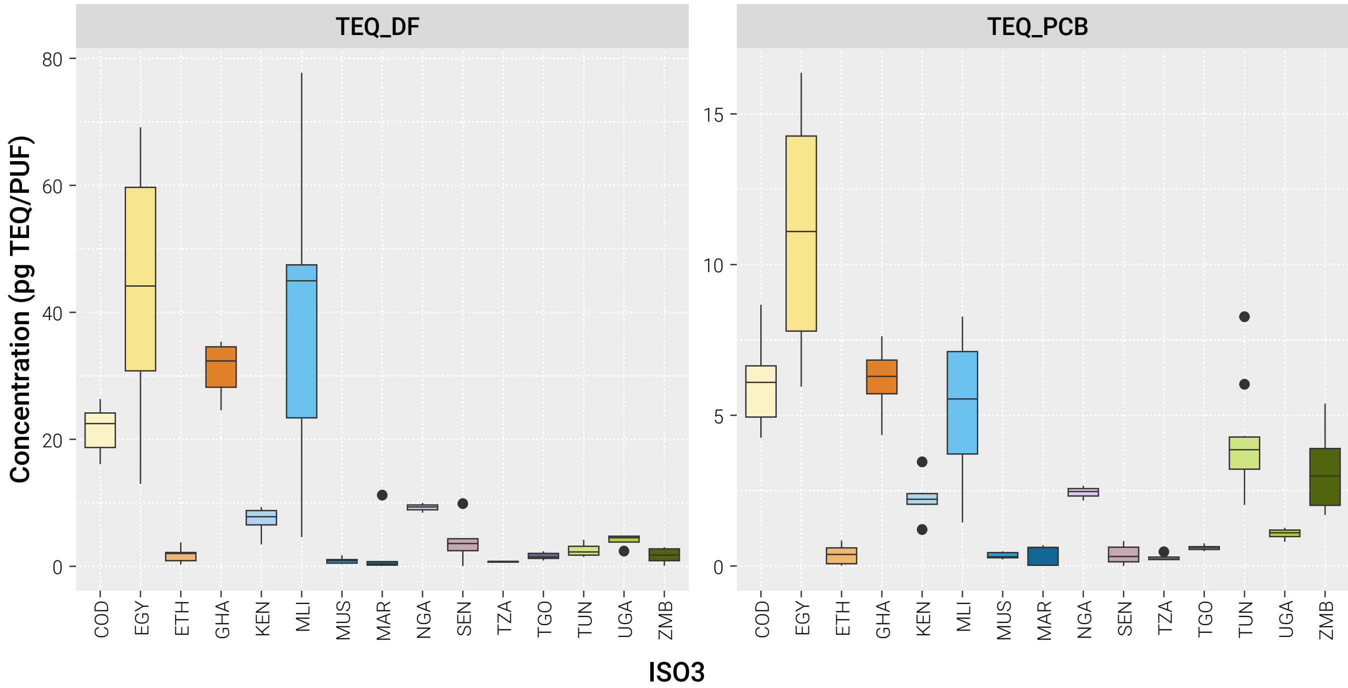


Figure 14: PAS/PUF: Scaled boxplots for concentrations by 2 TEQs for country

The Kruskal Wallis test for two TEQs gave significant differences between countries (p=$2.2x10^{-16}$) with many pairwise significant differences.

4.2.3. Brominated POPs

Brominated POPs included the PBDE (eight substances) and in addition PBDE 209, which was listed in 2017 (Secretariat of the Stockholm Convention 2017), PBB153 and three stereoisomers of HBCD.

Across all samples, $PBDE_8$ had higher mean but lower median values than HBCD. The highest $PBDE_8$ value was found in COD and the highest HBCD in ZMB. It is noticed that PBDE 209 had higher values than the sum of the eight PBDE ($PBDE_8$). Zambia had the highest values for PBDE 209 and HBCD but Togo had the highest share of HBCD from all countries (Figure 16, Figure 19, Figure 20). PBB153 was hardly quantified and was found only in samples from COD (5), GHA (3) and ZMB (2).

Across all samples, there were significant differences between all countries (p=4.0×10^{-13}); however, there were not so many pairwise significant differences identified, indicating that the data were very scattered.

Table 28: Number of PUFs per country and year, analyzed for Br-POPs

Country	2017 (N=47)	2018 (N=55)	2019 (N=11)	Overall (N=113)
COD	2	4	2	8
EGY	4	4		8
ETH	3	4	1	8
GHA	4	4		8
KEN	4	4		8
MLI	4	4		8
MUS	4	4		8
MAR	3	3		6
NGA	1	4	3	8
SEN	4	4		8
TZA		1	4	5
TGO	4	4		8
TUN	4	4		8
UGA	2	3	1	6
ZMB	4	4		8

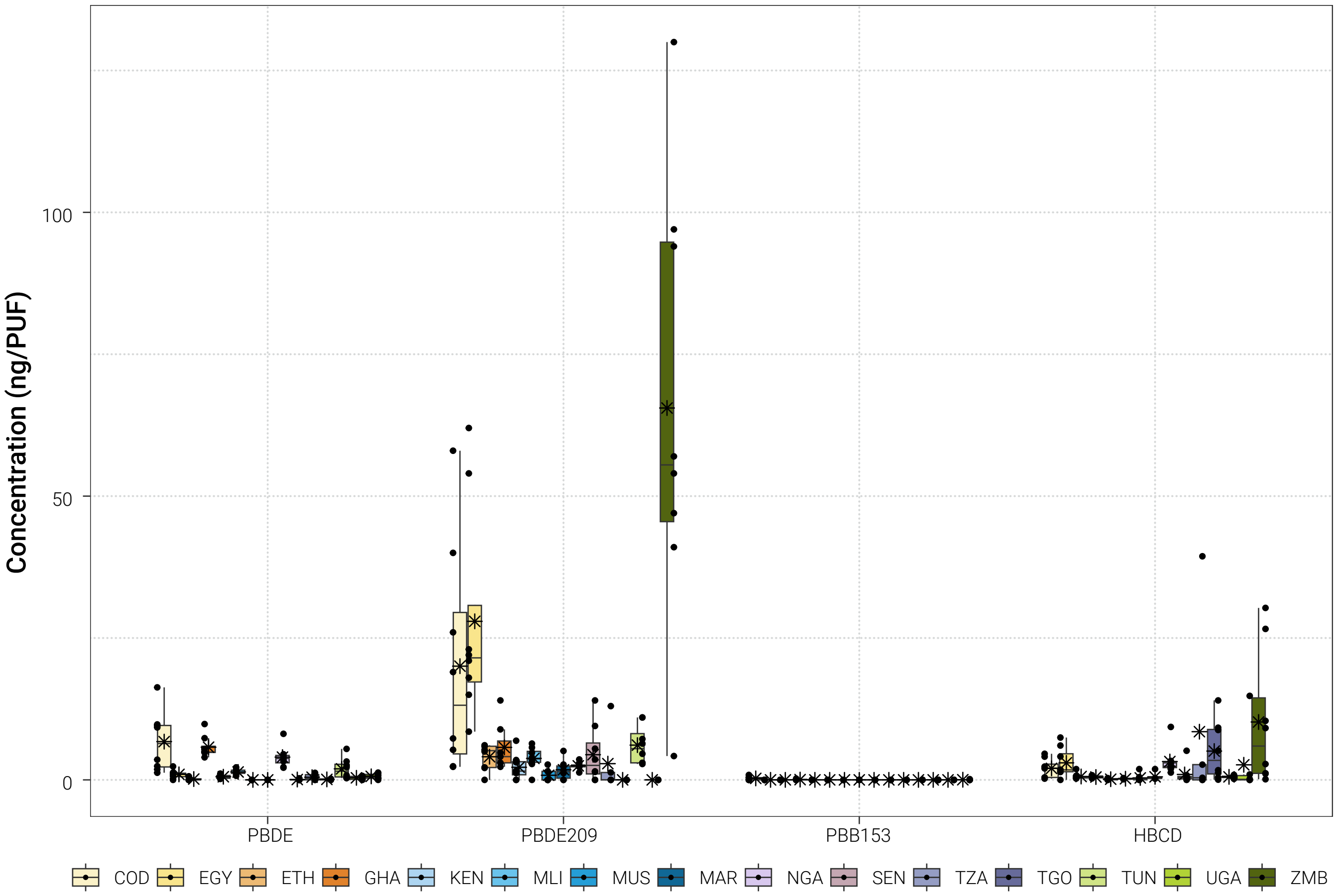


Figure 15: PAS/PUF: Box plots for brominated POPs: summary across all samples (n=113)

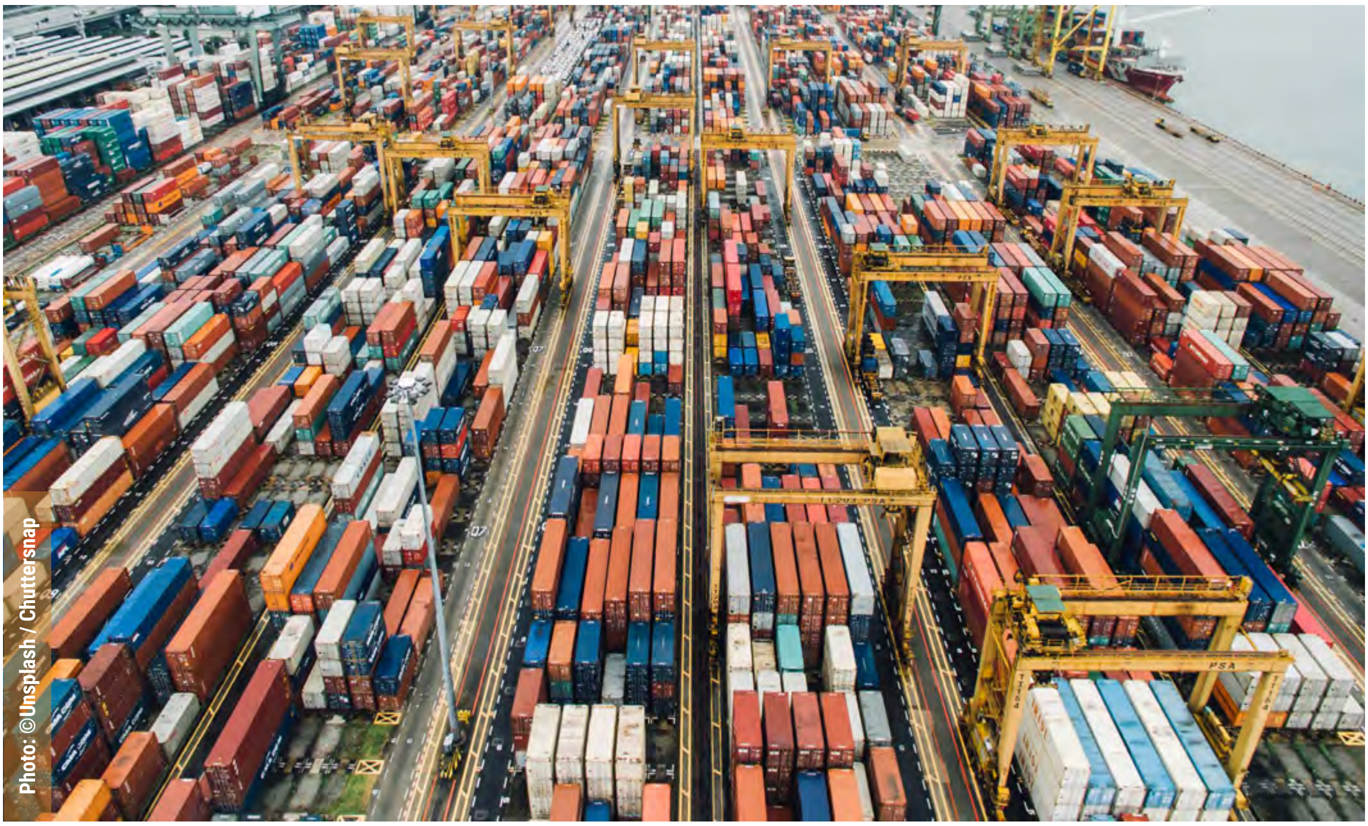


Table 29: Brominated POPs in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (ng/PUF)

	Central tendencies	COD (N=8)	EGY (N=8)	ETH (N=8)	GHA (N=8)	KEN (N=8)	MLI (N=8)	MUS (N=8)	MAR (N=6)
$PBDE_8$	Mean (SD)	6.74 (5.31)	0.973 (0.730)	0.148 (0.274)	5.76 (1.92)	0.553 (0.338)	1.40 (0.476)	0 (0)	0 (0)
	Median [Min, Max]	6.40 [1.26, 16.3]	1.05 [0, 2.37]	0 [0, 0.630]	4.90 [3.97, 9.84]	0.495 [0.170, 1.11]	1.32 [0.730, 2.20]	0 [0, 0]	0 [0, 0]
PBDE209	Mean (SD)	20.0 (20.3)	27.9 (19.2)	4.08 (2.32)	5.73 (4.26)	2.23 (2.27)	3.79 (1.97)	0.814 (1.09)	1.78 (1.93)
	Median [Min, Max]	13.2 [2.30, 58.0]	21.5 [8.50, 62.0]	5.15 [0, 6.10]	4.10 [2.30, 14.0]	1.55 [0, 6.90]	3.70 [0, 6.40]	0 [0, 2.70]	1.45 [0, 5.10]
	Missing	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)	0 (0%)	0 (0%)	1 (12.5%)	0 (0%)
PBB153	Mean (SD)	0.264 (0.308)	0 (0)	0 (0)	0.0488 (0.0792)	0 (0)	0 (0)	0 (0)	0 (0)
	Median [Min, Max]	0.205 [0, 0.870]	0 [0, 0]	0 [0, 0]	0 [0, 0.220]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]
HBCD	Mean (SD)	2.03 (1.67)	3.00 (2.61)	0.596 (0.547)	0.503 (0.221)	0.121 (0.121)	0.200 (0.0784)	0.348 (0.648)	0.535 (0.670)
	Median [Min, Max]	2.08 [0.220, 4.60]	1.76 [0, 7.46]	0.385 [0.240, 1.90]	0.400 [0.260, 0.810]	0.0850 [0, 0.310]	0.185 [0.110, 0.310]	0.0650 [0, 1.90]	0.280 [0.210, 1.90]

	Central tendencies	NGA (N=8)	SEN (N=8)	TZA (N=5)	TGO (N=8)	TUN (N=8)	UGA (N=6)	ZMB (N=8)	Overall (N=113)
$PBDE_8$	Mean (SD)	4.01 (1.87)	0.0613 (0.115)	0.474 (0.571)	0.0850 (0.0913)	1.95 (1.81)	0.362 (0.314)	0.619 (0.469)	1.62 (2.68)
	Median [Min, Max]	3.77 [2.15, 8.12]	0 [0, 0.280]	0.210 [0, 1.24]	0.0800 [0, 0.190]	1.53 [0.320, 5.46]	0.400 [0, 0.700]	0.520 [0, 1.28]	0.580 [0, 16.3]
PBDE209	Mean (SD)	2.48 (0.654)	4.44 (5.02)	2.86 (5.70)	0 (0)	6.13 (3.42)	0 (0)	65.5 (39.4)	10.5 (21.2)
	Median [Min, Max]	2.40 [1.30, 3.60]	2.55 [0, 14.0]	0 [0, 13.0]	0 [0, 0]	5.50 [2.80, 11.0]	0 [0, 0]	55.5 [4.20, 130]	3.00 [0, 130]
PBB153	Mean (SD)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.0263 (0.0504)	0.0240 (0.105)
	Median [Min, Max]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0.130]	0 [0, 0.870]
HBCD	Mean (SD)	3.23 (2.54)	0.954 (1.71)	8.49 (17.3)	5.07 (5.12)	0.534 (0.227)	2.66 (5.96)	10.2 (11.9)	2.44 (5.72)
	Median [Min, Max]	2.41 [1.29, 9.33]	0.430 [0, 5.13]	0.370 [0, 39.4]	3.43 [0.040, 14.0]	0.570 [0.180, 0.890]	0.0850 [0, 14.8]	5.96 [0.110, 30.3]	0.440 [0, 39.4]

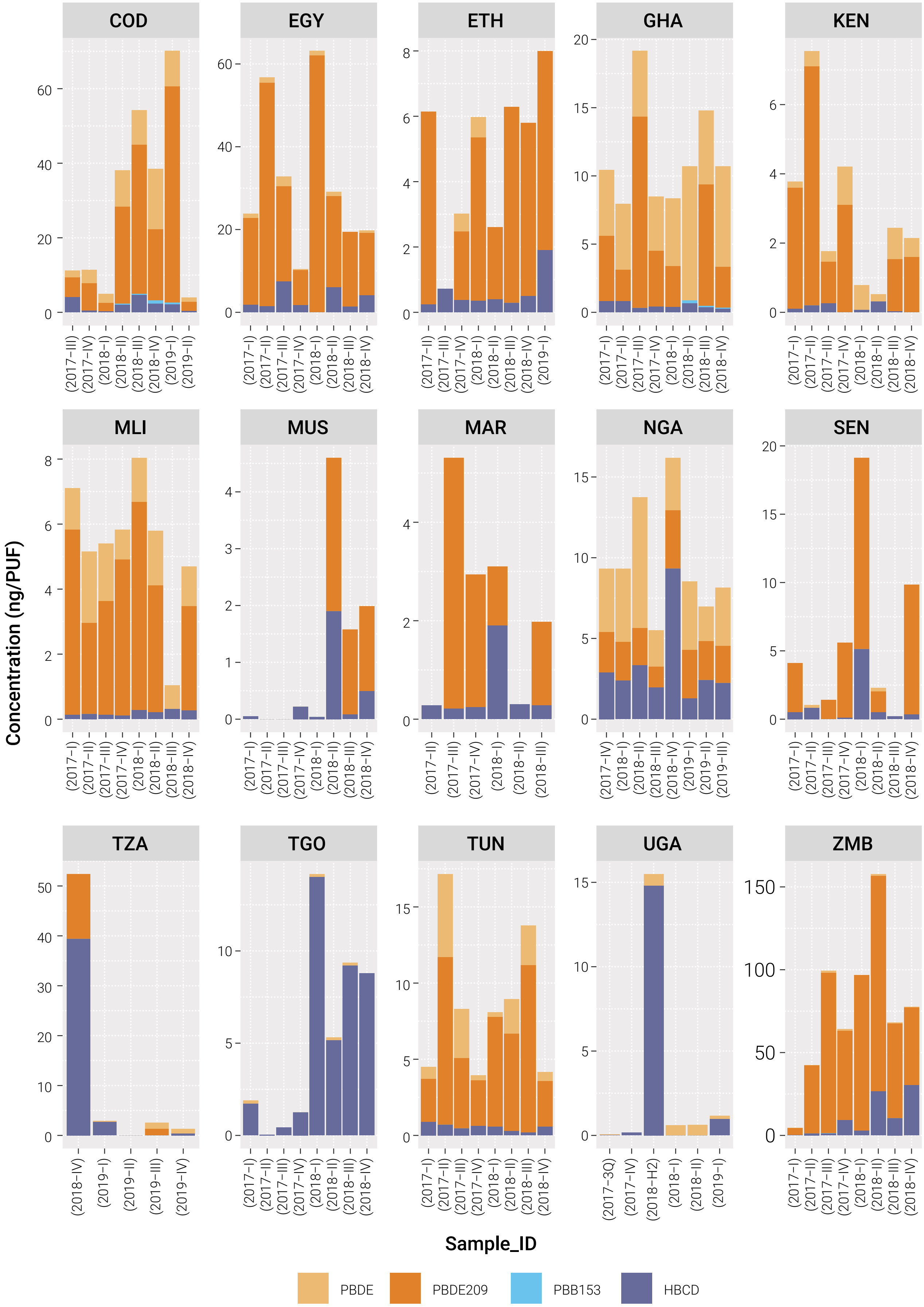


Figure 16: PAS/PUF: Stacked bar graphs for brominated POPs by country and sample (n=113)

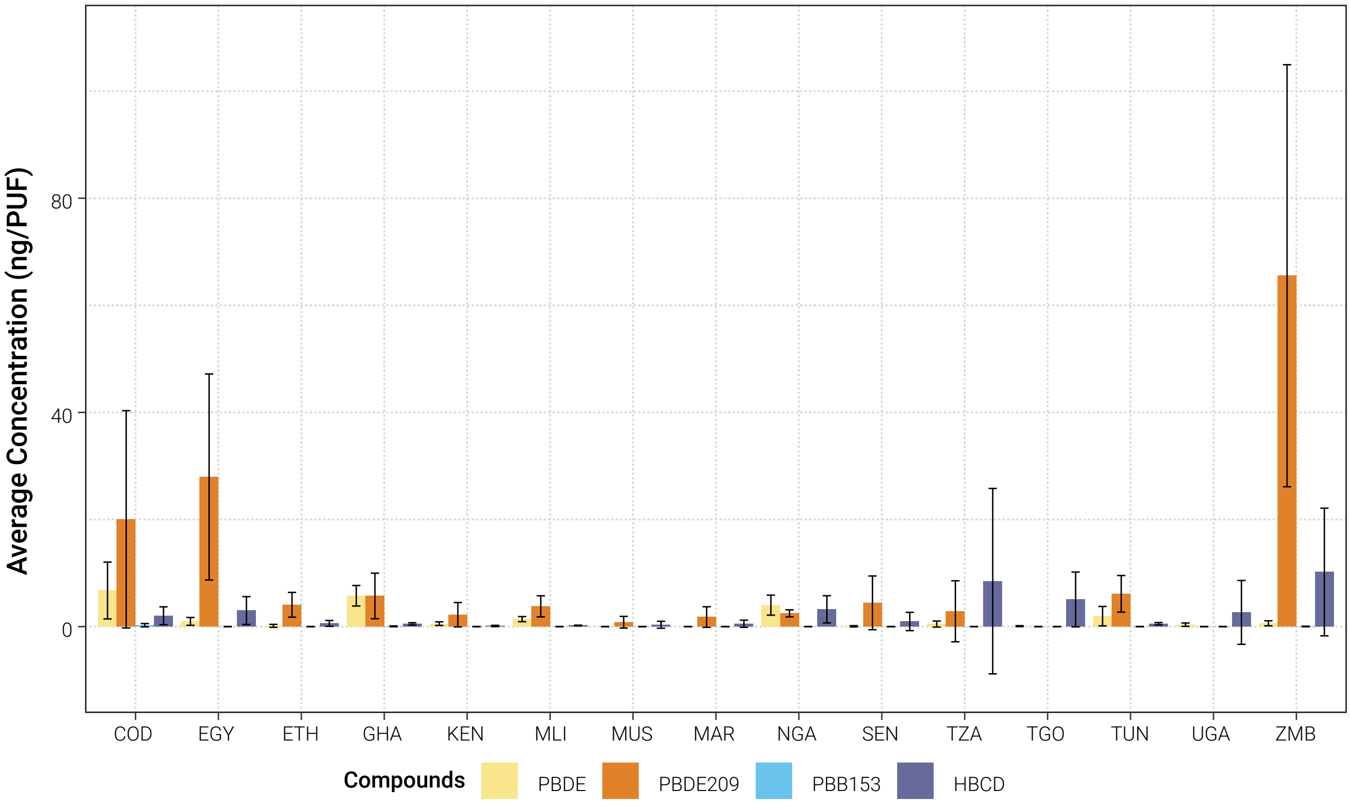


Figure 17: PAS/PUF: Mean values and SD for brominated POPs (n=113)

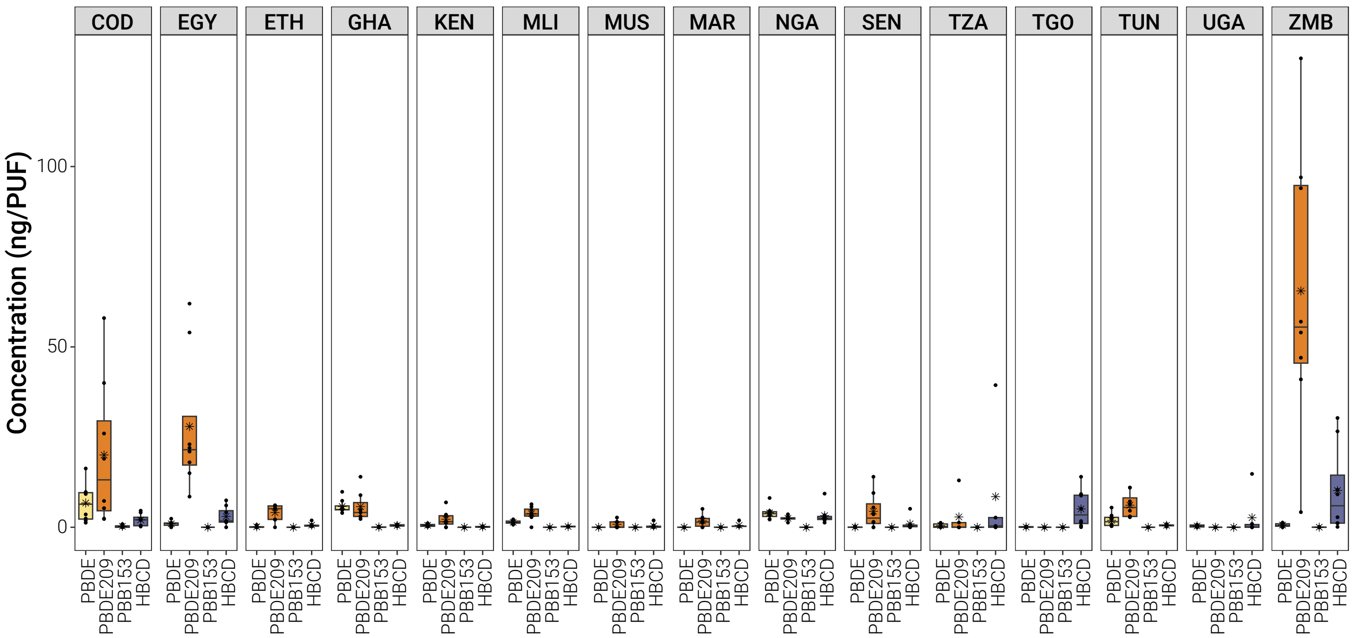


Figure 18: PAS/PUF: Unscaled boxplots for brominated POPs per country; y-axis zoomed to 20 ng/PUF. Concentrations in ng/PUF (n=113)

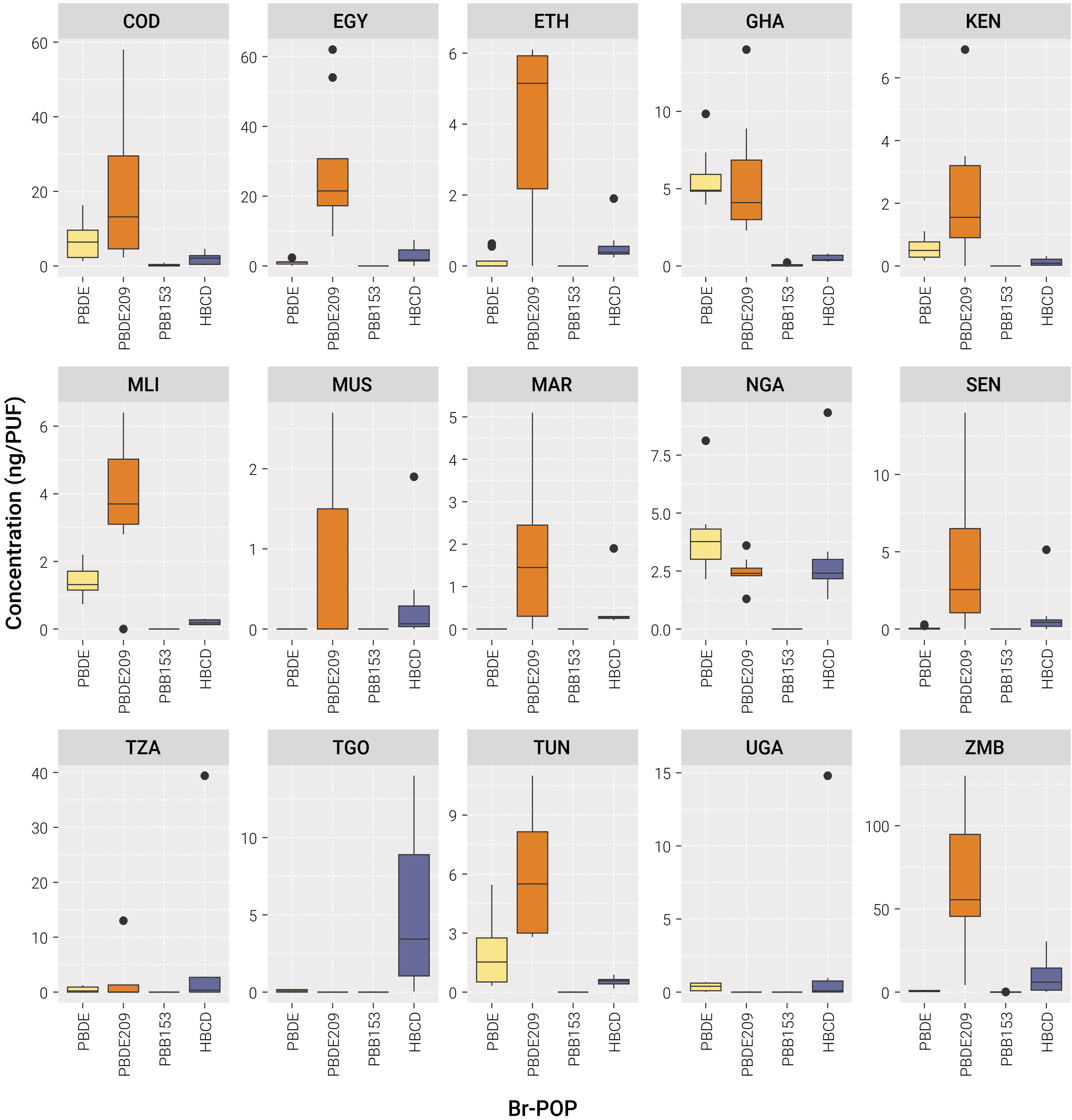


Figure 19: PAS/PUF: Scaled boxplots for sums of brominated POPs by country(n=113)

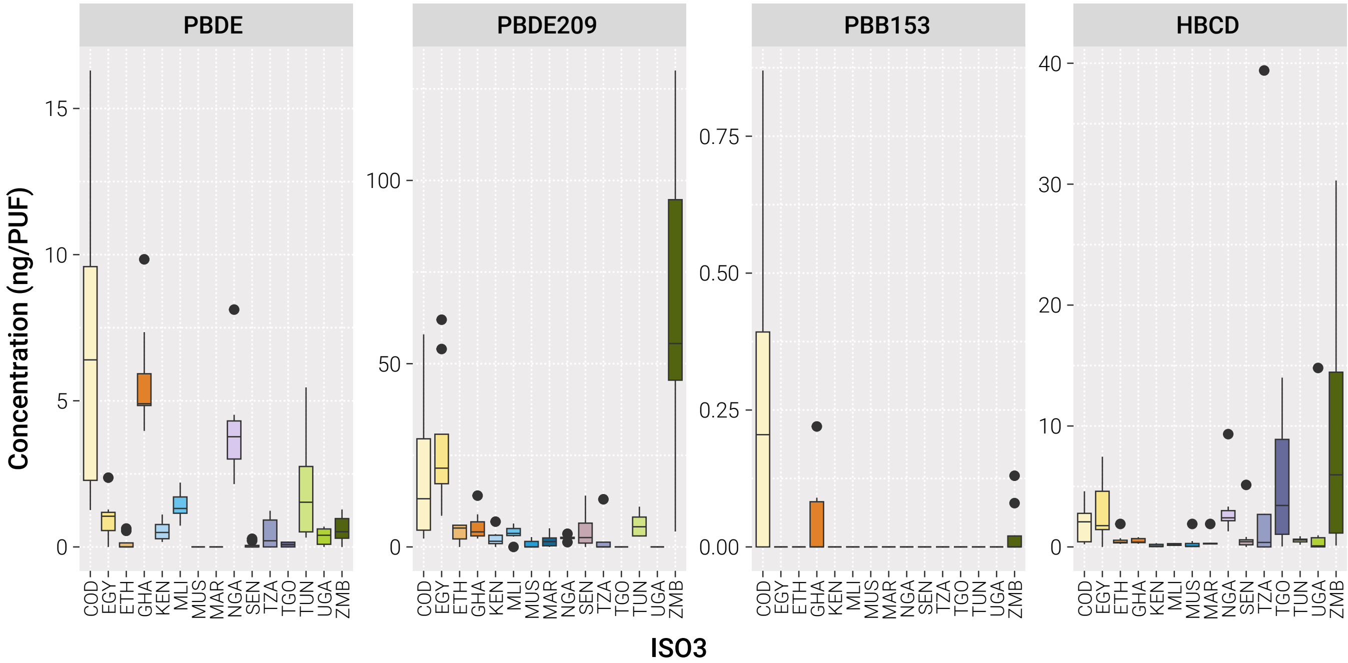


Figure 20: PAS/PUF: Scaled boxplots for country by brominated POPs (n=113)

4.2.4. Fluorinated POPs

127 samples were analyzed (Table 30). Noteworthy that TZA did not send any methanol pretreated PUFs for PFAS analysis. For all countries, the number per year includes an annual sample where the extracts from all quarterly samples of the same year were combined and reanalyzed. Exceptions are NGA in 2017 and TUN in 2019 when only one PUF was received.

The results of the PUF extracts for PFAS are detailed in Table S7 as have been analyzed. It can be seen that for quite a large number of samples, especially FOSA could not be quantified (cells containing NR). In this section, all results were normalized to 1 PUF and 3 months exposure to allow comparison of data.

Table 31 provides the mean, median, minimum and maximum values for each country. The values refer to pg per PUF and 1 quarter of the year, *i.e.,* 3-month exposure time. The median values for PFHxS and FOSA were zero. From the PFOS precursors, only FOSA could be quantified in the samples; FOSEs and FOSAs did not play a role. Details have been published elsewhere (Camoiras González *et al.* 2021). Overall, the mean value of PFOS was higher than the mean value of PFOA; for the median values, PFOA was higher than PFOS.

Table 30: PAS/PUFs: Overview of samples analyzed for PFAS by year of sampling

Country	2017 (N=57)	2018 (N=63)	2019 (N=7)	Overall (N=127)
COD	4	5	2	11
EGY	4	4		8
ETH	4	4	1	9
GHA	5	5		10
KEN	3	5		8
MLI	5	5		10
MUS	5	5		10
MAR	4	4		8
NGA	1	3	3	7
SEN	5	5		10
TZA				
TGO	5	5		10
TUN	5	5		10
UGA	3	3	1	7
ZMB	4	5		9

The measured data for ZMB are included in Table 30; they show extremely high values. The results for the four PFAS as stacked bars for each sample are shown in Figure 22.

Graphical sketches provide the summary and comparison of results of chemical analyses for the four PFAS. The overview on the amounts PFAS found in African samples is shown as box whisker plots in Figure 21. For each country, the results are displayed in Figure 24, Figure 25, and Figure 26. All data refer to 1 PUF and 3 month of exposure time and are given in pg/PUF. The mean values with SD are displayed in Figure 23.

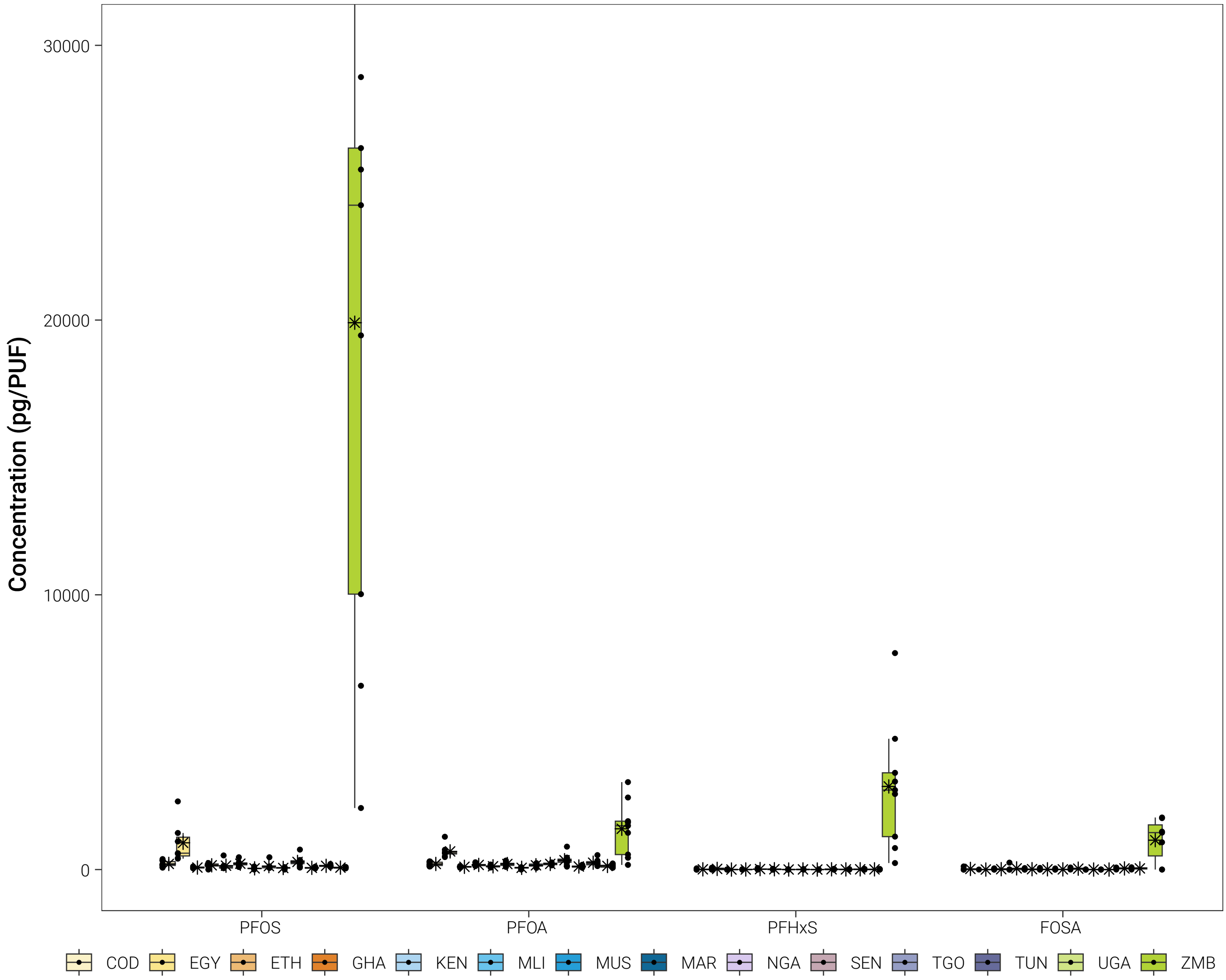


Figure 21: PAS/PUF: Summary of PFAS in PAS/PUFs Box whisker (n=127). Values normalized to 1 PUF and 3 months exposure

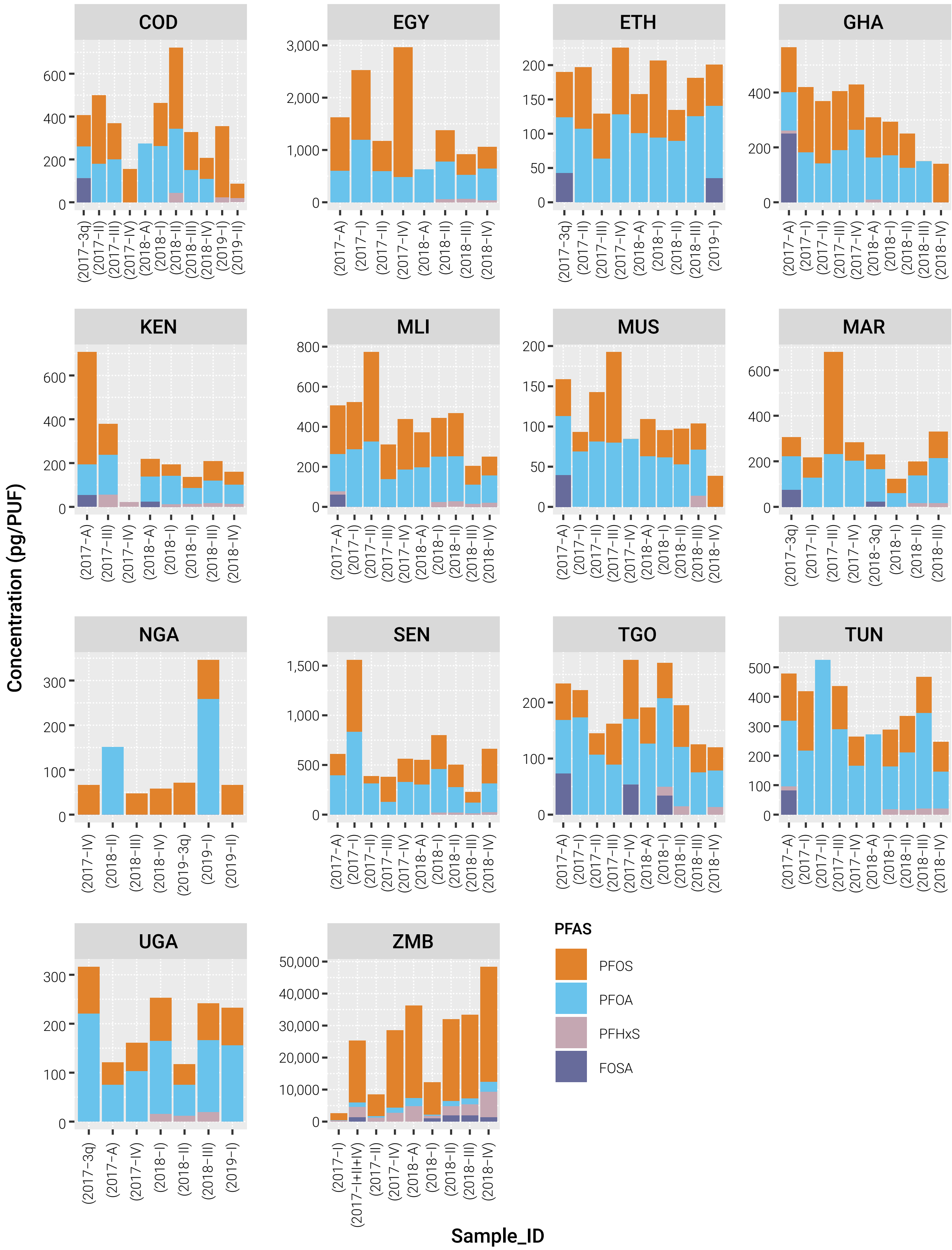


Figure 22: PAS/PUF: Stacked bar graphs for PFAS POPs by country and sample (n=127)

Table 31: Four PFAS in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (pg/PUF and 3 month exposure)

	Central tendencies	COD (N=11)	EGY (N=8)	ETH (N=9)	GHA (N=10)	KEN (N=8)	MLI (N=10)	MUS (N=10)	MAR (N=8)	NGA (N=7)	SEN (N=10)	TGO (N=10)	TUN (N=10)	UGA (N=7)	ZMB (N=9)	Overall (N=127)
PFOS	Mean (SD)	205 (104)	973 (747)	72.2 (22.5)	154 (68.5)	141 (167)	212 (99.7)	44.0 (29.1)	125 (131)	56.9 (27.9)	277 (180)	62.1 (19.7)	135 (34.1)	69.0 (20.5)	19900 (11200)	1640 (5940)
	Median [Min, Max]	172 [68.2, 380]	595 [396, 2480]	66.0 [44.6, 112]	155 [0, 238]	81.3 [50.1, 514]	204 [93.5, 447]	41.5 [0, 113]	82.7 [60.0, 447]	66.7 [0, 87.3]	241 [72.1, 726]	63.4 [37.8, 105]	124 [98.5, 202]	75.0 [42.5, 95.7]	24200 [2240, 36000]	110 [0, 36000]
	Missing	1	1			1							2			5
PFOA	Mean (SD)	203 (68.8)	660 (231)	99.5 (20.5)	169 (41.5)	118 (35.9)	200 (69.9)	62.2 (24.3)	154 (54.7)	205 (76.1)	339 (202)	111 (34.2)	248 (116)	131 (54.4)	1480 (1000)	305 (464)
	Median [Min, Max]	190 [109, 299]	603 [454, 1190]	101 [63.5, 128]	153 [125, 264]	113 [72.7, 181]	191 [96.1, 326]	65.8 [0, 84.6]	146 [59.6, 232]	205 [151, 259]	309 [106, 833]	106 [65.3, 173]	220 [126, 525]	147 [63.0, 221]	1600 [169, 3180]	153 [0, 3180]
	Missing	3			1	1				5						10
PFHxS	Mean (SD)	7.81 (14.6)	23.6 (30.6)	0	2.05 (4.32)	16.5 (17.7)	10.5 (11.5)	1.38 (4.35)	4.08 (7.55)	0	8.69 (10.7)	4.39 (7.09)	8.71 (9.41)	6.70 (8.60)	3020 (2320)	224 (980)
	Median [Min, Max]	0 [0, 43.6]	0 [0, 67.1]	0	0 [0, 10.6]	13.1 [0, 56.2]	7.44 [0, 27.3]	0 [0, 13.8]	0 [0, 16.7]	0	0 [0, 24.7]	0 [0, 15.6]	6.42 [0, 20.3]	0 [0, 19.1]	2890 [237, 7880]	0 [0, 7880]
	Missing		1								1					2
FOSA	Mean (SD)	22.5 (50.4)	0 (NA)	12.9 (20.1)	41.8 (102)	12.9 (22.1)	8.57 (22.7)	6.58 (16.1)	32.2 (38.3)	0	0	40.3 (31.3)	41.3 (58.4)	NA (NA)	1070 (795)	132 (414)
	Median [Min, Max]	0	0	0 [0, 42.4]	0 [0, 251]	0 [0, 53.7]	0 [0, 60.0]	0 [0, 39.5]	22.0 [0, 74.5]	0	0	43.9 [0, 73.3]	41.3 [0, 82.6]	NA [NA, NA]	1340 [0, 1890]	0 [0, 1890]
	Missing	6	7	3	4	2	3	4	5		6	6	8	7	2	63

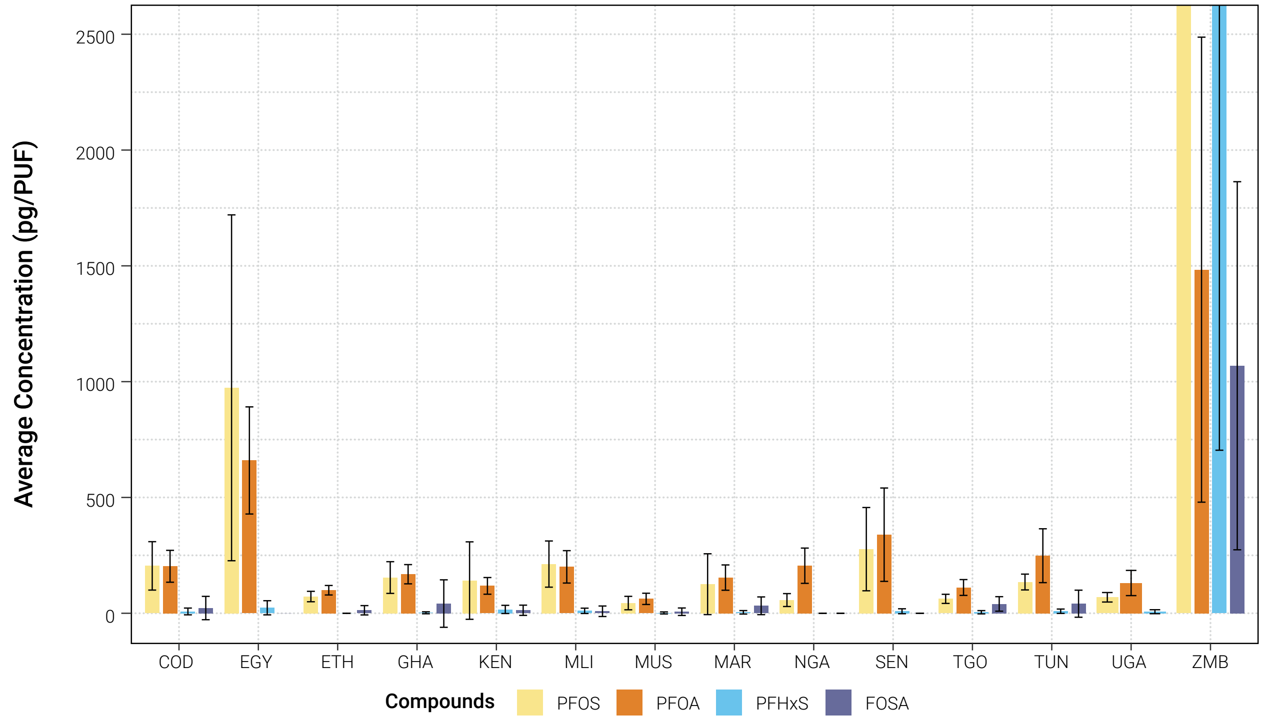


Figure 23: PAS/PUF: Mean values and SD for 4 PFAS (n=127)

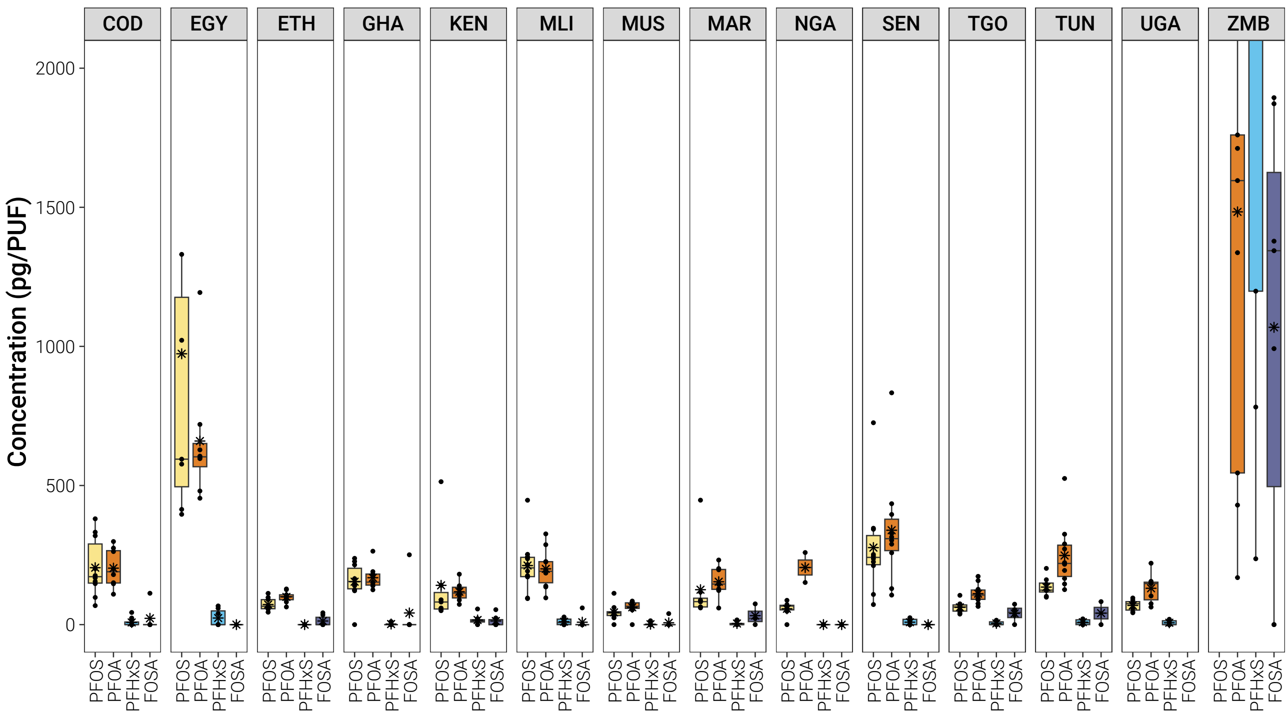


Figure 24: PAS/PUF: Unscaled for concentrations of 4 PFAS in PUFs by country. Y-axis zoomed to 2000 pg/PUF (n=127)

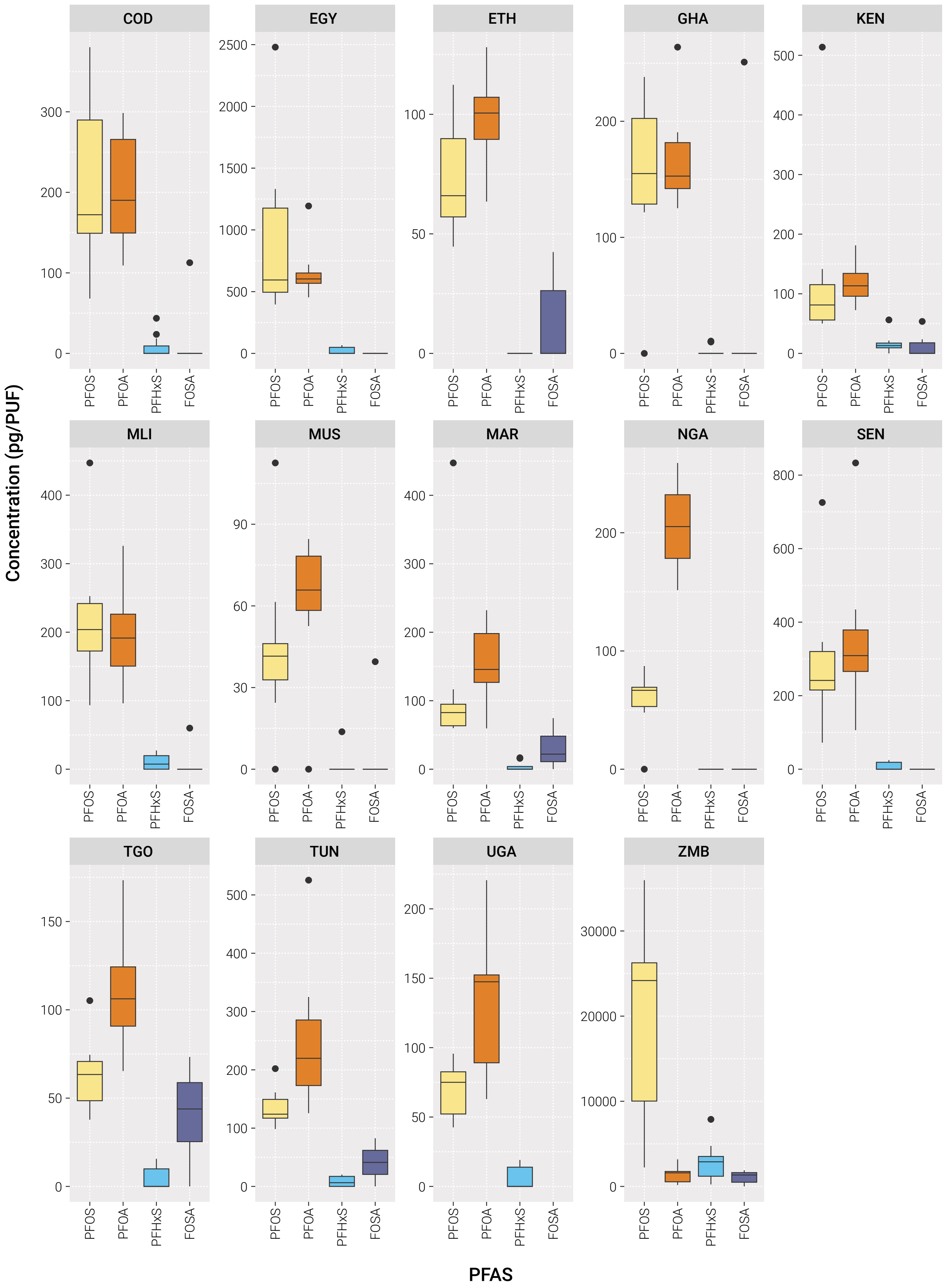


Figure 25: PAS/PUF: Scaled boxplots for concentrations of 4 PFAS by country (pg/PUF) (n=127)

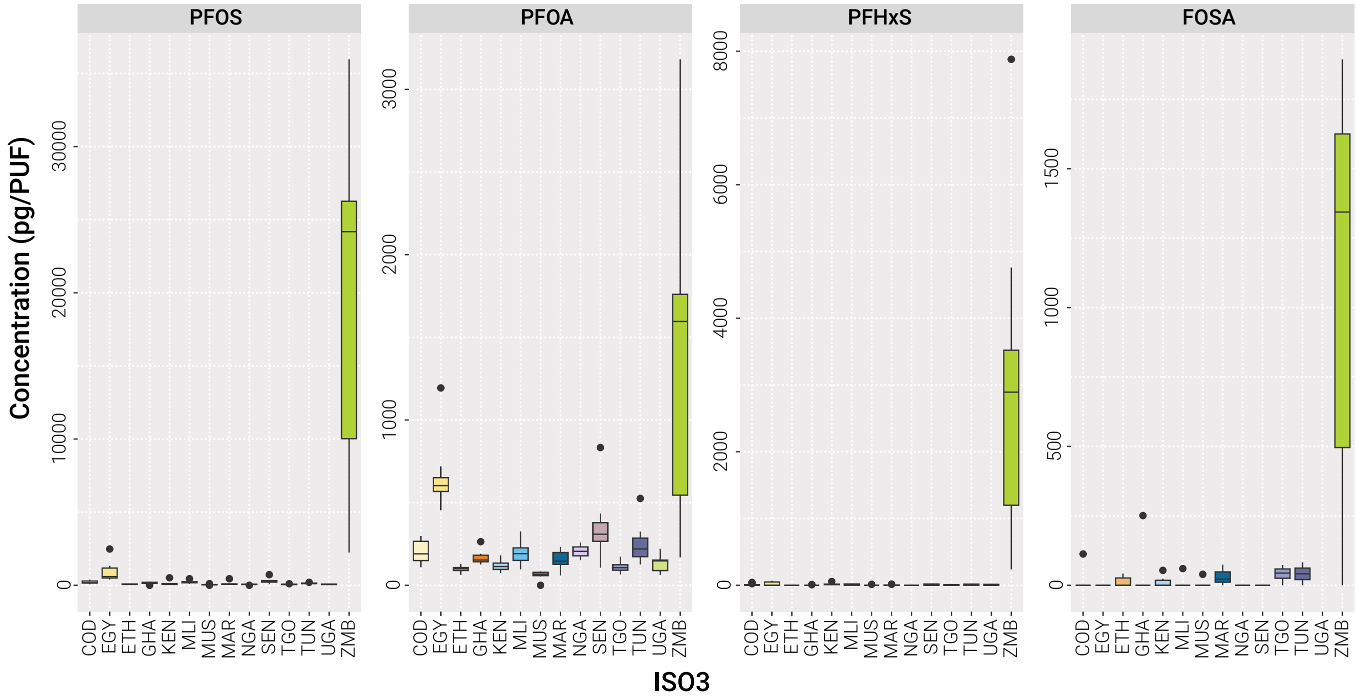


Figure 26: PAS/PUF: Scaled boxplots for concentrations according PFOS, PFOA, PFHxS by country (pg/PUF) (n=127)

4.2.5. Ambient Air with Active Sampler

Active air sampling (AAS) was performed in Kenya, Ghana and Mauritius. Data are available in Ghana for 2016 and 2017, in Kenya for 2017 and 2018, and in Mauritius for October 2020. In Ghana the AAS was installed in the premises of Ghana Atomic Energy Commission in Accra. Kenya had the active air sampling location on the roof top of the Chemistry Department, Chiromo campus, University of Nairobi. It is located within the University of Nairobi, Faculty of Science and Technology (FST) premises (1°16’26”S 36°48’21”E).

A summary of the results is presented in Table 32. The highest mean and median were found for PCB with values of 366 pg/m³ and 204 pg/m³, respectively Figure 27. All other POPs showed values two orders of magnitude lower, being higher for endosulfan and HBCD (Figure 28). No difference was found between 2016 and 2017, with the exception of chlordane (Figure 28) that showed higher values during 2017.

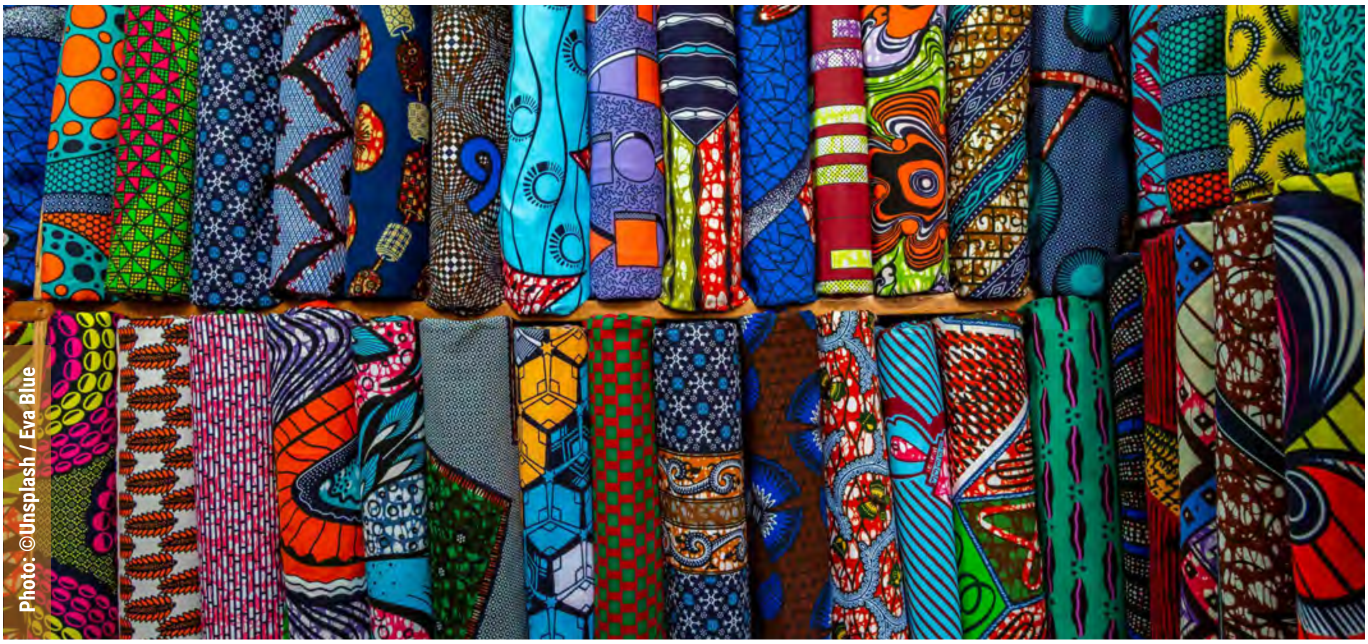


Table 32: Active air sampling: Results for Cl-POPs, Br-POPs and PFAS (pg/m3) (endosulfan=a-endosulfan)

Sample_ID	drins	chlordane	DDT	heptachlor	mirex	HCHs	endosulfan	PCB6	HCB	PeCBz	PBDE7	PBDE209	HBCD	PFOS	PFOA	PFHxS
KEN_AAS (2017-07)	27.0	4.53	48.8	0.77	0.04	3.68	4.68	8.09	9.33	2.26				17.1	2.29	3.81
KEN_AAS (2017-09)	31.2	5.68	44.7	1.01	0.04	9.80	5.95	13.7	14.06	3.33				29.1	0.00	4.39
KEN_AAS (2017-10)	13.6	2.75	82.8	0.72	0.02	3.89	4.98	9.49	8.10	2.12				36.0	0.00	5.16
KEN_AAS (2017-10b)	40.3	7.14	46.5	1.17	0.04	5.33	5.46	10.7	6.73	0.85				27.2	2.75	3.72
KEN_AAS (2017-11)	33.0	6.04	26.3	1.05	0.04	4.74	5.30	8.74	8.07	0.92				35.1	3.74	6.84
KEN_AAS (2017-12)	29.0	4.03	21.7	0.80	0.03	4.74	6.06	9.14	10.50	2.30				42.5	5.82	14.2
KEN_AAS (2018-01)	32.6	5.76	34.6	0.95	0.04	5.33	12.7	10.9	10.00	1.69				57.2	8.62	35.2
KEN_AAS (2018-02)	12.7	2.59	26.4	0.52	0.04	3.16	2.69	9.66	11.80	1.62				64.0	9.66	22.4
KEN_AAS (2018-03)	21.7	5.61	46.8	0.85	0.04	6.08	4.84	13.5	9.73	1.44				28.0	2.42	11.8
KEN_AAS (2018-03b)	25.5	6.41	53.0	1.16	0.04	2.88	3.16	8.84	8.31	1.13				31.3	0.00	9.96
KEN_AAS (2018-04)	45.0	10.7	42.0	1.20	0.04	5.93	5.05	14.4	6.46	0.91				1.65	0.00	5.63
KEN_AAS (2018-05)	0.00	0.01	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.09				0.94	0.00	5.57
GHA_AAS (2017-06-1)	0.00	0.00	2.47	0.00	0.00	1.91	0.00	197	1.70	0.19	4.14	1.86	21.8	0.53	2.48	0.00
GHA_AAS (2017-06-2)	0.00	0.00	5.16	0.00	0.00	1.60	0.01	314	0.96	0.11	11.4	2.12	16.9			
GHA_AAS (2017-07-1)	0.00	0.00	6.02	0.00	0.00	0.90	0.01	205	1.52	0.19	4.94	2.03	17.9	1.17	3.74	0.08
GHA AAS (2017-3a)	0.57	0.27	8.84	0.29	0.00	2.80	0.00	918	1.56	0.40	6.21	1.48	1.98			
GHA AAS (2016-3b)	0.33	0.10	7.89	0.06	0.01	1.62	2.00	1013	1.18	0.25	5.68	0.60	0.44			
GHA AAS (2016-4)	0.51	0.17	10.1	0.16	0.01	1.83	2.89	778	1.52	0.33	7.17	1.59	0.43			
GHA AAS (2016-5a)	0.19	0.07	8.83	0.03	0.00	1.22	0.00	1103	0.91	0.19	7.50	1.19	0.36			
GHA AAS (2016-5b)	0.38	0.11	4.94	0.06	0.00	0.90	0.00	616	0.68	0.00	5.47	0.60	0.34			
GHA AAS (2016-5c)	0.15	0.06	7.62	0.03	0.00	1.98	1.58	968	0.84	0.18	5.78	1.01	0.48			
GHA AAS (2016-6a)	0.37	0.25	4.15	0.27	0.00	1.22	0.00	352	0.82	0.13	2.45	0.51	0.34			
GHA AAS (2016-6b)	0.00	0.26	4.18	0.20	0.00	0.76	0.00	174	0.81	0.19	3.27	0.65	0.51			
GHA AAS (2016-7a)	0.37	0.20	4.06	0.18	0.00	1.05	0.00	259	1.34	0.38	3.78	0.84	0.35			
GHA AAS (2016-7b)	1.50	0.82	4.36	0.83	0.00	1.44	0.00	118	3.05	2.02	3.41	0.87	0.90			
GHA AAS (2017-8)	0.62	0.21	3.65	0.13	0.01	0.72	4.95	194	0.96	0.15	4.27	0.61	0.43			
GHA AAS (2017-1a)	0.25	0.11	8.92	0.14	0.00	1.84	0.00	716	2.63	0.86	16.7	4.85	2.17			
GHA AAS (2017-1b)	0.31	0.10	9.55	0.12	0.01	1.99	1.37	836	3.24	0.38	17.6	5.44	1.80			
GHA AAS (2017-1c)	0.33	0.26	8.00	0.41	0.00	2.18	7.87	357	3.19	0.78	24.8	7.96	1.69			
GHA AAS (2017-2a)	0.32	0.10	7.49	0.09	0.00	1.17	1.41	699	1.10	0.22	8.58	0.84	1.74			
GHA AAS (2017-2b)	0.00	0.18	0.78	0.16	0.00	0.39	38.4	72.0	0.78	0.19	1.31	1.01	0.47			
MUS (2020-10)	5.56	0.834	35.9	0.000	0.14	15.5	0.000	10.9	40.3	46.3						

For the PFOS precursors, there were measured data available only for two samples and for PCDD/PCDF and dl-PCB only for one sample from Mauritius. These data are shown in pg TEQ/m^3 (Table 33).

The following graphics display the pattern found in the AAS samples from Africa. OCPs with industrial POPs, PCB_6 and HCB, and PeCBz, were measured in Ghana, Kenya, and Mauritius (Figure 27). In Ghana and Kenya samples were taken several times *per* year and analyzed by RECETOX.

There was only one sample from Mauritius, which was analyzed by E&H VU Vrije universiseit. Whereas the scales of the measurements were comparable, the pattern were very different. In Ghana, the vast majority of the POPs were PCB_6, whereas in Kenya, drins and DDT dominated, HCHs were present at low concentrations. PeCBz was not quantified in these two countries. In Mauritius, more than 50% of the POPs was from the industrial POPs with high shares of HCB and PeCBz, and low shares of PCB_6.

Table 33: Active air sampling: Results for PFOS precursors and dl-POPs (pg/m^3)

Sample_ID	FOSA	MeFOSA	EtFOSA	MeFOSE	EtFOSE	TEQ_DF	TEQ_PCB
GHA_AAS (2017-06-1)	0.03	0.00	0.00	0.42	0.13		
GHA_AAS (2017-07-1)	0.02	0.00	0.00	0.23	0.04		
MUS (2020-10)						0.78	0.03

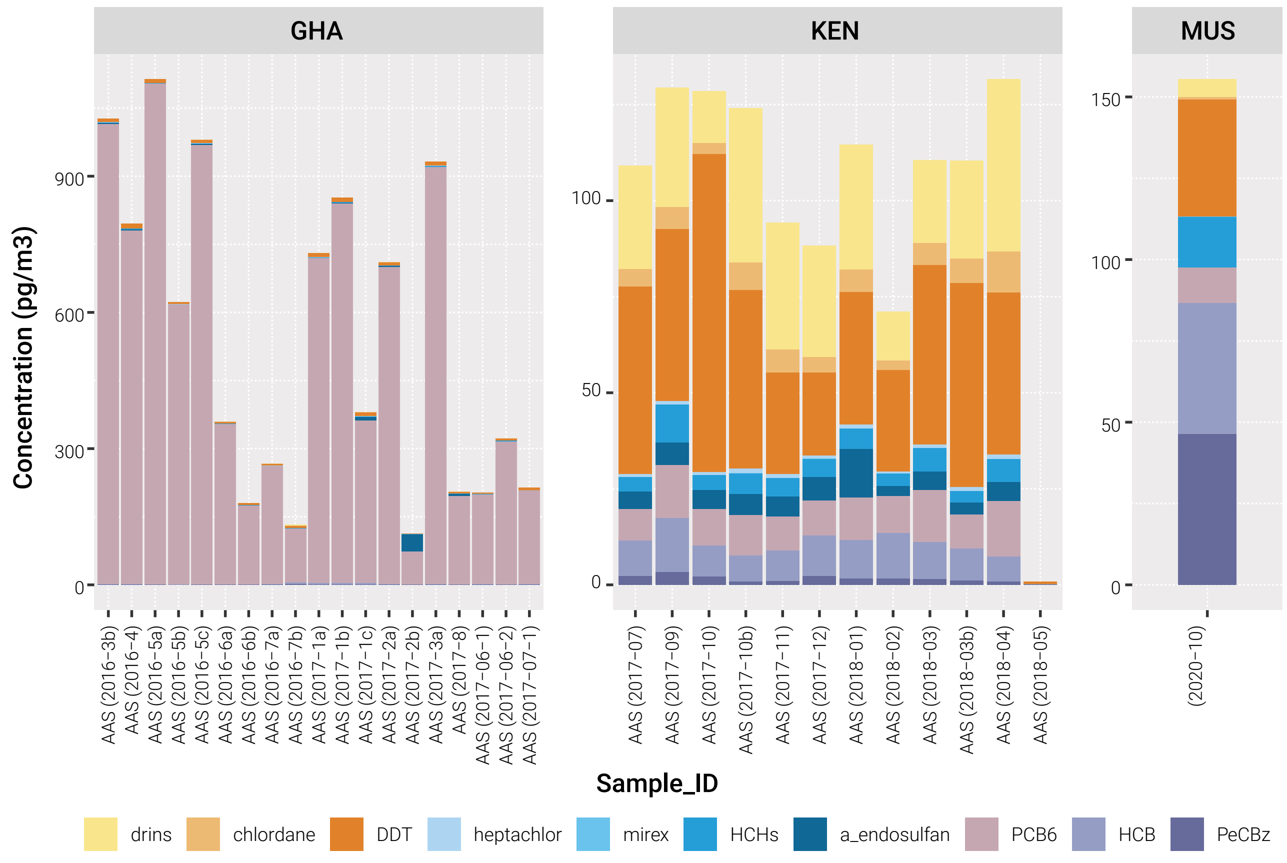


Figure 27: AAS Africa: Stacked bars for OCPs+industrial POPs

Dioxin-like POPs have not been analyzed in Ghana and Kenya; from Mauritius there was only one measurement available (Figure 28). The concentrations were very low (< 1 fg TEQ/m^3) with high share of TEQ_DF.

Br-POPs data were available only from Ghana (Figure 29). The samples from June and July 2017, GHA_AAS (2017-06-1), GHA_AAS (2017-06-2), GHA_AAS (2017-07-1) showed a very distinct pattern in comparison to the 2016 and the early 2017 samples with high shares of HBCD.

PFAS measurements were not available from Mauritius since no methanol-treated PUF was exposed (Figure 30). The data from Ghana and Kenya were very different as to the scale of the amounts and the composition of the PFAS. The few Ghana samples were dominated by PFOA whereas the Kenya data were dominated by PFOS. The PFOS precursors were either not analyzed or at very low levels.

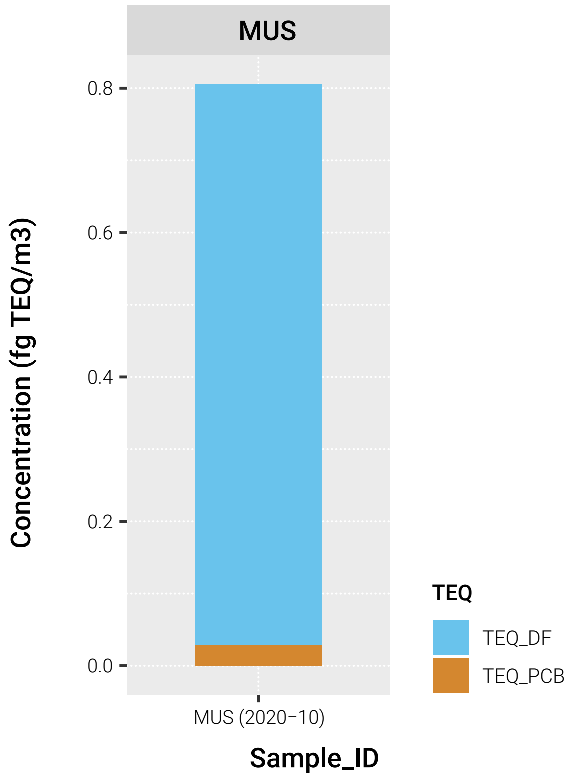


Figure 28: AAS Africa: Stacked bars for dl-POPs

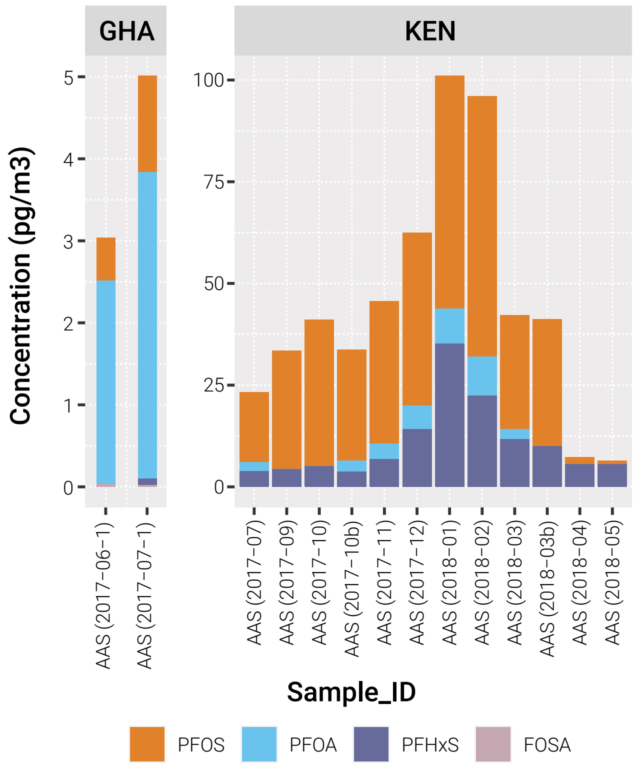


Figure 30: AAS Africa: Stacked bars for PFAS

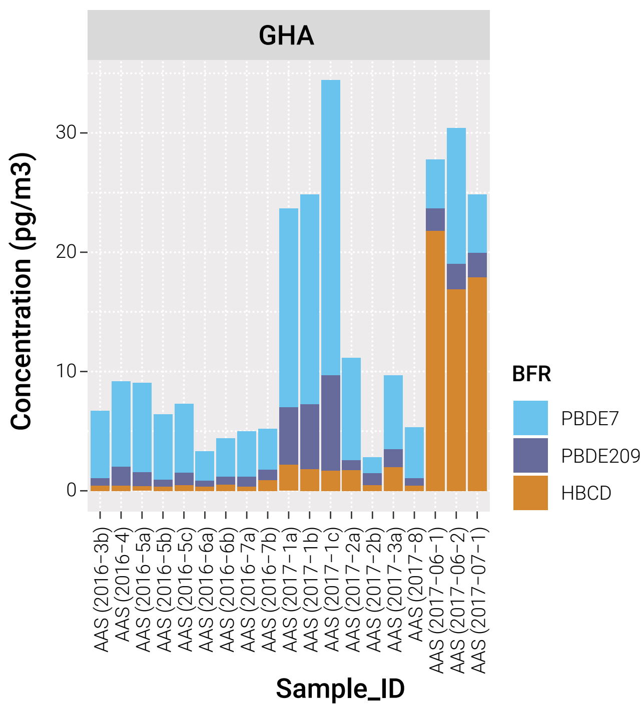


Figure 29: AAS Africa: Stacked bars for Br-POPs

4.3. Water

There are two groups of samples: 44 samples were from the six countries that participated in the water sampling network; in addition, Nigeria and Uganda sent water samples as part of the national samples for PFAS analysis. These six samples are included in this section since they were collected using the water SOP. As can be seen from Table 34, a full set of samples was provided by three countries – KEN, TUN, and ZMB. For EGY, GHA, and SEN, the full set of four samples was not achieved in 2018. One sample from Senegal was lost during transport since the bottle leaked and there was no material left upon arrival.

Graphical sketches provide an overview on all samples analyzed from Africa in Figure 31. The comparison of results of chemical analyses for PFAS as boxplots is shown in Figure 32. In contrast to the other regions, the Africa results are quite homogeneous and there is only one outlier for L-PFOS. The mean values with SD are shown in Figure 31. Br-PFOS was detected in almost all samples results see Table S 8.

Table 34: PFAS in water: overview on samples

	2017 (N=24)	2018 (N=20)	2019 (N=6)	Overall (N=50)
From water sampling network				
EGY	4	3		7
GHA	4	3		7
KEN	4	4		8
SEN	4	2		6
TUN	4	4		8
ZMB	4	4		8
From national samples				
NGA			1	1
UGA			5	5

Overall, the median concentrations of PFOS and PFOA were similar and PFHxS was about 2-times lower. The Africa mean concentration of PFOA was higher than for PFOS.

The highest concentrations for all three PFAS were found in Kenya, whereas the highest concentration of PFOS was found in a single sample from ZMB whereas the highest mean concentrations was in Kenya (Figure 31).

Graphical sketches provide an overview on all samples analyzed from the African countries in Figure 31. The comparison of results of chemical analyses for PFAS as boxplots is shown in Figure 32.

The amounts of PFAS found in Africa according to countries and by year is shown in Figure 33. It can be seen that in Kenya, the concentrations are quite different between years: Also, Ghana has some differences between 2017 and 2018. The reasons are not known since the sampling locations have not changed.

Table 35: PFAS in water: Mean (with standard deviation, SD), median, minimum and maximum values (ng/L)

	Central tendencies	EGY (N=7)	GHA (N=7)	KEN (N=8)	SEN (N=6)	TUN (N=8)	ZMB (N=8)	NGA (N=1)	UGA (N=5)	Overall (N=50)
PFOS	Mean (SD)	0.333 (0.0960)	0.371 (0.392)	1.50 (0.628)	0.275 (0.209)	0.636 (0.161)	0.549 (0.878)	0.340 (NA)	0.213 (0.213)	0.589 (0.614)
	Median [Min, Max]	0.341 [0.193, 0.477]	0.230 [0, 1.21]	1.73 [0.621, 2.18]	0.242 [0.073, 0.554]	0.611 [0.362, 0.942]	0.135 [0.0553, 2.64]	0.340 [0.340, 0.340]	0.101 [0.0343, 0.454]	0.418 [0, 2.64]
PFOA	Mean (SD)	0.528 (0.226)	0.273 (0.066)	1.91 (1.26)	0.111 (0.057)	1.17 (0.287)	0.165 (0.0825)	0.239 (NA)	0.580 (0.738)	0.707 (0.831)
	Median [Min, Max]	0.465 [0.268, 0.935]	0.238 [0.214, 0.393]	1.57 [0.592, 4.02]	0.102 [0.052, 0.209]	1.13 [0.755, 1.60]	0.134 [0.099, 0.349]	0.239 [0.239, 0.239]	0.244 [0.112, 1.86]	0.355 [0.052, 4.02]
PFHxS	Mean (SD)	0.063 (0.041)	0.046 (0.019)	0.921 (0.536)	0.010 (0.016)	0.099 (0.015)	0.0705 (0.094)	0.081 (NA)	0.0434 (0.061)	0.197 (0.381)
	Median [Min, Max]	0.051 [0.029, 0.153]	0.043 [0.026, 0.077]	0.968 [0.328, 1.63]	0 [0, 0.034]	0.098 [0.081, 0.125]	0.0363 [0, 0.233]	0.081 [0.081, 0.081]	0 [0, 0.126]	0.057 [0, 1.63]


Photo: ©Pexels / D•• Nyau

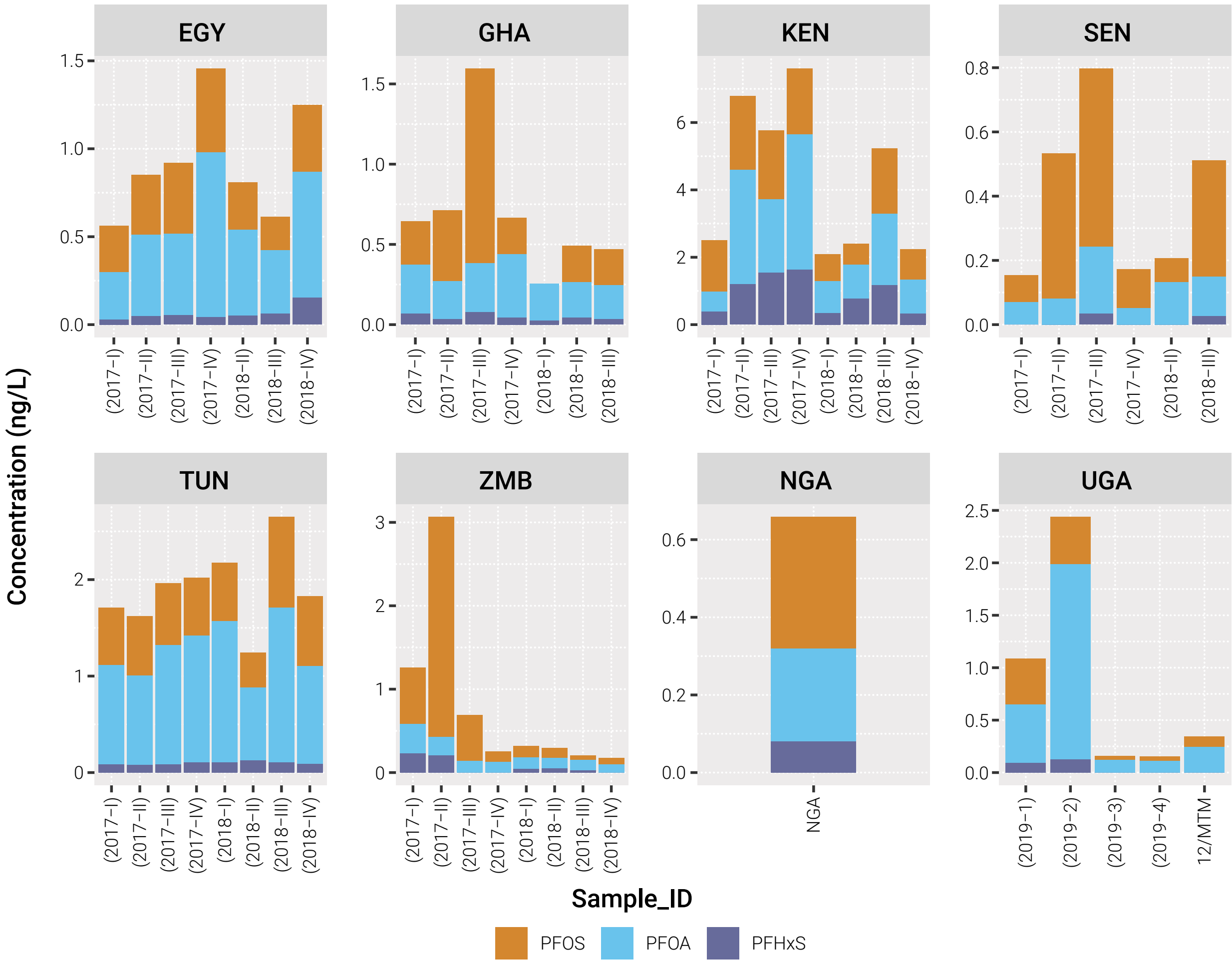


Figure 31: Water: Overview on PFAS concentrations by sample and country (stacked boxplots). Concentrations in ng/L

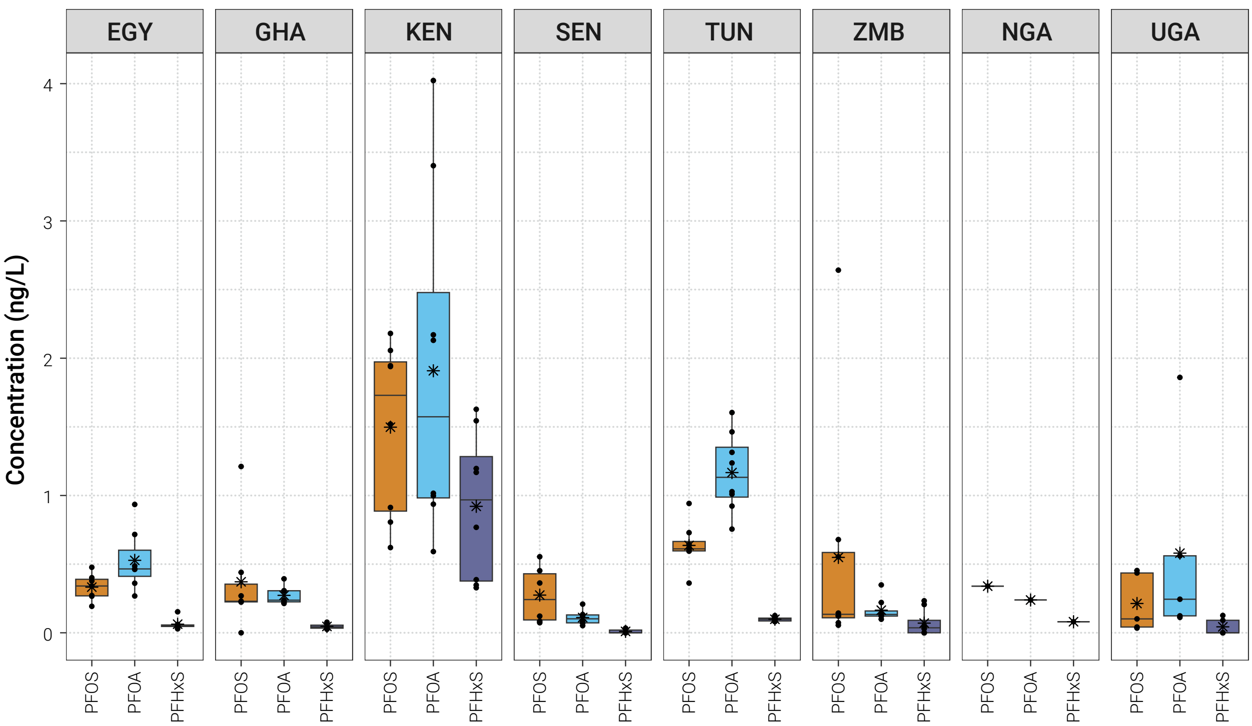


Figure 32: Water: Unscaled boxplots by country

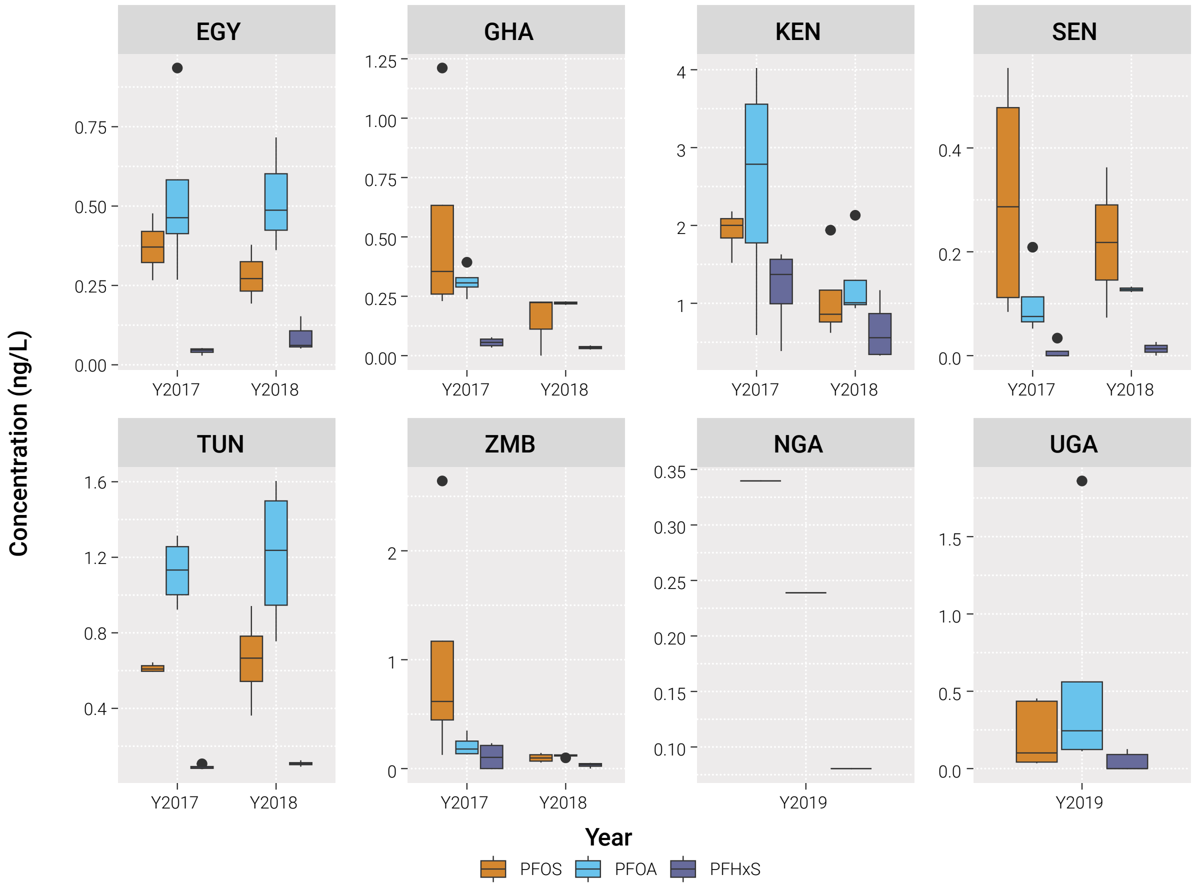


Figure 33: Water: Amounts according PFOS, PFOA, PFHxS by country and year (ng/L)

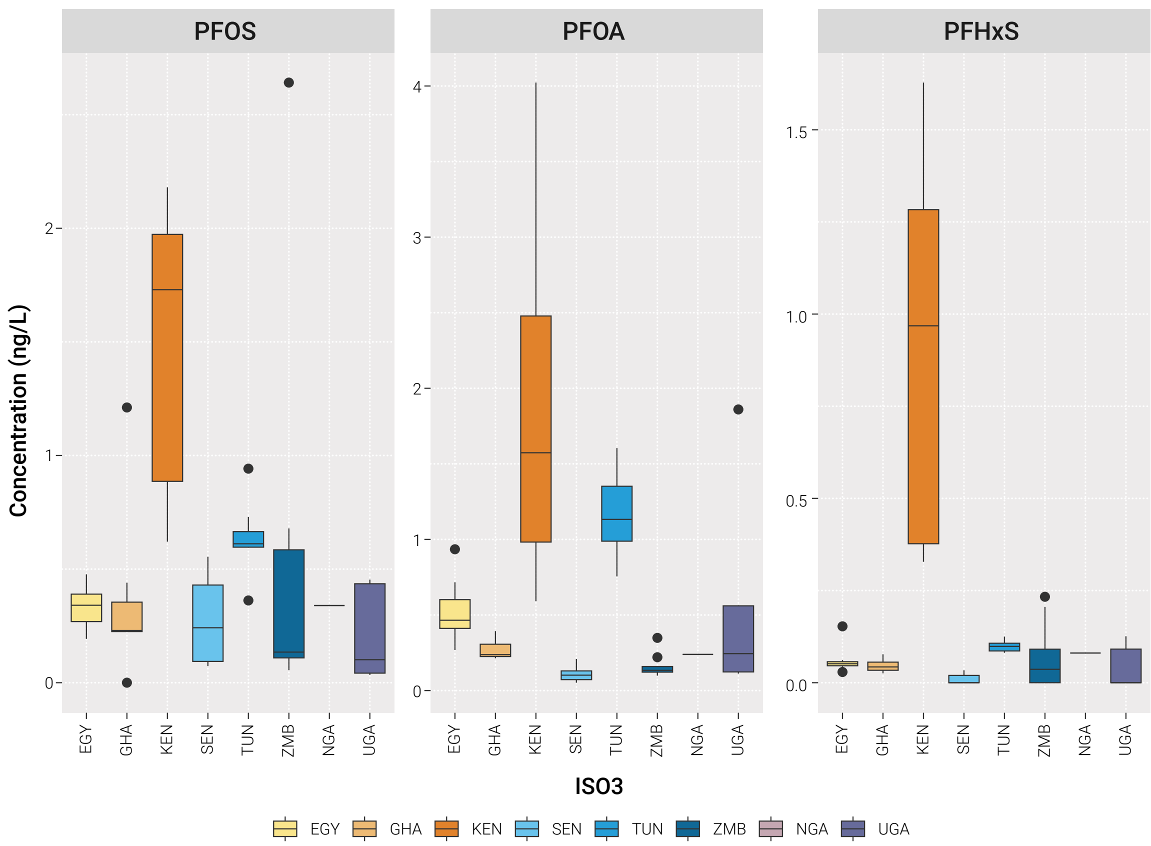


Figure 34: Water: Comparison of values for each country for PFOS, PFOA, PFHxS concentrations (ng L^{-1}) according to Year

4.4. Human Milk

Human milk samples were sent to the CVUA in Freiburg, Germany, for analysis of chlorinated and brominated POPs and to Örebro University for PFAS analysis. All participating countries submitted national pools. The descriptive statistics for the quantified POPs are shown in Table 36 and Table 37.

Table 36: Human milk: Descriptive statistics for chlorinated and brominated POPs in national pools

	Mean (SD)	Median [Min, Max]
	ng/g lipid	
Chlordane	2.09 (2.37)	1.16 [0, 7.54]
Dieldrin	1.15 (0.692)	1.15 [0, 2.11]
DDTs	665 (1640)	177 [15.2, 6560]
HCHs	4.54 (5.72)	2.20 [0, 21.0]
cis_Hepo	0.326 (0.829)	0 [0, 3.20]
Mirex	0 (0)	0 [0, 0]
HCB	2.40 (0.864)	2.29 [1.26, 3.67]
SCCP	73.1 (27.5)	67.5 [39.8, 121]
PCB6	20.4 (26.4)	13.7 [0.897, 90.3]
PBDE6	1.30 (0.663)	1.38 [0.385, 2.31]
PBDE_209	0.274 (0.355)	0.162 [0, 1.51]
HBCD_a	0.193 (0.274)	0 [0, 0.800]
Toxaphenes	0.319 (0.613)	0 [0, 2.28]

Table 37: Human milk: Descriptive statistics for dl-POPs and PFAS in national pools

	Mean (SD)	Median [Min, Max]
dl-POPs	pg TEQ/g lipid	
TEQ_DF	3.08 (2.38)	2.51 [1.02, 9.97]
TEQ_PCB	1.34 (1.15)	0.930 [0.271, 3.70]
PFAS	pg/g f.w.	
PFOS	9.55 (7.34)	10.3 [0, 21.9]
PFOA	12.7 (3.75)	12.5 [6.20, 18.1]

The concentrations of the quantified chlorinated and brominated POPs (as sums), the TEQs, and PFAS as barplots with a comparison between countries are shown in Figure 35. Detailed results are included in Table S 9 for Br- and Cl-POPs, Table S 10 for dl-POPs and Table S 11 for PFOS, PFOA, and PFHxS.

Among the Cl-POPs, DDT had the highest mean and median concentrations (665 ng/g lipid and 177 ng/g lipid, resp.) and the maximum found in ETH (6560 ng/g lipid) (Figure 36). All other values were at least 10-fold lower. Second highest mean and median values were for SCCP (73.1 ng/g lipid and 67.5 ng/g lipid, resp.) with the maximum value in TZA (121 ng/g lipid), ZMB (112 ng/g lipid), and SEN (102 ng/g lipid). PCB_6 (20.4 ng/g lipid, 13.7ng/g lipid, resp.) had higher means and medians than $PBDE_6$ (1.30 ng/g lipid, 1.38 ng/g lipid, resp.). PCB_6 was highest in MUS and ZMB, chlordanes in Mar and SEN, HCHs in TUN and MUS.

Other chlorinated or brominated POPs are shown in Figure 38.

With respect to dl-POPs, the TEQs from PCDD/PCDF (TEQ_DF) were always higher than the TEQ from dl-PCB (TEQ_PCB) (Figure 37). The highest value for TEQ_DF was found in COD and in MAR and EGY for TEQ_PCB.

PFOA was found in all countries with the maximum in the pool from TUN (followed by MUS and TGO) and PFHxS in none of the pools. It shall be noted that there was no pool from EGY available for PFAS analysis. PFOS was highest in MLI followed by TUN (Figure 39). For further information, please consult a scientific publication (Fiedler and Sadia 2021a).

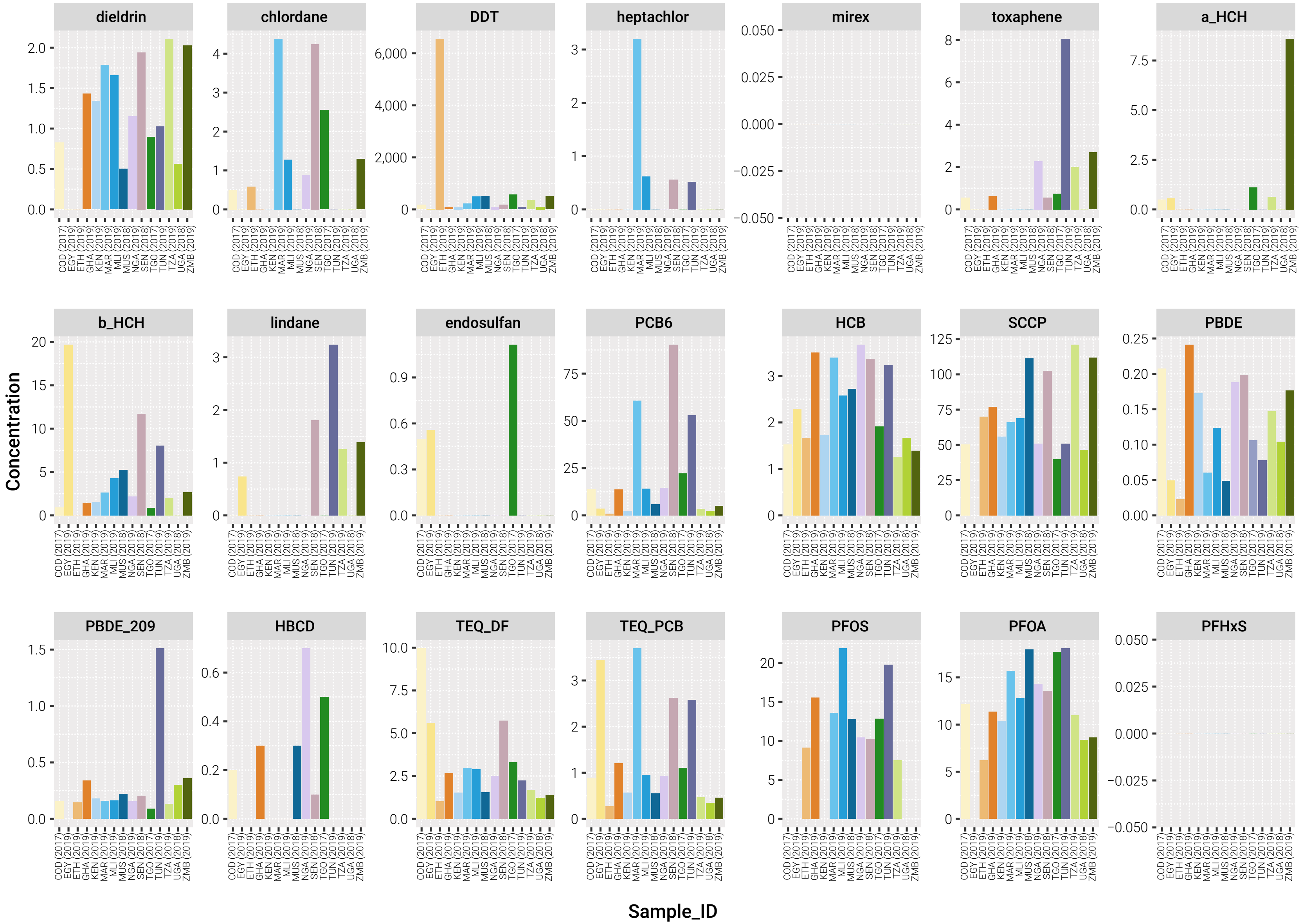


Figure 35: Human milk: Scaled barplots for each POPs with concentrations by country (pg TEQ/g lipid for the dl-POPs, pg/g f.w. for PFOS and PFOA; all other in ng/g lipid)

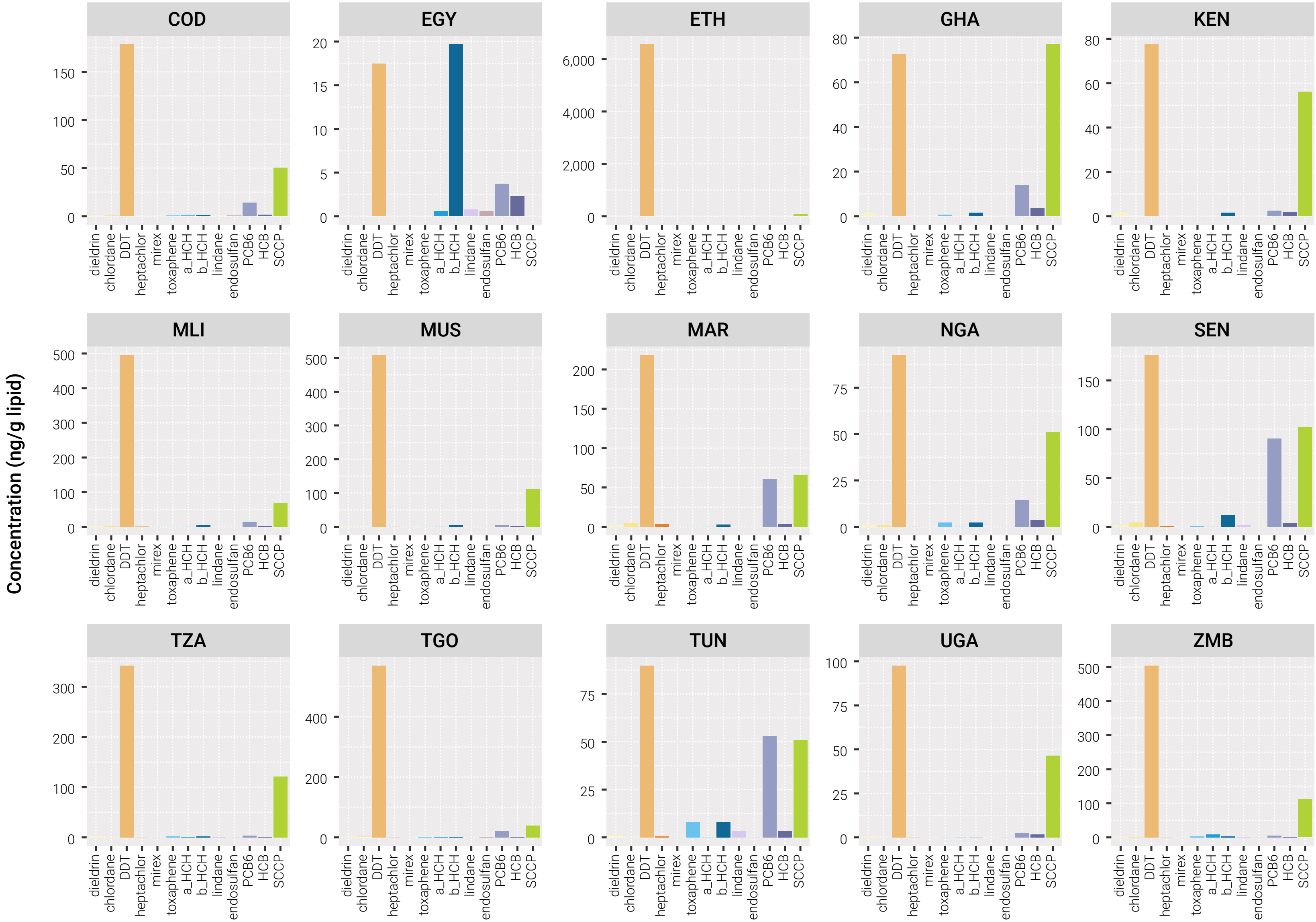


Figure 36: Human milk: Scaled barplots for Cl-POPs by country (ng/g lipid)

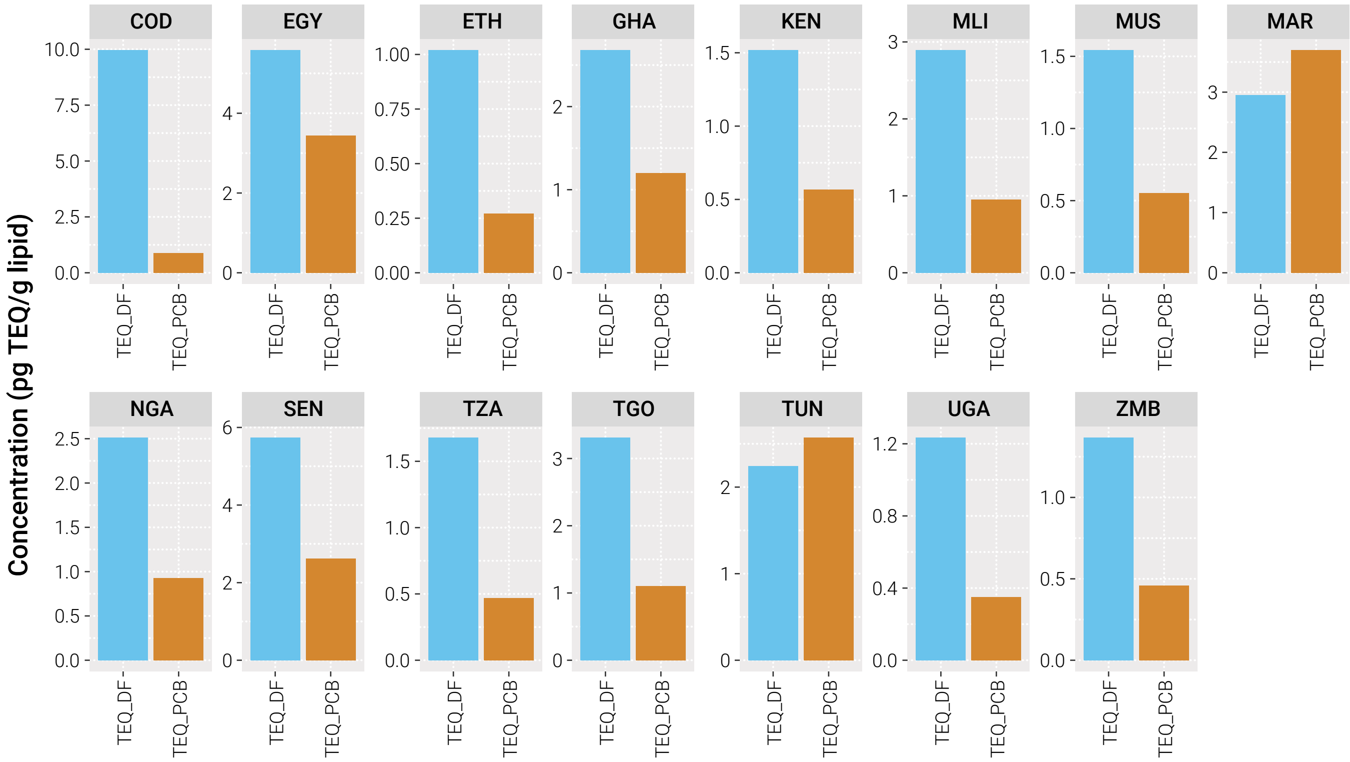


Figure 37: Human milk: Scaled barplots for dl-POPs as TEQ for PCDD/PCDF and dl-PCB by country (pg TEQ/g lipid)

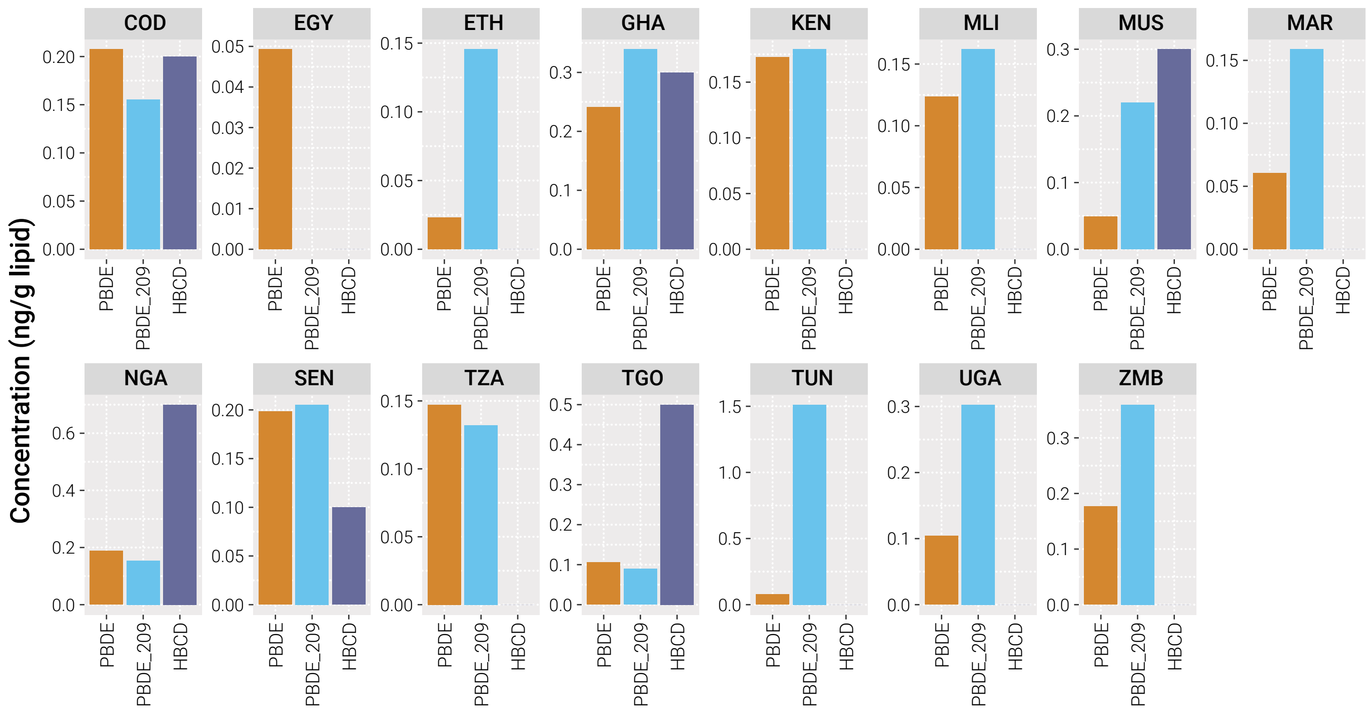


Figure 38: Human milk: Scaled barplots for brominated POPs by country (ng/g lipid)

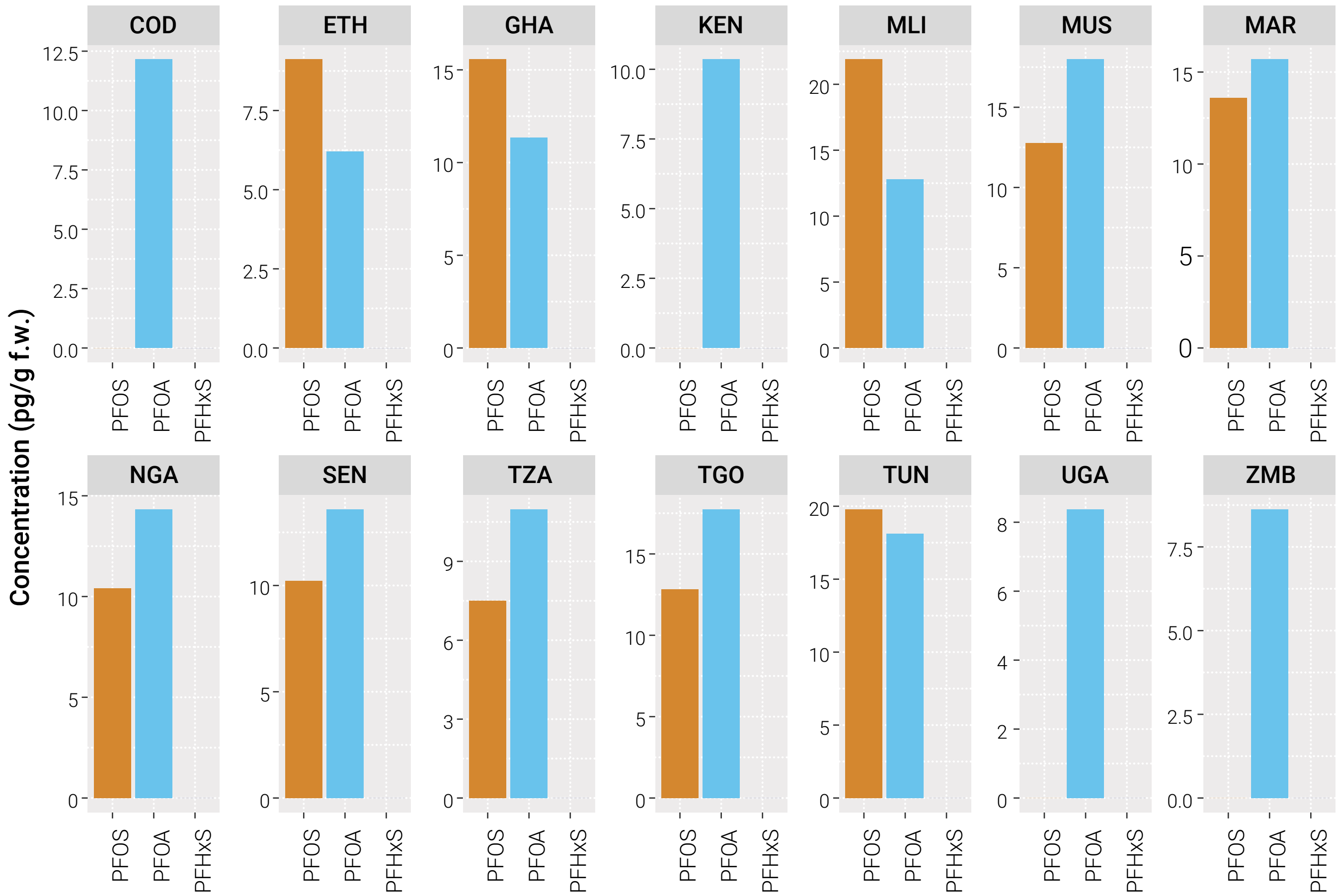


Figure 39: Human milk: Scaled barplots for PFAS by country (pg/g f.w.)

SECTION 5

Regional Workshops, Capacity Building Activities, and Comparison between Expert and National Laboratories

Photo: ©UNEP / Victor Estellano

5. REGIONAL WORKSHOPS, CAPACITY BUILDING ACTIVITIES, AND COMPARISON BETWEEN EXPERT AND NATIONAL LABORATORIES

Activities related to the two rounds of interlaboratory assessments, are referred to in a separate report (UNEP 2023a).

5.1. Inception Regional Workshop

The inception workshop for the UNEP/GEF project ´Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Africa Region´ and the Final Results Workshop for the UNEP/GEF project ´Establishing the Tools and Methods to Include the Nine New POPs into Global Monitoring Plan´ were held on 6-8 July 2016 in Accra, Ghana. The workshops mainly delivered the following outputs:

- Good understanding of the context of the project, including the effectiveness evaluation of the Stockholm Convention and the outcomes of the GMP1 regional project in Africa
- Clarification of the roles and responsibilities of the participating countries and institutions
- Increased familiarity with the set-up, workplan, timeline, budget and activities of the UNEP/GEF GMP2 project, including air sampling and analysis, human milk sampling and laboratory training
- Discussion and finalization of the drafted legal agreements between UNEP and the participating countries.

Documents, presentations and the report of the workshop are available in UNEP website (UNEP 2016).

5.2. Mid-term Regional Workshop

The midterm workshop of the GEF-funded project ‘Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention’ in the Africa Region was held on 23-25 July 2018 in Lusaka, Zambia.

The midterm workshop aimed to strengthen communication among core partners on the progress of the UNEP/GEF GMP2 project in Africa Region, and discussed about needs, opportunities and challenges beyond GMP2, as well as the sustainable monitoring of POPs on national, regional and global level.

Documents, presentations and the report of the workshop are available UNEP website (UNEP 2018).

5.3. Regional Results Workshop

5.3.1. Air and Water

The regional results virtual meeting for ‘air and water of the GEF/UNEP GMP2 project in the Africa Region’ was held on 6 October 2020. The main objectives of the meeting were:

- Explain the analytical results on the levels of POPs in air and water shared with project countries.
- Provide clarifications on data, if any.
- Discuss on including the data in national project final reports

5.3.2. Human Milk and National Samples

The regional results virtual meeting for ‘human milk and National Samples of the GEF/UNEP GMP2 project in the Africa Region’ was held on 23 November 2021. The main objectives of the meeting were:

- Explain the analytical results on the levels of POPs in Human Milk and National samples shared with project countries.
- Provide clarifications on data, if any.
- Discuss on including the data in national project final reports

5.4. Laboratory Trainings

Under the GEF GMP2 projects, one-week training on the analysis of core media was provided to national laboratories in 30 countries. Due to COVID-19, some planned trainings could not be conducted, and a few others were delivered virtually. As of February 2022, 10 scheduled trainings have been completed with 11 countries participated (Table 37).

Table 38: Training workshops in project countries planed and progress made.

Region	No. of trainings panned	No. of trainings conducted	No. of countries participated
Africa	12	10	11*

* Note: Senegal and Mali joined the same training

5.5. Comparison of Results from National Laboratories and Expert Laboratories

The project offered sampling material and technical assistance to all participants to undertake chemical analyses in their national laboratories. In the course of this project, national laboratories have been trained by one of the expert laboratories – E&H VU Amsterdam University, RECETOX Masaryk University, or MTM Örebro University – according to the laboratories needs based on available instrumentation (see section 6.4). In this section, the results obtained from the PAS/PUF and human milk monitoring by national laboratories and expert laboratories are compared. Nationally generated data are contained in section 4.2 and expert laboratory data in Chapter 5. The performance of all laboratories was checked through two rounds of interlaboratory assessments and can be found in two reports by UNEP (Fiedler, van der Veen and de Boer 2017; Fiedler, van der Veen and de Boer 2021b) and publications in the peer-reviewed literature (Fiedler, van der Veen and de Boer 2020b; de Boer, van der Veen and Fiedler 2022; Fiedler, van der Veen and de Boer 2022a; Fiedler, van der Veen and de Boer 2022b; van der Veen, Fiedler and de Boer 2023). The comparison of results has not been thoroughly assessed and is presented in the following graphics according to the data provided.

In the graphics, results from expert laboratories and results from national laboratories are shown; further the Sample_ID for the parallel samples have identical year and season codes but the ISO3 abbreviations for samples analyzed by expert laboratories are all upper case letters and those analyzed by national laboratories are all lower case letters

Ghana had undertaken national lab analysis for selected OCPs and indicator PCB in the PAS/PUFs and human milk. The laboratory did not quantify any of the POPs investigated (section 4.2.1).

The Egypt national laboratory had reported PCB_6 for human milk. The results from the national laboratory were several times higher than those from the expert laboratory (Figure 40).

Figure 41 shows the data from PAS/PUFs exposed in Mali with the values provided by the national laboratory (section 4.2.3) and the expert laboratory. In general, the values from the national laboratory were much higher than those from the expert laboratory. β-HCH could not be quantified by the national laboratory.

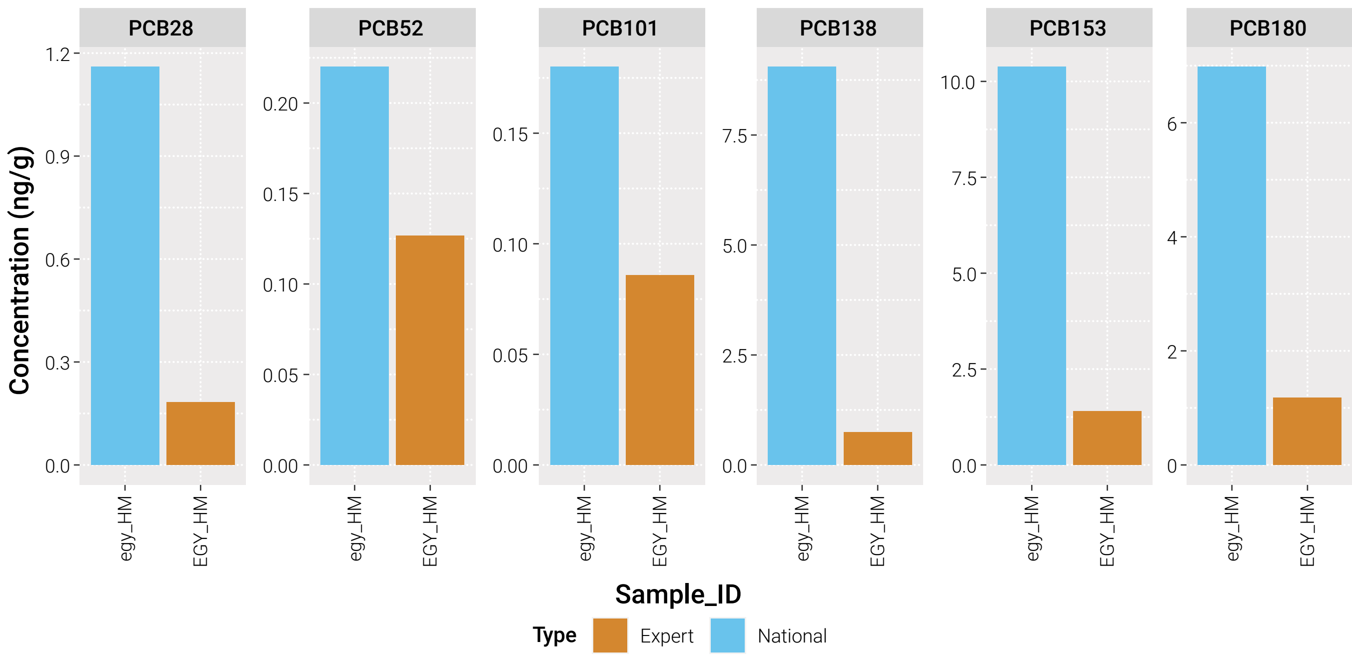


Figure 40: Egypt inhuman milk pool: Comparison of results for six PCB congeners between national and expert laboratory by sample

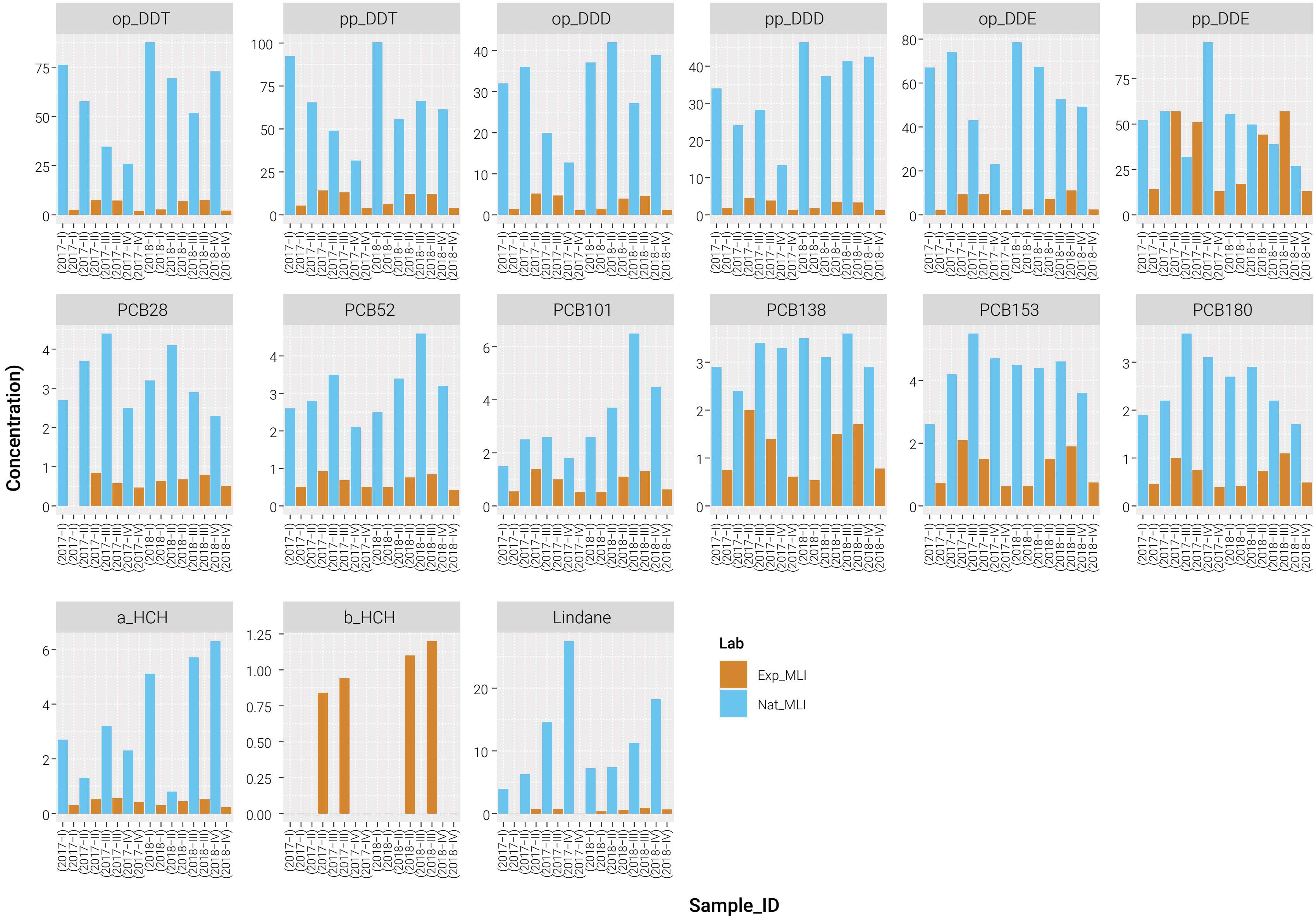


Figure 41: Mali: PAS/PUFs, comparison of OCP and PCB_6 results between national and expert laboratory by sample

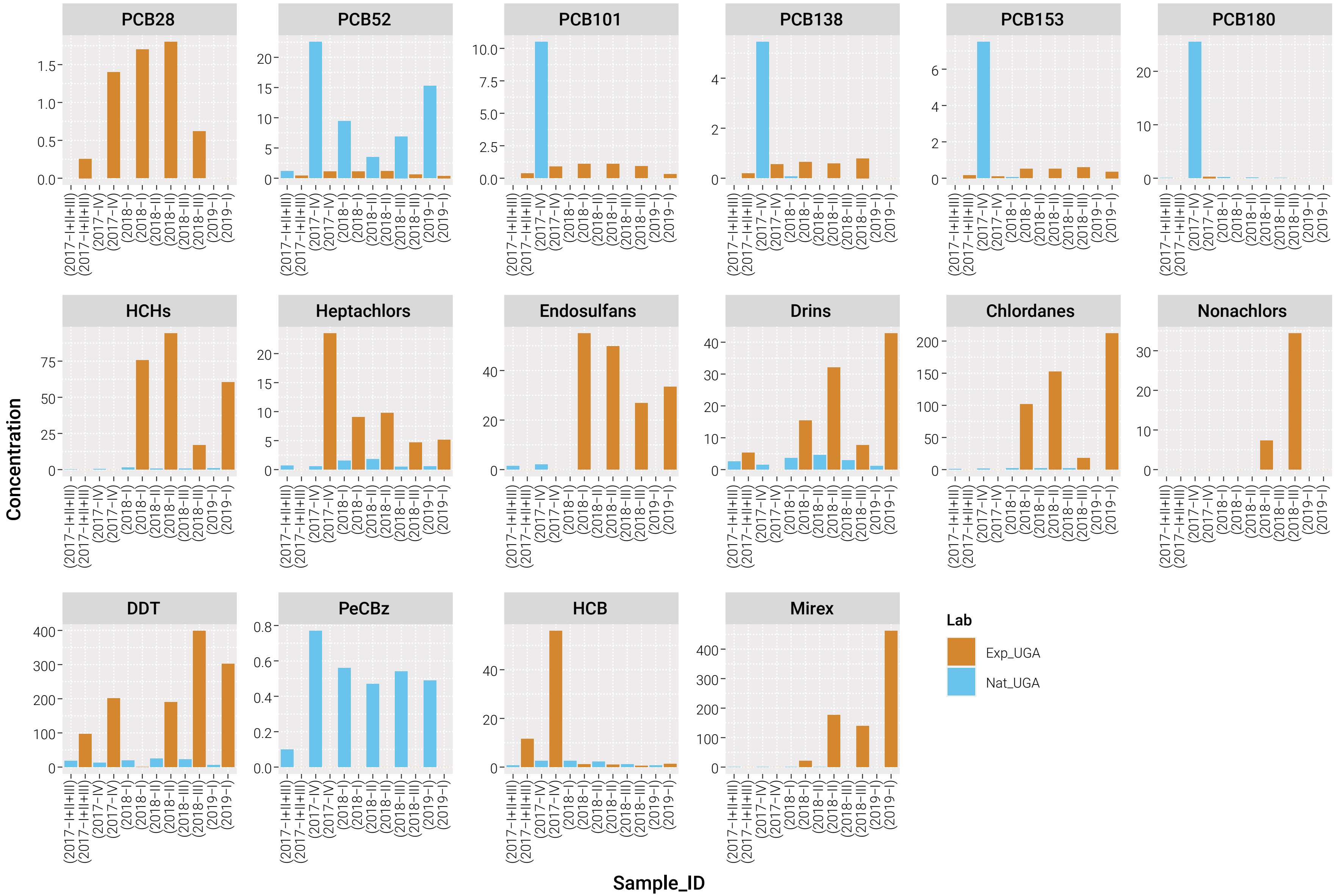


Figure 42: Uganda: PUFs, comparison of OCP and PCB_6 results between national and expert laboratories by sample

The data from Uganda, section 4.2.6 are displayed for PAS/PUF results in Figure 42 and for human milk results in Figure 43. The PAS/PUF results show very different values but also pattern. For most samples, the expert laboratory had provided larger values than the national lab. On the other hand, the national laboratory seemed to have higher LOQs since some compounds were quantified by the expert lab only (Figure 42). For the human milk there is no correlation visible between the two labs.

5.6. Data Accessibility

The PAS/PUF data generated by the expert laboratories in the UNEP/GEF GMP2 projects (UNEP 2024a) and presented in nanogram or picogram per PUF have been converted into volumes using the model developed by Harner (2016). These converted data have been submitted to the GMP data warehouse (Secretariat of the Stockholm Convention n.d. a) where they were aggregated to annual values according to the procedures established for the regional and global reports under the Convention.

Data from this project have been made available for the BRS GMP data warehouse and can be retrieved from a dashboard developed by UNEP Chemicals and Health Branch UNEP n.d.).

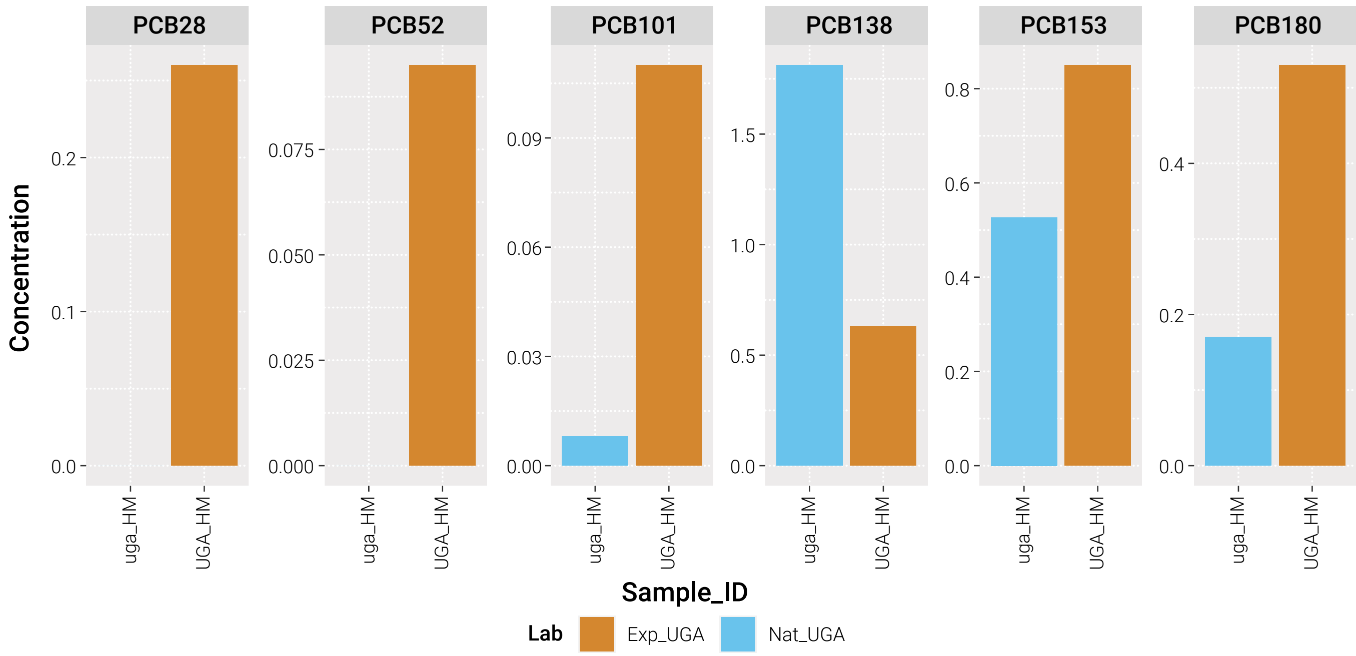


Figure 43: Uganda: Human milk, comparison of OCP and PCB_6 results between national and expert laboratories as barplots.

SECTION 6

Sustainability plans

Photo: ©Unsplash / Lina Loos

6. SUSTAINABILITY PLANS

6.1. National Sustainability Plans

The following national sustainability plans are an extract of the plans submitted by project countries in their national reports.

6.1.1. Egypt

Developed sustainable monitoring plan for POPs, unintentional POPs and Long-range environment transport chemicals

As discussed in the previous paragraph the impacts of POPs, unintentional POPs and long-range environment transport (LRETs) toxic chemicals as a health burden in Egypt and North Coast African countries should face serious monitoring considerations. Most of the countries around the east and southern part of the Mediterranean due to their political unrest and social turmoil are creating foci of highly hazardous chemicals in their environment. These LRETs should be monitored by installing air quality monitoring stations at the boundaries of those countries with their neighbours to assess those chemicals flux and act as a motive in the UN to push for stopping those causes creating environmental deterioration leading to escalating economic and socio-economic impacts extended to other countries of the region and Egypt is one of them.

Health impacts of LRETs should be accessed through health-related surveys under the wind from industrial areas in Egypt. The monitoring programme should be started with large industrial complexes to evaluate their impacts on neighbouring residential areas. Complexes in 10th of Ramadan, 6Th of October, around greater Cairo and Sharkia governorates, Burg El Arab near Alexandria Governorate, and Mehalla El Kobra at the center of Delta can be the starting location for monitoring LRETs chemicals, POPs and unintentional POPs.

Water resources for domestic and industrial main uses could be analyzed for those chemicals detection. As done before in the previous monitoring plan Mothers Milk was sampled and analyzed for their content of PCBs. More elaboration for detection of LRETs could be done to access the economics of health burden expected to be incurred by the country budget.

In order for Egypt as well as North African countries to conduct similar monitoring around their industrial complexes all countries need serious support of their analytical capabilities of accredited labs and well trained personnel where results could be properly determined and compared.

Establishing such monitoring network will result into a scientific based assessment to be addressed in all parts of the world suffering similar political and social unrest. People and Politian in those countries will be directed to act differently while tackling those issues creating environmental deterioration created by their actions and causing long term effects not easily and if ever removed.

Soil monitoring is an added environmental source for those LRETs as they precipitate on industrial and or/army battles grounds. The problem with soil material is its fragmentation and transport by wind action as suspended particulate matter (SPM) to other faraway places creating sources of contamination in their air, water and soil and finally humans' body.

Monitoring marine life organisms in areas of fish catch is vital as fish accumulate all toxic chemicals in the microorganisms they feed on them. Monitoring LRETs in their fats and flesh can pinpoints measures to be taken by consumers to reduce their LRETs chemicals intake.

6.1.2. Ghana

Both GMP 1 and 2 initiatives have provided some level of training for scientists and technicians engaged in the project. However, there is the need to continuously strengthen the capacity of human resource in the area of chemical analytical protocols, interlaboratory studies and quality assurance among selected institutions across key regions in the country which are essential to develop sustainable nationwide POPs monitoring.

The unavailability of operational dedicated laboratory for POPs monitoring in the country makes it practically impossible for undertaking realistic analytical studies of these chemicals in humans and the environment. There is the need to select and upgrade at least one national laboratory to the state-of-the-art experimental facility for POPs analysis especially measurement pertaining to newly listed and emerging POPs such as PBDE, PFOS/PFOA and BFRs in order to maintain regular monitoring of environmental releases. Besides, some laboratories in the African region can also be upgraded to serve as a regional hub for POPs analysis that can strengthen the regional monitoring network to enhance the mechanism for transboundary movement of these toxic chemicals in the region.

The GMP project through stakeholder consultations has raised public awareness on the impacts of POPs in Ghana that needs to be promoted to ensure public participation at all levels to advance the sound management of chemicals in the country.

6.1.3. Kenya

Sustainability of POPs monitoring at the country level is crucial to allow long-term assessment of POPs levels in the manner that meets international standards, and to enable the country to determine trends in concentrations of the chemicals in the environmental media. The ability to provide comparable monitoring data is important to allow countries to evaluate the effectiveness of the national legislation and regulations instituted to reduce/or eliminate releases of POPs into the environment.

Under the current project, sustainability of POPs monitoring has been pursued in different contexts to build on complementary efforts. POPs monitoring encompasses building human capacity and technical infrastructure necessary for actual monitoring POPs chemicals in the environmental.

Human capacity building in POPs monitoring involves training of the personnel involved in monitoring activities to build knowledge base, to be able to conduct field work and laboratory sample preparation, analysis and interpretation of the results in a manner that meets international standards. This also includes proper handling of the sampling devices and the sampling media in ways that do not introduce artifacts that may contaminate the samples during field work and laboratory operations. In this regard development and accurate application of the sampling protocols and laboratory methods is critical to ensure correct implementation of the QC/QA protocols. Hence retention and regular training of the personnel and their continuous exposure to fieldwork and laboratory sample processing is critical part of sustainability.

Capacity building in terms of technical infrastructure includes the provision of the equipment and tools required for fieldwork, sample transport, storage and laboratory sample handling and analysis, and data processing, archiving and dissemination.

Integration of the monitoring sites in the national monitoring protocol and PRTR

As part of long-term sustainability plan for POPs monitoring in the country, Kenya has recently developed the national monitoring protocol for POPs and other priority Chemicals, and a national Pollutant Release and Transfer Register framework to support Chemicals management activities in the country.

The national POPs monitoring protocol has identified the priority monitoring sites in the country where monitoring activities will be conducted on regular basis in air, water and soil.

The air monitoring sites under the UNEP/GEF project namely Kabete, and MONET Africa site (Mt. Kenya) have been included in the monitoring protocol and priority sites. This will ensure that the data collected from the sites will assist national reporting and guide policy decisions on chemicals management. The water monitoring sites have incorporated Sabaki River mouth as one of the priority water monitoring sites for POPs in the country.

Integration of the monitoring sites into the national research and monitoring activities

The Kabete monitoring site under the UNEP/GEF project and the Mt. Kenya sites are used in release activities as the control background sites for postgraduate students conducting research on POPs contamination in air. This will ensue continued use of the sampling equipment installed at the monitoring sites as well as the data generated.

Use of the laboratory facilities for training and research activities

The Department of chemistry involved in the UNEP/GEF project is mandated to conduct continued training of both undergraduate and postgraduate students at the University of Nairobi, and national capacity building. The capacity developed at the university will be utilized to train students and national personnel in POPs chemical analysis. Postgraduate students at the department utilize the laboratory facilities in their research activities in POPs, pesticides and other organic pollutants.

Participation in national and regional monitoring networks

The Department of Chemistry participates in the national and regional frameworks on chemicals analysis. Particularly the department participates in the Africa Network on chemical analysis of pesticides and other chemicals (ANCAP). ANCAP comprises of environmental research professionals across the Sub-Saharan Africa countries namely Kenya, Uganda, Tanzania, Ethiopia, Sudan, Nigeria, Malawi, Zimbabwe and Zambia.

Contractual services on reducing cost basis

The Department of Chemistry provides analytical services to the national institutions and industry on cost reducing cost basis. The Department offers analytical services in a broad range of POPs and non-POPs chemicals that include pesticides, PCBs, PBDEs. Polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH) analysis, heavy metal and other physical-chemical parameters on cost reduction basis.

6.1.4. Mali

Le Gouvernement de la République du Mali, pour une saine gestion de l'environnement, avait adhéré à plusieurs conventions internationales dont la Convention de Stockholm. Il possède des centres de liaison avec les principaux organes internationaux chargés de la mise en oeuvre des politiques de la gestion environnementale, en rapport avec les recommandations issues des conventions. L'appropriation, l'intérêt et l'engagement du gouvernement envers le projet sont garantis car il est membre de la Convention de Stockholm sur les POP. Il a soumis son PNM et reste engagé dans des projets post-PNM. Le pays participe à la mise en place d'un système mondial efficace et durable pour le suivi de l'efficacité de la mise en oeuvre de la Convention de Stockholm en fournissant des données nationales au GMP selon une approche harmonisée et convenue aux niveaux régional et international. Etant donné que le pays fait partie de la Convention de Stockholm, l'équipe du projet propose au point focal national d'inclure des mesures de durabilité dans leurs processus nationaux de planification et de budgétisation pour assurer la suite des activités en incluant des activités de surveillance des POPs pour assurer la durabilité des avantages du projet. Les premiers facteurs à prendre en compte sont la durabilité financière, institutionnelle et sociopolitique du plan. Le pays participe pour une 2ème fois à un programme mondial de surveillance des polluants organiques persistants, au terme de cette phase l'équipe nationale propose le plan suivant pour la durabilité des activités de surveillance au niveau national qui est axé sur deux priorités : le renforcement des capacités et le financement pérenne des activités de surveillance.

Activités	Responsable	Mesures proposées
Elaborer et mettre en oeuvre un plan national de la surveillance des POPs à long terme pour les matrices abiotiques et biotiques.	Ministère de l'Environnement	Réunions Communication Ateliers
Renforcer les capacités analytiques nationales et de surveillance des POPs du Mali	Gouvernement/Ministères de tutelle des services impliqués	Equipements des laboratoires Formation du personnel Coordination
Assurer les activités de formation continue des principaux acteurs de la surveillance des POPs	Gouvernement/Ministères de tutelle des services impliqués	Participation aux sessions régionales et internationales de formations
Appuyer la mise en oeuvre d'activités durables de la surveillance de l'air ambiant dans le pays.	Gouvernement/Ministères de tutelle des services impliqués	Affection d'un budget aux activités nationales de la surveillance
Assurer la continuité de la surveillance des milieux prioritaires que sont l'air et le lait maternel	Gouvernement/Ministères de tutelle des services impliqués Laboratoires	Dotation en fonds Dotation en réactifs et consommables
Réunir les conditions pour étendre la surveillance au sulfonate de perfluorooctane dans les eaux superficielles	Gouvernement/Ministères de tutelle des services impliqués Laboratoires	Formation du personnel Equipements des laboratoires Acquisition de matériel, réactifs et consommables.
Nouer un partenariat avec les programmes internationaux existants de surveillance de la pollution atmosphérique.	Gouvernement	Information Communication Saisie des opportunités Signatures des conventions
Assurer la pérennisation des activités de surveillance	Gouvernement/Ministères de tutelle des services impliqués Laboratoires	Dotation et mobilisation des ressources pour les activités de la surveillance

6.1.5. Mauritius

One of the objectives of the project is to strengthen the national capacity of The Republic of Mauritius for monitoring POPs. At the end of this project, the following has been achieved:

Mauritius has been successful in developing capacity for passive and active sampling of 23 POPs in ambient air.

The objective of this project in connection with generation of background data (basic POPs and dioxins/furans) for the Republic of Mauritius has been achieved. However, in terms of capacity building for quantitative analysis of basic POPs in Mauritius, further training, assistance and practice on the use of GC-MS techniques are required.

The Government of Mauritius has initiated a project of setting pesticides residues testing facility at the NEL for monitoring of pesticides in the environment. Funds have been obtained for acquisition of a GC-MS in October 2021. Further to the acquisition of the GC-MS, staff at NEL will be in better position to develop their analytical skill on GC-MS. With the acquisition of the GC-MS, NEL will strengthen its capacity for monitoring of POPs in air and sediment.

The organisation of interlaboratory assessment exercises by UNEP/GEF will be helpful for strengthening the national capacity for analysis of POPs. This will be an opportunity to assess their competency in the analysis of POPs in different matrices. It is proposed that UNEP/GEF continue to support the organisation of the inter-laboratory assessment to African Countries. This exercise will help the different laboratories assess their competencies.

Under the NIP, a task (Output 2.3) relates to "identify the impacts of POPs exposure on human health and the environment".

This activity will focus on preparing a gender-responsive report on POPs exposure and impacts on human health and the environment. In this context, the POPs GMP2 monitoring results will be used by the NIP Consultants to assess the exposure and impact of POPs (old and newly listed POPs) on human health and the environment. It is also expected that the NIP Consultants integrate the results in the NIP project (including in the proposed action plan). The activities undertaken and the main outcomes the POPs GMP2 project will also be reflected under article 11 of the National report of the Stockholm Convention for the Republic of Mauritius.

6.1.6. Morocco

La croissance économique et industrielle de ces dernières décennies a généré des polluants qui impactent sérieusement l'environnement et la santé publique.

Le souci de préserver ces indicateurs liés au développement a poussé le Maroc à adhérer aux différentes conventions internationales et à devenir un acteur actif dans le processus de préservation de l'environnement et du développement durable.

L'adhésion à la convention de Stockholm a permis au Maroc de réaliser le Plan National de Mise en oeuvre de la convention (PNM) et le Plan d'Action National (PAN), pour évaluer la situation de l'usage de ces produits et amorcer la gestion écologique de ces polluants. Dans cet élan, le Maroc a aussi procédé à plusieurs réformes institutionnelles et administratives visant plus de coordination entre les départements et une meilleure gestion rationnelle de la question environnementale.

Le fruit de ces efforts coordonnés par le MdE a abouti à plusieurs dispositifs réglementaires répondant aux exigences de la convention et à la loi cadre.

Considérant l'état des lieux en termes des exigences de la convention, de l'arsenal juridique et les capacités techniques nationales, il conviendrait d'oeuvrer pour la mise à niveau des différents axes et orientations liés à la problématique des POPs. Suite à l'analyse et aux constatations soulevés à l'issus de cette 3eme mission des suggestions ont été déclinées en plans d'action englobant l'aspect juridique et règlementaire, l'aspect technique et l'aspect sensibilisation et information.

Aspect technique

Chacune des structures qui ont répondus aux questionnaires qui leur ont été adressés ou que les experts ont pu visiter dans le cadre de cette mission, travaillent selon une approche dictée par les prérogatives fixées par leurs statuts respectifs. Les ressources humaines et techniques sont limitées et cadrées par les objectifs de leurs missions limitant ainsi leurs ouvertures sur des champs nouveaux nécessitant des investissements et recrutement supplémentaires. Certaines structures ont profité de la coopération internationale pour renforcer leurs capacités en ressources humaines, mais cela reste insuffisant devant l'ampleur de la tâche et la diversité des polluants et le non-accompagnement immédiat avec du matériel adéquat.

Ainsi il est nécessaire d'accompagner ces entités pour la pérennisation des activités liées à la surveillance et à la recherche dans ce domaine précis notamment par :

- Mise en place d'un programme national de surveillance des POPs dans les matrices Air, Eau et lait maternel
- Participer à des inter-comparaisons au niveau international pour assurer la fiabilité des analyses

Intitulé de l'Action : juridique et institutionnelle	
Justification de l'Action	La mise à niveau de la législation nationale pour prendre en compte les exigences de la convention de Stockholm pour tous les POPs
Consistance	- Renforcer le cadre législatif et réglementation relatifs aux POPs - Disposer d'une législation sur les POPs permettant de contrôler les résidus dans les produits alimentaires et les matrices majeurs ainsi que les sédiments et les eaux usées. - Elaboration de normes obligatoires relatives aux émissions de PCDD/PCDF dans l'atmosphère (n°2-09-286) - Décret n° 2-07-253 du 18 juillet 2008 n'inclut pas les PCBs
Objectifs	- Réduire les émissions dans l'air et dans les déchets - Améliorer le cadre de vie environnemental - Protection de la santé
Département responsable	- Ministère de l'environnement et ses annexes - Ministère de la santé et ses organes annexes - Ministère de l'agriculture et ses annexes - Secteur privé
Partenaires	- LNESP - IAV Hassan II, INH, CAPM - ONSSA, INRH - Secteur Privé - Autorités locales - Chambre des représentants - Ministère de l'environnement et ses organes - Ministère de la santé et ses organes annexes - Ministère de l'agriculture et ses annexes - Ministère de justice
Lieux d'exécution :	- National : départements concernés - Régional : délégations des départements impliquées
Délai et calendrier d'exécution	1 à 2 ans
Financement	- Etat - PNUD - Région - Coopération
Moyens de mise en oeuvre	- Projets de coopération - Bureau d'études - Conventions avec les universités
Observations	Le cycle de vie des POPs sera couvert par des normes précises. Cela contribuera à l'amélioration de la qualité de vie en termes d'environnement et de santé publique

Intitulé de l'Action : Surveillance des niveaux des pesticides organochlorés, des PCBs et des Hydrocarbures aromatiques polycyclique au niveau des matrices environnementales (Eau de surface, Eau de mer et sédiments)	
Justification de l'Action	En tant que signataire de la convention de Stockholm, le Maroc est contraint de réaliser un suivi et une surveillance des POPs dans l'environnement
Consistance	- Définir des points de prélèvements fixes au niveau de la Méditerranée et de l'Atlantique pour le prélèvement des échantillons. - Réaliser des campagnes de prélèvements et des analyses des pesticides organochlorés ainsi que des PCBs et des HAPs dans les matrices environnementales (Eau de surfaces, eau de mer et sédiments). - Analyser les tendances spatio-temporelles des POPs au niveau des points prélevés
Objectifs	- Honorer les engagements nationaux et internationaux du Royaume en ce qui concerne la suivi et l'évaluation de l'état de l'environnement ; - Renforcer la surveillance des POPs et PCB au niveau des côtes de la méditerranée marocaine ; - Instaurer un réseau de surveillance des POPs et PCBs dans les matrices environnementales, notamment au niveau des côtes atlantiques.
Département responsable	Département de l'environnement par le biais du Laboratoire National des Etudes et de Surveillance de la Pollution
Partenaires	Institut national de la recherche Halieutique ONEE-Branche Eau Institut National d'Hygiène (INH) Universités
Lieux d'exécution :	Au niveau National et Régional
Délai et calendrier d'exécution	2021-2025
Financement	Ministère de l'énergie des mines et de l'environnement – Département de l'environnement- Départements ministérielles concernées Bailleurs de fond Projets et conventions internationales
Moyens de mise en oeuvre	Moyens logistiques pour le prélèvement des échantillons Moyens humains pour la réalisation des analyses
Observations	Le renforcement des capacités technique des laboratoires est primordial

Intitulé de l'Action : Surveillance des POPs dans l'air	
Justification de l'Action	- Engagement du Maroc à surveiller les polluants organiques en vertu de la Convention de Stockholm. - Manque de données relatives à la surveillance des POPs dans l'air au Maroc. - Mise en oeuvre les dispositions du décret relatif à la surveillance de la qualité de l'air notamment l'article 5. - Mise en oeuvre du Programme National de Surveillance de la Qualité de l'Air.
Consistance	- Continuer la Surveillance des POPs dans l'air à la ville d'Ifrane. - Surveiller les POPs dans toutes les Régions du Maroc. - Réaliser des campagnes de prélèvement et d'analyse des POPs. - Renforcement du Réseau National de Surveillance de la Qualité de l'Air (RNSQA) avec les données de surveillance des POPs ; - Production des données relatives aux POPs dans un site de fond ;
Objectifs	- Connaître l'état de la qualité de l'air lié aux polluants organiques persistants dans la ville d'Ifrane. - Sensibiliser les décideurs locaux, des autorités locales et la population aux risques liés à la pollution de l'air notamment les POPs. - Constituer une base de données sur les niveaux des POPs ;
Département responsable	Laboratoire National des Etudes et de Surveillance de la Pollution
Partenaires	Wilayas des Régions
Lieux d'exécution	- National : toutes les régions - Régional - Local - Autre :
Délai et calendrier d'exécution	Chaque 3 mois
Financement	Autofinancement
Moyens de mise en oeuvre	Moyens logistiques pour le prélèvement des échantillons Moyens humains pour la réalisation des analyses
Observations	Les opérations de prélèvement et d'analyse seront effectuées en fonction des capacités du Laboratoire national des Etudes et de Surveillance de la Pollution.

Intitulé de l'Action : Contrôle des POPs dans les émissions atmosphériques	
Justification de l'Action	- Engagement du Maroc à surveiller les polluants organiques en vertu de la Convention de Stockholm. - Manque des données relatives au contrôle des POPs dans l'air au Maroc. - Contrôle des POPs dans les rejets atmosphériques des unités industrielles conformément au décret en vigueur. - Mise en oeuvre du Programme National de Contrôle Environnementale.
Consistance	- Réaliser des campagnes de prélèvement et d'analyse des POPs. - Production des données relatives aux POPs dans les rejets des unités industrielles ;
Objectifs	- Connaître les teneurs des POPs dans les émissions atmosphériques - Sensibiliser les décideurs locaux, des autorités locales et la population aux risques liés à la pollution de l'air notamment les POPs. - Constituer une base de données sur les teneurs des POPs dans les rejets atmosphériques
Département responsable	- Laboratoire National des Etudes et de Surveillance de la Pollution
Partenaires	- Acteurs et Départements concernés au niveau national et local ;
Lieux d'exécution :	- National : les unités industrielles - Régional - Local - Autre :
Délai et calendrier d'exécution	2022
Financement	Autofinancement
Moyens de mise en oeuvre	Moyens logistiques pour le prélèvement des échantillons Moyens humains pour la réalisation des analyses
Observations	Les opérations de contrôle seront effectuées en fonction des capacités du Laboratoire national des Etudes et de Surveillance de la Pollution.

I ntitulé de l'Action : Surveillance des polluants organiques persistants dans le lait maternel	
Justification de l'Action	Engagement du Maroc à surveiller les polluants organiques en vertu de la Convention de Stockholm. Consolidé les données de la première étude relatives aux concentrations des POPs dans le lait maternel au Maroc Participation du Maroc aux campagnes de mesure des polluants organiques persistants (POP) dans le lait maternel, coordonnées par l'OMS / UNEP
Consistance	Cette action consiste à déterminer les niveaux moyens de contamination du lait maternel par les POPs au niveau des différentes régions du Maroc Réalisation d'une campagne de collecte du lait maternel au niveau national selon le protocole national de la collecte d'échantillons Réalisation d'un questionnaire basé sur le protocole de l'OMS indiquant toutes les informations nécessaires pour la bonne réalisation des interprétations Analyses des pops dans : - Premièrement, des échantillons individuels - Deuxièmement, un échantillon groupé va être constitué par régions (12 régions) - Dernièrement un échantillon groupé sera constitué des 12 régions pour l'ensemble du Royaume
Objectifs	Connaître et décrire les niveaux d'imprégnation en POPs des femmes allaitantes et qui résident sur tout le territoire marocain afin de mieux appréhender l'exposition de la population marocaine à ces polluants Vérifier l'existence de différences régionales et la mise en évidence de facteurs de risque d'exposition personnels ou environnementaux, devrait nous Permettre d'identifier les caractéristiques d'un groupe de femmes à risque.
Département responsable	- Ministère de la santé (Institut National d'Hygiène, directions régional de la santé, délégations de santé)
Partenaires	- Ministère de l'environnement (Laboratoire National des Etudes et de Surveillance de la Pollution), - Ministre de l'enseignement supérieur, Ministère de l'Intérieur
Lieux d'exécution :	- National et régional
Délai et calendrier d'exécution	- 2021-2023
Financement	- Projets et conventions internationales - Bailleurs de fond - Départements ministérielles concernées
Moyens de mise en oeuvre	- Se doter de moyens humains pour la réalisation des enquêtes et échantillonnages du lait - Se doter de moyens logistiques pour le prélèvement des échantillons - Se doter d'appareillage permettant la réalisation des analyses et la génération de données fiables
Observations	Action Prioritaire

Intitulé de l'Action : Surveillance des pesticides dans les eaux destinées à la consommation Humaine	
Justification de l'Action	- Nécessité de contrôler et de suivre les tendances des POPs dans les matrices à risque tel que l'eau potable. - Le fort pouvoir contaminant des POPs pour la santé humaine via les eaux potables. - Garantir la sécurité sanitaire de l'eau de boisson - Assurer un contrôle régulier de la qualité des eaux destinées à la consommation humaine.
Consistance	- Réaliser des campagnes périodiques de contrôle des eaux destinées à la consommation humaine - Mettre en place un système d'alerte et de veille sanitaire afin d'être très réactif face à un problème de contamination. - Se doter d'un laboratoire de référence dans le domaine capable de générer des données fiables et exactes.
Objectifs	- Produire des données sur le niveau de contamination par les pesticides dans les eaux destinée à la consommation humaine au niveau national - Evaluer le niveau d'exposition au pesticides dans les eaux; - Fournir aux décideurs les données, les renseignements et les connaissances dont ils ont besoin pour prendre des décisions en matière de sécurité sanitaire de l'eau de boisson.
Département responsable	- Ministère de la santé (Institut National d'Hygiène, DELM)
Partenaires	- Ministère de l'environnement (Laboratoire National des Etudes et de Surveillance de la Pollution), ONEE (Office National de l'Electricité et de l'Eau potable), Régies, ministère de l'Intérieur
Lieux d'exécution :	- National
Délai et calendrier d'exécution	- 2021-2025
Financement	- Projets et conventions internationales - Bailleurs de fond - Départements ministérielles concernées
Moyens de mise en oeuvre	- Se doter de moyens humains pour la réalisation des enquêtes et échantillonnages des eaux - Se doter de moyens logistiques pour le prélèvement des échantillons - Se doter d'appareillage permettant la réalisation des analyses et la génération de données fiables
Observations	- Action Prioritaire

Intitulé de l'Action : Renforcement de capacités techniques	
Justification de l'Action	- Manque d'informations de l'administration publique vis à vis du potentiel toxique des POPs et des matériaux dans lesquels ils entrent en constitution, en particulier les départements de la santé, des douanes et l'agriculture. Leur formation permettra de bien identifier les problèmes liés aux POPs pour mener des actions communes et efficaces pour une gestion rationnelle. - Les medias sont presque absents du suivi des problématiques des POPs. La formation de certains journalistes aux propriétés des POPs aidera à améliorer la transmission du message au public
Consistance	- Doter les laboratoires existants de matériel adéquat pour assurer l'analyse des POPS et surtout à faibles teneur dans l'air, l'eau, le lait et les sédiments - Créer des unités de suivi pour l'échantillonnage des POPs dans les différentes matrices d'intérêt et les ramener aux laboratoires concernés. - Réaliser des études épidémiologiques sur l'impact des POPs sur la santé humaine en particulier dans les zones confinées, industrielles et agricoles (ou les POPs ont été utilisées comme pesticides) - Renforcement des capacités de gestion et d'élimination écologique des déchets d'articles contenant les POPs et en particulier les POPs "PBDE, HBCD et PFOS». - Renforcement du Réseau National des Laboratoires impliqués dans la gestion des POPs - Encourager les laboratoires à participer aux essais inter laboratoires à l'échelle nationale et internationale. - Organiser des ateliers de transfert de technologie dans le domaine des POPs - Multiplier les formations et les ateliers d'amélioration des capacités techniques au Maroc et à l'extérieur.
Objectifs	- Répondre aux exigences de la convention de Stockholm - Mettre le Maroc au niveau des pays avancé dans ce domaine - Assurer la protection de la santé humaine et de l'environnement - Disposer de donnée fiables et à jour dur la situation des POPs au Maroc - Disposer de plateforme performante pour améliorer le savoir-faire et les compétences techniques des intervenants dans ce domaine.
Département responsable	- Ministère de l'industrie - Ministère de la santé - Ministère de l'agriculture - Ministère de l'environnement - Ministère de l'intérieur - Ministère de l'éducation nationale et de l'enseignement supérieur
Partenaires	- IAV Hassan II ; Direction des douanes ; ONSSA ; INH ; INRH ; CNRST ; Universités
Partenaires	Départements ministériels Coopération Le prive

Intitulé de l'Action : Renforcement de capacités techniques	
Lieux d'exécution :	National ; à l'échelle des ministères concernés pour promouvoir les niveaux techniques de leurs agents et cadres technique. Régional : pour superviser ce qui se passe localement
Financement	Etat, Coopération, secteur privé
Moyens de mise en oeuvre	Convention Projet de coopération bilatérale
Observations	Action Prioritaire

Intitulé de l'Action : Formation et sensibilisation	
Justification de l'Action	- Le personnel et cadres de certains départements administratifs ne sont pas bien informés ou moins formés visa à vis du potentiel toxique de POPs et des matériaux dans lesquels ils entrent en constitution, en particulier les départements de la santé, des douanes de l'agriculture. Leur formation permettra de bien identifier les problèmes liés aux POPs pour mener des actions communes et efficaces pour une gestion rationnelle. - Les medias sont presque absents du suivi des problématiques des POPs. La formation de certains journalistes aux propriétés des POPs aidera à améliorer la transmission du message au public
Consistance	- Produire des films et des spots publicitaires sur les POPs - Produire et disséminer des prospectus sur les POPs et leur danger. - Sensibilisation des cadres nationaux dans les secteurs publics (en particulier dans les communes) et privé en matière de POPs - Mettre en un programme sur les Meilleures Techniques Disponibles (MTD) et des Meilleures Pratiques Environnementales (MPE) dans le secteur industriel national afin de réduire les émissions non intentionnelles des POPs - Sensibilisation des personnes travaillant dans la collecte des déchets du danger de certains produits toxiques ou contenant des composants toxiques. - OEuvrer pour l'introduction de cursus pédagogiques (masters) sur les POPs en général, traitant leur propriétés physico-chimiques, toxiques et analytiques - Elaborer des manuels, prospectus et pictogrammes de sensibilisation en arabe et en Français et éventuellement en rabe dialectale. - Elaborer des spots publicitaires en relation avec les POPs et leur danger - Impliquer les organes des medias (la télévision et la radio) à participer aux compagnes de sensibilisation. - Maintenance, mise à jour et administration du site Web sur les POPs (www.pop-maroc.gov.ma)
Objectifs	- Sensibiliser ces acteurs de la famille des POPs et de leur danger pour la santé et l'environnement - Améliorer leurs connaissances sur leurs usages et les matériaux qui les contiennent - Améliorer leurs connaissances sur les techniques existant pour leur élimination ou leur gestion rationnelle.
Département responsable	- Ministère de l'industrie - Ministère de la santé - Ministère de l'agriculture - Ministère de l'environnement - Ministère de l'intérieur - Ministère de l'éducation nationale - Ministère de l'enseignement supérieur
Partenaires	- IAV Hassan II, - Direction des douanes - ONSSA - INH - INRH - CNRST
Lieux d'exécution :	National ; à l'échelle des ministères concernés pour promouvoir leur coopération et leur coordination Régional : pour transmettre les mêmes messages
Délai et calendrier d'exécution	La formation et la sensibilisation ne doivent pas tarder et doivent être échelonnées en fonction du budget alloué à cette action. Ces formations doivent être réalisées dans un délai de 2 ans maximum
Financement	- Etat - PNUD - Région - Coopération
Moyens de mise en oeuvre	- Projets de coopération - Bureau d'études - Conventions avec universités
Observations	Action indispensable

6.1.7. Nigeria

Nigeria has submitted an input on sustainability plan for GMP in the Africa Region, in May 2019, titled: Concept Note on Development of a Sustainable Regional Monitoring Plan for Persistent Organic Pollutants.

In the submission, current gaps of GMP implementation were identified and recommendations made on how to sustain its gains in the region. The following are among issues, which addressed, will entrench GMP sustainability in Nigeria and Africa Region at large:

- While global monitoring of POPs has led to appreciable data generation on their presence in the environment, time trends and regional and global transport, periodic additional listing of new POPs makes capacity enhancement increasingly exigent to meet emerging monitoring obligation;
- Capacity building needs are of high priority, to enable the region effectively participate in GMP and effectiveness evaluation of the Stockholm Convention[1];
- Analytical capacities in a number of institutions and laboratories are limited to basic POPs such as pesticides and PCBs, due to gaps in infrastructures, sustainable financing and knowledge transfer;
- Logistic and administrative challenges encountered in the shipment of samples of national interests, including biotic matrices, due to strict international regulations;
- Gaps in prompt delivery and availability of analytical data generated by international expert laboratories for national policy decision-making;
- Limitations in sustained financial resources for existing monitoring programmes and new financial resources for programmes addressing data gaps are a major constraint in ensuring the sustainability of the GMP[2].
- Disparity between regions and their capabilities to implement POPs monitoring activities leaves a capacity gap in effectiveness of Stockholm Convention; hence, it is increasingly exigent to provide predictable, innovative and sustainable technical/ financial supports for dedicated POPs laboratories, in line with articles 11 and 13 (2) of SC.

1 - Second Regional Monitoring Report Africa Region, 2015.
2 - UNEP/POPS/COP.8/22/Add.1

Nigeria as an emerging economy records monumental chemicals – based industries, trades and investments, which substantially contribute to the national gross domestic product (GDP), in which POPs have been historically used, unintentionally generated or discharged as waste.

Nigeria developed her National Implementation Plan (NIP) for POPs management as obligated under Article 7of Stockholm Convention, which was transmitted to COP in April 2009.

Following amendments to Annexes to the Convention, through additional listing of POPs-chemicals in 2015, 2017 and 2019, it became mandatory to amend the NIP, for Nigeria to effectively address her emerging responsibilities arising from the amendments.

Nigeria has developed a number of sectoral policy documents from the UNEP/GMP-POPs monitoring results which are adoptable and adaptable platforms for enshrining sound management of chemicals and waste, including POPs issues of national priority.

6.1.8. Senegal

Dans le cadre de l'élaboration du Plan Environnement Sénégal Emergent (PESE) du Plan Sénégal Émergent, le Ministère de l'Environnement et du Développement durable y a intégré un volet produit Chimique.

État actuel de la capacité de surveillance et d›analyse des POPs et plans de développement futur, le cas échéant.

Le Centre Antipoison (CAP) est en phase d'installation d'un LC-MS mais pour le dosage des POP, des substances de références et des détecteurs spécifiques seront nécessaires. Ces suppléments de matériels nécessitent un financement pour lequel le Ministère en charge de la Santé n'a pas encore dégagé de ligne. Donc le CAP est en phase de recherche de partenaires pour la prise en charge de ce volet pour l'effectivité des méthodes de dosage des POPs par son laboratoire.

Le CERES Locustox a un laboratoire d'analyse de résidus de pesticide accrédité ISO 17025/2017. Ce laboratoire est doté de deux GCMS, d'une HPLC et d'un GCµECD. Le personnel du laboratoire a suivi des formations délivrées par les laboratoires experts sur les techniques d'analyse des POPs dans les matrices du projet. Le laboratoire a souscrit à plusieurs projets pour l'achat d'un LCMSMS.

Les politiques nationales actuelles relatives à la surveillance des POPs et les dispositions prises pour les laboratoires d'analyse nationaux.

Les politiques nationales actuelles relatives à la surveillance des POPs et les dispositions prises pour les laboratoires d'analyse nationaux : révision du Code de l'Environnement pour une meilleure prise en compte des POP. Aussi, le Sénégal est bénéficiaire des fonds du FEM exécuté par le PNUE pour la mise en œuvre d'un projet d'observatoires Santé-Environnement et renforcement des capacités institutionnelle et règlement pour une gestion saine des produits chimiques. Par ailleurs, le Ministère de la Santé, le LC-MS, cherche à disposition d'appareil de détection et de dosage des POPs au Centre Antipoison.

Besoins au niveau national pour maintenir un échantillonnage et/ou une surveillance continue des POP, en plus des besoins de financement.

Pour maintenir un échantillonnage et/ou une surveillance continue des POP, en plus des besoins de financement, il y a des besoins de séances de formation régulières des personnels des laboratoires ; des équipements, appareils, réactifs et autres entrants pour des laboratoires outillés et fonctionnels avec des compétences réelles dans l'exécution des étapes de dosage des POPs et dans l'interprétation des résultats.

Contexte relatif aux dispositions prises au Sénégal pour utiliser les résultats de la surveillance des GMP- POPs pour les NIP (Plan national de mise en œuvre) et l'établissement de rapports.

Un rapport final du volet Santé a été soumis au Ministère de la santé par voie hiérarchique et un atelier de restitution des résultats a été organisé à l'endroit des partenaires et des professionnels de santé qui ont eu à participer à la collecte des échantillons de lait maternel. Un rapport national est élaboré et est largement diffusé aux personnes intéressées.

Le rapport de surveillance GMP- POPs a fait l'objet de partage avec la Commission nationale de Gestion des Produits chimiques qui est l'interface entre les communautés sénégalaises et l'Etat et entre l'état et le secrétariat à travers le point focal de la Convention de Stockholm qui devra établir le rapport du pays.

Les résultats du projet GMP2 ont fait l'objet de publication dans le journal de Toxicologie Analytique et Clinique (ToxAC) « Persistent organic pollutants (POP) concentrations in human breast milk : evolution of concentrations over time in Senegal » (Touré *et al.* 2021).

6.1.9. Tanzania

Sustainability of the monitoring of POPs for supporting the implementation of the GMP under the Stockholm Convention in the country lay within capacity development, cost-effectiveness, financial sustainability, and replication and up-scaling and political will. All these have been considered when building a case on how the country can ensure continuity of the activities after project phase out.

The government will continue to support state-related agencies to perform their role with respect to country's ambition to effectively phase out and/or reduce releases of POPs. The current government effort to facilitate Government Chemist Laboratory Authority (GCLA) and Tanzania Pesticides Research Institute (TPRI) with LC-MS/MS and GC-MS/MS respectively will strengthen analytical capacity of these institutions for basic POPs and to foresee the analysis of the new POPs which seems to be more complex.

Sustainability in terms of cost-effectiveness will be reflected in the use of existing institutions and structures. Inter-calibration to improve quality of analysis and comparability of data within the country will be undertaken in TBS, GCLA, TPRI and other institutions. This approach is cost effective as it would allow the country to be self-reliant with regard to long term monitoring of POPs nationwide. Participating institutions will also provide resources towards the implementation of the various activities related to management and monitoring of POPs.

Since the GEF/UNEP GMP project has proven successful in the generation of national data in a systematic and comparable way that has characterized public's exposure to POP, the participating institutions will consider integrating monitoring activities into their budget and plans. In addition, the Government has made considerable efforts in creating awareness by among others; encouraging other respective institutions to establish partnership focusing on the development and implementation of projects that reflect the management of POPs.

On the other hand, the Government has taken long term measures to provide policy, legal and institutional reforms in control and management of POPs by developing regulations on control and management of POPs. Other measures include the enactment of the Plant Health Act, 2020 that facilitated establishment of the Tanzania Plant Health and Pesticides Authority (TPHPA) which shall be the main regulatory body for pesticides and plant health. The Plant

Health Act, 2020 also intends to introduce among others, safeguarding of human health and the environment / ecosystem by ensuring sustainable and efficient management of pesticides with an effective monitoring and surveillance system of inspectors and reputable laboratory analysis.

Sustainability will also be reflected from up scaling and replication of experience and lesson learned from the project in other areas of the country. Furthermore, the up-scaling potential of the Project approach is high, given its complementarity and integration with national policies, plans, programmes and projects. Some of these involve the ongoing and possible pipeline projects linked to this project such as Disposal of PCB oils contained in Transformers and disposal of Capacitors containing PCB and Promotion of BAT/BET to reduce unintended POPs releases from waste Open Burning. The government will also continue to enhance its efforts in management and monitoring of industrial POPs as per the Industrial and Consumer Chemicals Act, 2003.

Tanzania has shown a high level of Political will in addressing challenges associated with POPs through ratifying the Convention (Secretariat of the Stockholm Convention n.d. b); development and implementation of National Implementation Plan (NIP) for the Stockholm Convention on Persistent Organic Pollutants in 2005 and reviewed the NIP in 2018; and the national strategy on the management of chemicals and hazardous waste 2019 - 2024. These measures will enhance Government's commitment to continue implementing strategy for the sustainable management of POPs and fulfill its obligations under the Stockholm Convention.

6.1.10. Tunisia

The sustainability plan was submitted to UNEP as a standalone document intitle: Elaboration d'un plan de surveillance national des polluants organiques persistants "POP". Le plan est présenté brièvement ci-dessous.

Un plan national de surveillance durable des POP a été élaboré en Tunisie par un expert national. La mission s'est déroulée en deux phases:

Mission de la phase 1

- Relatinisation d'un diagnostic de l'état actuel de la surveillance des polluants organiques Persistants (POP) en Tunisie et évaluer les activités mises en oeuvre dans le cadre du projet pour les différentes matrices.
- Réalisation un diagnostic du cadre institutionnel, juridique, réglementaire intégrant les dispositions sur la gestion des polluants organiques persistants actuellement mises en place.
- Détermination et évaluation des capacités nationales en matière d'analyses des POP (diagnostic des laboratoires opérant dans le domaine analytique des POP (collecte des données, structuration, exploitation et analyse).

Mission de la phase 2

Dans un second temps, l'expert a:

- Collecté et étudié les données analytiques périodiques réalisés respectivement sur les matrices abiotiques (Air, eau) et matrices d'intérêt national (poisson, huile d'olive, oeufs, beurre) par le laboratoire du CITET ainsi que sur le lait maternel (DHMPE- Ministère de la santé publique), dans le cadre du ce projet.
- Evalué les activités réalisées (Fréquence des prélèvements, Analyses, matrices,) et les résultats obtenus.
- En se basant sur les données collectés, les points forts et les points faibles, un plan national de surveillance durable des POP a être élaboré.
- Le plan de surveillance teint en compte des principaux défis à relever pour assurer la durabilité de ce projet sont :
- L'amélioration des moyens techniques des laboratoires existants et renforcement de leurs capacités afin d'assurer la surveillance durable des POP ; l'amélioration des compétences analytiques existantes devrait être une priorité;
- Développement de mécanismes de coordination inter laboratoire au niveau national (plateforme, réseau, moyens de coordinations, précisions des responsabilités de chaque laboratoire, missions et modes de fonctionnement du réseau) dans le domaine de surveillance des POP.

6.1.11. Uganda

Project Summary

A sustainable plan to ensure the desired outcomes of the global monitoring plan (GMP) are achieved as well as maintain the ability to continue over time has been designed for effective evaluation. It includes, among others recording and monitoring the presence & levels of POPs in the environment & in humans.

The plan in place is in respect to the project "Continuing Regional Support for the Persistent Organic Pollutants (POPs) Global Monitoring Plan (GMP) under the Stockholm Convention" (UNEP 2015a).

The overall objective of the GMP is to identify changes in POPs concentrations with time and assess their regional and global transport trends. This shall be done by implementing the GMP for POPs according to article 16 of the Stockholm Convention on the effectiveness evaluation by generating comparable data on the concentrations of POPs in the core media / matrices: Human Milk to examine human exposure, Ambient Air to examine long-range transport of the pollutants and surface water to examine PFOS, which was later on added on the convention.

The activities continuously strengthen the national capacity to implement the GMP for POPs and also create the conditions for the sustainable monitoring of the 23 POPs in the region.

Key Elements for Sustainability

The plan constitutes four main domains which include:

Political Support

The Government of Uganda is the main backbone of the project plan through our mother ministry: Ministry of Internal Affairs under which the Directorate of Government Analytical Laboratory (DGAL) – to which the National POPs lab belongs.

The Ministry of Justice and Constitutional Affairs (Office of the Solicitor General) & Ministry of Finance, Planning & Economic Development have issued the necessary clearances, on behalf of Gov't of Uganda, to enable the plan to be put in place and the multi-year project to be captured accordingly. The Office the President, as far back as 2009 gave the clearance to carry out research on the survey of POPs in human milk in Uganda. All the said clearances are still in effect to-date.

The country's legal framework constitutes current national policies related to POPs monitoring which include National Environment Management Policy (NEMP) that births The National Environment Act No. 5 of 2019 and the National Agriculture Policy under which The Agricultural Chemicals (Control) Act falls. These comprise some of the environmental laws in place to control and regulate the manufacture, storage, distribution and trade in, use, importation and exportation of agricultural chemicals and for other related matters as well as providing for emerging environmental issues including climate change, the management of hazardous chemicals and biodiversity offsets.

Funding Stability

The plan is to rely largely on the funding from the Government of Uganda through financing to facilitate the purchase of laboratory reference materials/ standards, consumables, chemicals, facilitate the field sampling activities of air, human milk and water country-wide, conduct in-house trainings to continuously boost the national technical capacity skillset and ability to analyze these POPs according to international standards consistent with GMP guidelines and protocols in order to facilitate reporting under the GMP.

However, both the Implementing agency: United Nations Environment Programme (UNEP) represented by its Economy Division, Chemicals and Health Branch, the Global Environment Facility (GEF) in Switzerland and the executing agency: UNEP and the Regional Centre Uruguay BCCC-SCRC can continue to provide financial support.

Partnerships

The plan shall continuously be implemented and monitored in close cooperation with, among others all participating countries in the different regions (Africa, Asia, Latin American, the Caribbean and Pacific), BRS (Basel, Rotterdam and Stockholm Conventions) Secretariats, World Health Organization, expert labs: IVM VU University Amsterdam; the Netherlands, MTM Research Centre, Orebro University; Sweden, Spanish Council for Scientific Research (CSIC-IDAEA)- Barcelona; Spain, UNEP-WHO Reference Laboratory; CVUA- Freiburg; Germany, and Regional Centre eastern Europe hosted by RECETOX-Brno; Czech Republic.

Organizational Capacity

There is existing technical capacity as well as capacity building established through associated training to enable the analysis and determination of POPs. The working conditions of the POPs laboratory are necessary to contribute to a sustainable POPs monitoring plan.

From a national perspective, in order to have a sustainable POPs monitoring plan, the existing legislative framework needs to be firmed up. The chemicals management monitoring & regulatory framework is still being developed and should incorporate the specific needs of POPs. As of now it is still general addressing the overall monitoring of releases. However, NEMA has taken note of this and it shall be included in the chemical regulations draft yet to be finalized in January 2022.

Another aspect that can contribute to the sustainability is being able to mainstream our results into the institutional and national plans. The NIP should clearly spell out DGAL as the national focal POPs lab. NEMA has designated DGAL for this role and it should be tasked to submit a report from the sampling and analysis done by the inspectors & analysts on a 3-5 years reporting basis.

Existing Capacity to analyze POPs

The main activity of the Pesticides Residues Division at DGAL is to carry out multi-residue analysis of organic contaminants: organochlorines, organophosphorus, polychlorinated biphenyls (PCBs), pyrethroids, carbamates pesticides in different matrices. The different matrices include; water, agricultural products, biota: human milk, cow-milk, fish, sediment and other environmental samples. The economic resources / main incomes of the lab are largely drawn from the consolidated fund through collection of Non –Tax Revenue payable by clients to a government account.

Its present role in relation to the Stockholm Convention on POPs is reflected by the participation in the projects UNEP/GEF GMP1 and the current GMP2. The laboratory also carries out analytical work collaborations with other laboratories and institutions like UNBS, Directorates for Fisheries, Crop and Animals under Ministry of Agriculture, Animal Industry and Fisheries, Makerere University, Chemiphar laboratory, Uganda Industrial Research Institute among others.

The laboratory has a quality management system in place and uses both standardized and laboratory customized methods. Blank tests are applied as well as recovery tests. Performance tests of the equipment are carried out and certified reference materials are used. The laboratory also participates in both local & international inter-laboratory studies to assure the quality of measurements and uniformity of test methods used in different laboratories. Documentation for sampling procedures, registration, receipt and storage of samples, analytical methods, result reports are in place.

The personnel have undergone numerous trainings (both local and abroad): theoretical and hands-on instrumentation in pesticide residues analysis which has enhanced their technical skills necessary to analyze POPs.

Action Steps for Implementation of the POPs National Monitoring Plan.

The POPs recommended for analysis and monitoring on a continuous basis are grouped according to the core matrices; Air, Human milk and Water.

For this national monitoring plan, POPs concentrations in various matrices have to be determined and changes in the concentration need to be documented. Highest requirements on analytical performance are therefore needed to identify small changes in concentrations. For purposes of aligning with the GMP, it is recommended to collect data for all 23 POPs in the stated matrices including water in order to address the more water soluble POPs: PFOS.

There is need to evaluate and assess whether the levels of POPs are actually being reduced or eliminated as requested by Articles 3 and 5 of the Convention. Information on environmental levels of the chemicals should enable detection of trends over time.

Therefore, focus is upon monitoring of background levels of POPs at locations not only influenced by local point sources but also other indirect sources as well. Reliable identification of trends shall constitute statistical evaluation; powerful enough to detect trends in time. This has to be carried out in the national monitoring programme / plan so as to contribute to the Global Monitoring Plan.

A systematic planned out country-wide survey has been designed to cover and have a representation of the different geographical areas and spaces. Passive air samplers with PUF disks shall be installed for 3-month durations periods appropriately to capture the different POPs. Analysis shall be done thereafter. The analytical methodology to be used for this analysis is in place and data management shall be handled accordingly.

Analysis of individual human milk samples from different regions countrywide is to be targeted as opposed to analysis of a representative pool from each of the 5 regions. In the concluding survey, 50 individual mother milk samples were collected. The donors were obtained from five different traditional regions in the respective regional hospitals in Uganda *i.e.*, South Western, Eastern, Northern, Central and Southern. A total of 10 human milk samples was collected from each; with each selected woman providing one milk sample. This sample space shall be increased to at least 50 samples to be obtained from each region in order to allow for more detailed analysis, have a more representative result of the national population and generate sufficient data/findings and information on the distribution of exposures and on factors contributing to exposure.

In order to also have a sustained continued sampling and /or monitoring of POPs in addition to funding needs, there is need for continued capacity development both technical / human resource and having the right analytical equipment. This is necessary to cover the whole procedure from sampling to analysis correctly. The funding support will go a long way in ensuring the procurement and availability of the reference materials and chemicals. The need for maintaining the right and dedicated personnel and trained analysts in DGAL for POPs is a key requisite.

Continued sampling and / or POPs monitoring in Uganda will also require having dedicated trained inspectors designated for POPs monitoring, setting up a sentinel PUF passive air sampling center, additional resources to include transport means to allow the timely installation / retrieval of field samples as per schedule. The National Environment Management Authority (NEMA), has the mandate and authority to designate inspectors for this exercise whose scope of work is entirely POPs monitoring, as per the Acts in place which empower and give them exclusive access to environmental sampling sites.

Setting up more sampling sites over and above the current ones would also go a long way in sustaining sampling as well as setting up information sharing multi stakeholder framework. This includes DGAL fostering working relationships, building strategic partnerships with NGOs, raising awareness, and continuing collaboration with international agencies such as the BRS Conventions to enrich the body of knowledge, whilst creating the relevant checks and balances in the POPs monitoring.

6.2. Involvement in Other Monitoring Activities and Networks

The following involvement in other monitoring activities and networks are an extract of the information submitted by project countries in their national reports.

6.2.1. Egypt

Egypt EEAA participated in similar modular integrated environmental management of PCBs in collaboration with MEDPOL for the protection of the Mediterranean Sea.

Egypt has succeeded in monitoring, assessment with companies involved in electricity generation, transportation and distribution of electricity of oils containing PCBs (175 tons) and through the efforts of a specialized French company the contaminated oils were destroyed through special incineration out of the country

Through the efforts of the WB UNEP residual pesticides which has been left in warehouses due to their ban in Elssaf warehouse and Adabia Port (1000 tons) and they were destroyed through a specialized company outside the country.

Conduct of the project concerning the unintentional emissions of POPs in electronic and medical wastes incinerations.

6.2.2. Ghana

Since 2008, Ghana participated in the MONET_Africa: MOnitoring NETwork, which is a monitoring programme operated by the Research Centre for Toxic Compounds in the Environment (RECETOX) of the Masaryk University in Brno, Czech Republic, which aims at the detection of environmental contaminants in the African region specifically, Congo, Ghana, Ethiopia, Kenya, Mali, Mauritius, Morocco, Nigeria, and Sudan. It is a research activity focusing on long-term trends to support the POPs monitoring projects. RECETOX provides materials for atmospheric air sampling as well as analyses of samples from the various countries.

The air monitoring is supplemented by AQUA-GAPS initiative since 2017. a passive sampling for fresh water samples. Samples were taken from the lake at the University of Ghana Botanical Gardens, and Ghana Atomic Energy Flowering Section River, for the monitoring.

Through the MONET Programme, the experience at country level as well as the newly generated results on the concentrations of POPs in the two main matrices (air and water), contribute to the assessment of levels of POPs, chemicals and waste policy agenda, support and trigger further research initiatives, provide information to the general public at large, aid in capacity-building of the country, and finally for the effectiveness evaluation of the Stockholm Convention.

6.2.3. Kenya

Participation in Monitoring programmes

Kenya recognizes the significance of monitoring chemical pollutants in the environment to safeguard human health and the environment. The POPs and Pesticide Research laboratory at the University of Nairobi takes the lead in coordinating the national monitoring activities on POPs. Through the laboratory activities, the country participates in the POPs monitoring activities under the Global Monitoring Plan implementation in Africa region, which was initiated in 2008, to provide comparable POPs data. In 2008, Kenya identified Mt. Kenya as one of the regional background sites under the MONET Africa monitoring programme.

Monitoring activities at the site were initiated using passive sampling technique, and continues to date. The Global Atmospheric Passive Sampling (GAPS) sampler is collocated at the site to provide additional site capability for inter-programme comparison, which is critical in evaluating comparability across the programmes.

Under the UNEP/GEF GMP1 &2 projects, Kabete was selected as a suitable urban background, site provide data which is critical for evaluating the influence of the background activities on the levels POPs in ambient air.

The POPs and pesticide research laboratory also participates in the MEGA Cities monitoring of POPs and Mercury monitoring coordinated by Environment Canada, with sites located at Nairobi Industrial area and Mt. Kenya, respectively.

Participation in Regional Networks:

Kenya POPs and pesticide research group at the University of Nairobi is a member of the Africa Network of Chemical Analysis of Pesticides and other Pollutants (ANCAP) that draws membership from 8 regional countries namely Ethiopia, Kenya, Nigeria, Tanzania, Uganda, Rwanda, Sudan and Zimbabwe.

ANCAP is a legally registered scientific body devoted to the study, promotion and development of the science of all aspects of chemical analysis of pesticides, including residue analyses, degradation and environmental fate. It was established in July 2002 in Kampala, Uganda upon unanimous agreement by scientist and researchers in Africa to initiate, develop and promote research in the area of chemical analyses of pesticides and other pollutants in the Africa region.

ANCAP major objectives include:

- To promote research and training programs in chemical analysis of pesticide and other pollutants,
- To disseminate information pertaining to research on chemical pesticides and other pollutants,
- To coordinate and maintain inter-and intra-regional links among different research groups,
- To provide advice, based on sound scientific findings, to pertinent decision makers in the region on the use and/or disuse of certain pesticides, heavy metals, pharmaceuticals and other chemicals which have adverse effects on the environment and living organisms,
- To establish cooperation and collaboration with national and international organizations with similar objectives in promoting safe-use of chemicals and their research and analysis in the environment,
- To provide advice, based on sound scientific findings, to pertinent decision makers in the region on the use and/or disuse of certain chemicals ranging from pesticide, heavy metals, pharmaceuticals, cosmeceuticals etc. with adverse effects on the environment and living organisms.

Training activities:

ANCAP organises annual workshops to train the early career researchers in areas of pesticides and other pollutants to equip them with knowledge and skills necessary for research and monitoring. It also organises annual symposia to provide platform for sharing ongoing research activities and findings in the area of pesticides and other priority pollutants. The findings from the GMP2 project have been shared and disseminated during the ANCAP regional symposia to provide a region wide visibility of the project activities. In addition, there are ongoing initiatives to harmonise the methodologies across the network in order to provide comparable data, and the monitoring protocols and methods developed under the GMP2 will be promoted across the network.

6.2.4. Mali

Le Mali a collaboré avec plusieurs partenaires stratégiques en fournissant des données sur les milieux prioritaires aux fins de la surveillance régionale africaine et internationale.

Ces partenaires sont les suivants:

Le MONET-Africa: Le réseau de surveillance en Afrique, a été créé en 2008 pour surveiller l'incidence des polluants organiques persistants (POP) dans l'air ambient pour le Plan mondial de surveillance en vertu de la Convention de Stockholm sur les POP. A cette époque le continent africain ne disposait d'aucun cadre générant des informations sur l'apparition de POPs dans l'environnement. A partir de 2013, un pilote du réseau a commencé à prélever des échantillons d'eau par prélèvement passif (eau douce). Par ailleurs, deux échantillonneurs actifs (échantillonneurs à faible volume) ont été mis en place dans le réseau MONET fin 2013 par un don de RECETOX au Kenya et au Ghana pour établir deux super-sites sur le continent.

Le GMP1-Africa: la 1ère phase du programme mondial de surveillance des POPs, le PNUE/FEM au titre du projet de 2010-2011 sur l'air, le PNUE et l'OMS, dans le cadre d'une étude conjointe sur le lait maternel et au titre du projet PNUE/FEM de 2010-2011 visant à rassembler des données sur le lait maternel

Le PNUE/FEM et MONET-Africa pour la surveillance de l'air ambiant et des eaux superficielles, dans le cadre d'un projet pilote de 2014.

6.2.5. Mauritius

In the context of the Global Monitoring Plan, the Ministry of Environment & SD, with the collaboration of the United Nations Environment Programme (UNEP), participated in an air monitoring exercise for POPs between January and July 2008 (MONET Project). The project aimed to obtain information on POPs levels in ambient air in the African continent.

The Research Centre for Environmental Chemistry and Ecotoxicology (RECETOX) of the Masaryk University of the Czech Republic was the facilitator for the MONET project. The sampling site selected was the premises of the National Environmental Laboratory (NEL) at Réduit.

6.2.6. Morocco

Dés 2016, le Maroc a contribué à plusieurs projets internationaux dans le but de surveiller les tendances des polluants organiques persistants en Afrique et dans le monde. Ainsi, quelques matrices ont été surveillées notamment « l'air », « l'eau », le « lait maternel » et les « bivalves ».

Dans le cadre du projet Monet Afrique, des prélèvements et des analyses ont été effectuées pour la matrice « Eau » au niveau du Barrage Mohamed Ben Abdellah à Rabat alors que pour la qualité de l'air, des prélèvements ont été effectués au niveau de la région d'Ouarzazate. Cette surveillance s'est étalée sur 2 années (2017 et 2018) en collaboration avec le centre RECETOX.

La démarche suivie pour l'échantillonnage de l'eau était axée sur l'utilisation de membrane en silicone capable de piéger des molécules organiques. Ces membranes étaient fixées sur un support puis immergés dans la retenue d'eau du barrage pour une durée de 30 jours avant d'être récupérées et envoyées au centre RECETOX pour analyse.

La technique relative au contrôle de la qualité de l'air consistait à quantifier les molécules organiques piégées par des filtres en mousse polyuréthane appelés PUFs. Ces filtres étaient fixés dans des récipients en inox semi-ouvert (voir photo 1) permettant la circulation de l'air à l'intérieur. Ces filtres étaient récupérés après 3 mois. Une partie était envoyée pour analyse au niveau du centre RECETOX tandis que l'autre partie demeure au LNESP pour une intercomparaison des résultats. En général, les résultats obtenus étaient inférieurs à la limite de détection, ce qui a poussé à déterminer les résultats pour un groupe de 4 filtres avant d'en déduire les quantités détectées en moyenne dans 1 filtre.

Les résultats ont révélé la présence de toutes les catégories des POPs à des teneurs variables et faibles (voir mission 1). On note cependant une valeur élevée du congénère BDE-209 qui culmine à 1710 et 49200 pg/L.

6.2.7. Nigeria

Nigeria was a participating nation in the MONET-AFRICA mini Passive Air Sampling (PAS) and Water Sampling (PWS) campaign for the monitoring of certain Persistent Organic Pollutants (POPs) in background environment, as part of the Global Monitoring Plan (GMP) for effectiveness evaluation under the Stockholm Convention (SC 3/19).

The first cycle of the MONET-AFRICA campaign was implemented from January 2011 to 30th May 2012, while the second cycle started from 28th August, 2013 to 29th July, 2014. The third cycle commenced on 30th July, 2014 and ended on 30th June, 2015.

The PAS sampling site was Sheda, PWS was conducted at the FCT Fishery Abuja, effective from 15th September, 2013. Figure 14 shows the MONET PWS Sampling point.

However, due to the challenge of easy access to supplementary support from RECETOX, Nigeria is unable to continue to participate in the MONET mini PAS/PWS campaigns, just like some other African countries.

It is expedient to support Conventional Regional Centres in Africa Region, to enable them provide capacity support to served/Member-nations in POPs monitoring programmes.

6.2.8. Tanzania

There are several initiatives which are being undertaken in the country in the monitoring of POPs whereby the following projects are implemented:

Regional Project on Disposal of PCB oils contained in transformers and disposal of capacitors containing PCB in Southern Africa by Africa Institute and VPO

Tanzania in collaboration with other SADC countries is implementing the above named project which aims to reduce the environmental and human health risks from transformer oils contaminated with Polychlorinated Biphenyls (PCBs). This is a 5 years project which started in 2017. Preliminary results confirmed the presence of PCBs in the oils and therefore the need for environmentally sound disposal is of paramount importance.

Promotion of Best Available Technologies and Best Environmental Practices to reduce unintended POPs (u-POPs) releases from waste open burning in SADC countries Project by VPO

This project is implemented by the Vice President's Office in partnership with Local Government Authorities with the objective of reducing unintended POPs (u-POPs) releases from waste open burning in SADC countries. It is a 5 years project started in 2018. The project involves stakeholders in the preparation of Waste Management Plan to identify options that demonstrate the Best Environmental Practices that will reduce the release of u-POPs.

Management of pesticides residues in food stuffs (fresh fruits and vegetables and honey) including OCPs

The Government, through the Tropical Pesticides Research Institute (TPRI), is implementing national initiative to monitor pesticides, including OCP in food stuffs and environment to control the levels of pesticides residues. This is a 3 years project which started in 2017-2020.

6.3. Regional Monitoring under the Stockholm Convention Arrangements for GMP

The data generated under this project by either the national POPs laboratories or the expert laboratories were made available for the GMP data warehouse maintained by RECETOX at Masaryk University.

Photo: ©Unsplash / Annie Spratt

SECTION 7

Conclusion

Photo: ©UNEP

7. CONCLUSION

Environmental and human monitoring of POPs plays a crucial role in assessing the environmental and human exposure to these toxic chemicals, safeguarding the health of humans and the environment, and providing pivotal information to the effectiveness evaluation and implementation of the Stockholm Convention.

The UNEP/GEF POPs GMP project on POPs monitoring in Africa region has generated a wealth of information. This report attempts to present and summarize the set-up of the regional project and includes presentation of the main actors, characterize the sampling sites and other organizational structures. The report also highlights the quantitative findings for all samples analyzed for POPs. This report is limited to the core matrices as defined in the guidance document for the global monitoring plan and includes the POPs listed in the Stockholm Convention (UNEP 2021). Results of POPs monitoring in other matrices conducted at the national level, including for example sediment and food, are included in the project national reports and publications of national and international researchers.

Through this project, POPs in core matrices including air, water and human milk were sampled in parallel in four UN regions covering 42 projects countries worldwide. In order to assess these regional data, it is recommended to compare the findings presented here with the findings from the other three (sister) regional reports addressing GRULAC, Asia, and the Pacific Islands countries as well as the sectoral reports summarizing the air, water and human milk (UNEP 2023b; UNEP 2024a, UNEP 2024b; UNEP 2024c; UNEP 2024d; 2024e).

Valuable insights were generated, reflecting the extend of POPs concentrations in the three core matrices in the region and enabling comparison in the global context. Background levels of POPs have been confirmed to be widespread in the environment in the region. POPs were also detected in all the human milk samples collected. The site-specific information and the chemical measurements serve as a data reservoir for future assessments by the Parties of the Stockholm Convention but also for researchers conducting environmental or human monitoring.

Although the background information provided basic understanding of the extend of POPs levels in core matrices, significant data gaps still exist in most African countries particularly for new POPs. This challenge is attributed to the limited regional and national capacities and associated analytical difficulties of complex compounds. The capacity building activities conducted under the project, including trainings in national laboratories, two rounds of interlaboratory assessments, development of protocols and training courses, have contributed to strengthened national analytical knowledge and skills. With more POPs listed under the Stockholm Convention, regional collaboration and global coordination are critical to continue strengthening regional capacities and enable sustainable data generation on environmental existence and human exposure to POPs.

Project countries have developed sustainability plans, emphasizing key areas of mutual interest. These encompass continuing POPs monitoring; capacity building to improve data quality and comparability and to facilitate data interpretation and utilization. Additionally, the plans mentioned the integration of data generation into policy-making processes, including the development and updating of national implementation plans under the Stockholm Convention. There is also a focus on understanding the key messages derived from data interpretation, gaining enhanced knowledge on health impacts and environmental risks, and establishing a sustainable modality for POPs monitoring including the continuation of financial and technical assistance, as well as fostering increased regional collaboration.

Finally, data and information gathered under the project are also shared with the Secretariat of the Stockholm Convention to support the effectiveness evaluation of the Convention and are contained in thematic reports and project publications.

8. REFERENCES

Abad, E., Ábalos, M. and Fiedler, H. (2022). Air monitoring with passive samplers for dioxin-like persistent organic pollutants in developing countries (2017–2019). *Chemosphere* 287, 131931. https://doi.org/10.1016/j.chemosphere.2021.131931.

Avila, B.S., Mendoza, D.P., Ramírez, A. and Peñuela, G.A. (2022a). Occurrence and distribution of persistent organic pollutants (POPs) in the atmosphere of the Andean city of Medellin, Colombia. *Chemosphere* 307, 135648. https://doi.org/10.1016/j.chemosphere.2022.135648.

Avila, B.S., Ramírez, C. and Tellez-Ávila, E. (2022b). Human biomonitoring of polychlorinated biphenyls (PCBs) in the breast milk of Colombian mothers. *Bulletin of Environmental Contamination and Toxicology* 109(3), 526–533. https://doi.org/10.1007/s00128-022-03577-5.

Baabish, A., Sobhanei, S. and Fiedler, H. (2021). Priority perfluoroalkyl substances in surface waters - a snapshot survey from 22 developing countries. *Chemosphere* 273, 129612. https://doi.org/10.1016/j.chemosphere.2021.129612.

Bogdal, C., Scheringer, M., Abad, E., Abalos, M., van Bavel, B., Hagberg, J. and Fiedler, H. (2013). Worldwide distribution of persistent organic pollutants in air, including results of air monitoring by passive air sampling in five continents. *TrAC Trends in Analytical Chemistry* 46, 150–161. https://doi.org/10.1016/j.trac.2012.05.011.

Camoiras González, P., Sadia, M., Baabish, A., Sobhanei, S., and Fiedler, H. (2021). Air monitoring with passive samplers for perfluoroalkane substances in developing countries (2017–2019). *Chemosphere* 282. https://doi.org/10.1016/j.chemosphere.2021.131069.

de Boer, J., van der Veen, I. and Fiedler, H. (2022). Global interlaboratory assessments on PCBs, organochlorine pesticides and brominated flame retardants in various environmental matrices 2017/2019. *Chemosphere* 295. https://doi.org/10.1016/j.chemosphere.2022.133991.

de Boer, J., van Dijk, R., Abad, E. and Ábalos, M. (2023). Persistent organic pollutants in air from Asia, Africa, Latin America and the Pacific Islands. *Chemosphere* 324. https://doi.org/10.1016/j.chemosphere.2023.138271.

Fiedler, H., Abad, E. and de Boer, J. (2023a). Preliminary trends over ten years of persistent organic pollutants in air - Comparison of two sets in the same countries. *Chemosphere* 324. https://doi.org/10.1016/j.chemosphere.2023.138299.

Fiedler, H., Abad, E., van Bavel, B., de Boer, J., Bogdal, C. and Malisch, R. (2013). The need for capacity building and first results for the Stockholm Convention global monitoring plan. *TrAC Trends in Analytical Chemistry* 46, 72–84. https://doi.org/10.1016/j.trac.2013.01.010.

Fiedler, H., Ábalos, M., Parera, J. and Abad, E. (2022c). Spatial assessment of dioxin-like POPs in samples collected with passive air sampling using polyurethane foam disks. *Organohalogen Compounds* 83, 53-57. https://dioxin20xx.org/wp-content/uploads/pdfs/2022/OHC%2083_EnvMon02.pdf.

Fiedler, H., Ábalos, M., Parera, J., Abad, E., Neugebauer, F., Lohmann, N. *et al.* (2023c). Dioxin-like POPs in national samples from global monitoring plan projects (2017-2019). *Chemosphere* 325. https://doi.org/10.1016/j.chemosphere.2023.138386.

Fiedler, H., Baabish, A. and Sadia, M. (2022h). Multivariate analysis of abiotic and biota samples for three perfluoroalkane acids. *Frontiers in Analytical Science* 2, 1-13. https://doi.org/10.3389/frans.2022.954915.

Fiedler, H., Kallenborn, R., de Boer, J. and Sydnes, L.K. (2019). The Stockholm Convention: A tool for the global regulation of persistent organic pollutants. *Chemistry International* 41(2), 4–11. https://doi.org/10.1515/ci-2019-0202.

Fiedler, H., Kallenborn, R., de Boer, J. and Sydnes, L.K. (2020a). The Stockholm Convention: A living instrument for the global regulation of persistent organic pollutants (POPs). *KJEMI Digital* 80(4), 10-18. https://research.vu.nl/en/publications/the-stockholm-convention-a-living-instrument-for-the-global-regul.

Fiedler, H., Li, X. and Zhang, J. (2022e). Dioxin-like compounds in human milk – A time-trend analysis. *Organohalogen Compounds* 83, 191-194, 88681. https://dioxin20xx.org/wp-content/uploads/pdfs/2022/OHC%2083_ToxRisk02.pdf.

Fiedler, H., Li, X. and Zhang, J. (2023b). Persistent organic pollutants in human milk from primiparae – correlations, global, regional, and national time-trends. *Chemosphere* 313, 137484. https://doi.org/10.1016/j.chemosphere.2022.137484.

Fiedler, H. and Sadia, M. (2021a). Regional occurrence of perfluoroalkane substances in human milk for the global monitoring plan under the Stockholm Convention on persistent organic pollutants during 2016–2019. *Chemosphere* 277, 130287. https://doi.org/10.1016/j.chemosphere.2021.130287.

Fiedler, H., Sadia, M., Baabish, A. and Sobhanei, S. (2022f). Perfluoroalkane substances in national samples from global monitoring plan projects (2017–2019). *Chemosphere* 307, 136038. https://doi.org/10.1016/j.chemosphere.2022.136038.

Fiedler, H., Sadia, M., Krauss, T., Baabish, A. and Yeung, L.W.Y. (2022d). Perfluoroalkane acids in human milk under the global monitoring plan of the Stockholm Convention on persistent organic pollutants (2008–2019). *Frontiers of Environmental Science & Engineering* 16(10), 132. https://doi.org/10.1007/s11783-022-1541-8.

Fiedler, H., van der Veen, I. and de Boer, J. (2017). *Bi-ennial Global Interlaboratory Assessment on Persistent Organic Pollutants – Third Round 2016/2017*. Geneva: United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/21743.

Fiedler, H., van der Veen, I. and de Boer, J. (2020b). Global interlaboratory assessments of perfluoroalkyl substances under the Stockholm Convention on persistent organic pollutants. *TrAC Trends in Analytical Chemistry* 124, 115459. https://doi.org/10.1016/j.trac.2019.03.023.

Fiedler, H., van der Veen, I. and de Boer, J. (2021a). *Bi-ennial Global Interlaboratory Assessment on Persistent Organic Pollutants – Fourth Round 2018/2019*. https://wedocs.unep.org/handle/20.500.11822/30923.

Fiedler, H., van der Veen, I. and de Boer, J. (2022a). Interlaboratory assessments for dioxin-like POPs (2016/2017 and 2018/2019). *Chemosphere* 288, 132449. https://doi.org/10.1016/j.chemosphere.2021.132449.

Fiedler, H., van der Veen, I. and de Boer, J. (2022b). Assessment of four rounds of interlaboratory tests within the UNEP-coordinated POPs projects. *Chemosphere* 288, 132441. https://doi.org/10.1016/j.chemosphere.2021.132441.

Harner, T. (2016). 2016 v1 3 Template for calculating PUF and SIP disk sample air volumes. 11 March. *Unpublished [Data set]*. https://doi.org/10.13140/RG.2.1.3998.8884

Herkert, N.J., Martinez, A. and Hornbuckle, K.C. (2016). A model using local weather data to determine the effective sampling volume for PCB congeners collected on passive air samplers. *Environmental Science & Technology* 50(13), 6690–6697. https://doi.org/10.1021/acs.est.6b00319

Secretariat of the Stockholm Convention (2009). *SC-4/17: Listing of Perfluorooctane Sulfonic Acid, its Salts and Perfluorooctane Sulfonyl Fluoride*. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP4/COP4Documents/tabid/531/Default.aspx.

Secretariat of the Stockholm Convention (2017). *SC-8/10: Listing of Decabromodiphenyl Ether*. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP8/tabid/5309/Default.aspx

Secretariat of the Stockholm Convention (2019a). *SC-9/4: Perfluorooctane Sulfonic Acid, its Salts and Perfluorooctane Sulfonyl Fluoride*. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP9/tabid/7521/Default.aspx.

Secretariat of the Stockholm Convention (2019b). *SC-9/12: Listing of perfluorooctanoic acid (PFOA), its salts and PFOA-related compounds*. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP9/tabid/7521/Default.aspx.

Secretariat of the Stockholm Convention (2019c). *POPRC-15/1: Perfluorohexane Sulfonic Acid (PFHxS), its Salts and PFHxS-Related Compounds*. Persistent Organic Pollutants Review Committee of the Stockholm Convention on Persistent Organic Pollutants. http://chm.pops.int/theconvention/popsreviewcommittee/meetings/poprc15/overview/tabid/8052/default.aspx.

Secretariat of the Stockholm Convention (2022). *SC-10/13: Listing of Perfluorohexane Sulfonic Acid (PFHxS), its Salts and PFHxS-related Compounds***.** Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP10/tabid/8397/Default.aspx.

Secretariat of the Stockholm Convention (n.d. a). Global Monitoring Plan Data Warehouse - online tool to store and visualize data on levels of POPs in core matrices: ambient air, water, human milk and blood. https://www.pops-gmp.org/gmp-dwh.html. Accessed 29 August 2022.

Secretariat of the Stockholm Convention (n.d. b). Status of ratification. http://www.pops.int/Countries/StatusofRatifications/PartiesandSignatoires/tabid/4500/Default.aspx. Accessed 7 August 2022.

Secretariat of the Strategic Approach to International Chemicals Management (2018). *Gender and the Sound Management of Chemicals and Waste: Prepared for the Intersessional Process Considering the Strategic Approach and the Sound Management of Chemicals and Waste Beyond 2020*. 20 December. SAICM/IP.2/6. http://www.saicm.org/Portals/12/documents/meetings/IP2/IP_2_6_gender_document.pdf.

Shoeib, M. and Harner, T. (2002). Characterization and comparison of three passive air samplers for persistent organic pollutants. *Environmental Science & Technology* 36(19), 4142–4151. https://doi.org/10.1021/es020635t.

Surenjav, E., Lkhasuren, J. and Fiedler, H. (2022). POPs monitoring in Mongolia – core matrices. *Chemosphere* 297, 134180. https://doi.org/10.1016/j.chemosphere.2022.134180.

Touré, A., Cabral, M., Lam, A., Dioum, M.D., Sarr, A., Bah, F. *et al.* (2021). Les polluants organiques persistants (POP) dans le lait maternel: évolution des concentrations dans le temps au Sénégal - [Persistent organic pollutants (POP) concentrations in human breast milk: Evolution of concentrations over time in Senegal]. *Toxicologie Analytique et Clinique* 33(1), 91–100. https://doi.org/10.1016/j.toxac.2020.10.017.

United Nations Environment Programme (2012). *UNEP-coordinated Survey of Mothers' Milk for Persistent Organic Pollutants - Guidelines for Organization, Sampling and Analysis*.

United Nations Environment Programme (2014a). *Procedure for the Analysis of Persistent Organic Pollutants in Environmental and Human Matrices to Implement the Global Monitoring Plan under the Stockholm Convention - Protocol 2: Protocol for the Analysis of Polychlorinated Biphenyls (PCB) and Organochlorine Pesticides (OCP) in Human Milk, Air and Human Serum*. https://wedocs.unep.org/handle/20.500.11822/29680.

United Nations Environment Programme (2014b). *Procedure for the Analysis of Persistent Organic Pollutants in Environmental and Human Matrices to Implement the Global Monitoring Plan under the Stockholm Convention - Protocol 3: Protocol for the Analysis of Polybrominated Diphenyl Ethers (PBDE) in Human Milk, Air and Human Serum*. https://wedocs.unep.org/handle/20.500.11822/29681.

United Nations Environment Programme (2015a). *GEF/UNEP Project "Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Pacific Region"*. https://wedocs.unep.org/handle/20.500.11822/22157.

United Nations Environment Programme (2015b). *GEF/UNEP Project "Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Latin American and Caribbean Region"*. https://wedocs.unep.org/handle/20.500.11822/22158.

United Nations Environment Programme (2015c). *Procedure for the Analysis of Persistent Organic Pollutants in Environmental and Human Matrices to Implement the Global Monitoring Plan under the Stockholm Convention - Protocol 1: The Analysis of Perfluorooctane Sulfonic Acid (PFOS) in Water and Perfluorooctane Sulfonamide (FOSA) in Mothers' Milk, Human Serum and Air, and the Analysis of Some Perfluorooctane Sulfonamides (FOSAS) and Perfluorooctane Sulfonamido Ethanols (FOSES) in Air*. https://wedocs.unep.org/handle/20.500.11822/29676.

United Nations Environment Programme (2016). GMP2 Africa region inception workshop. https://www.unep.org/events/workshop/gmp2-african-inception-workshop-and-new-pops-workshop. Accessed 28 July 2022.

United Nations Environment Programme (2017a). *Global Monitoring Plan on Persistent Organic Pollutants: Guidelines for Organization, Sampling and Analysis of Human Milk on Persistent Organic Pollutants*. https://wedocs.unep.org/handle/20.500.11822/27639.

United Nations Environment Programme (2017b). *Global Monitoring Plan on Persistent Organic Pollutants: Protocol for the Sampling and Pre-treatment of National Samples within the UN Environment/GEF Projects to Support the Global Monitoring Plan of POPs 2016-2019*. https://wedocs.unep.org/handle/20.500.11822/21023.

United Nations Environment Programme (2017c). *Global Monitoring Plan on Persistent Organic Pollutants: Passive Sampling of Ambient Air - Methodology and Procedure*. https://wedocs.unep.org/bitstream/handle/20.500.11822/21742/Passive_Sampling_Ambient_Air_Procedure.pdf?sequence=1&isAllowed=y.

United Nations Environment Programme (2017d). *Global Monitoring Plan on Persistent Organic Pollutants: Protocol for the Sampling of Water as a Core Matrix in the UNEP/GEF GMP2 Projects for the Analysis of PFOS*. https://wedocs.unep.org/handle/20.500.11822/27637.

United Nations Environment Programme (2018). GMP Africa region midterm workshop. https://www.unenvironment.org/events/workshop/gmp-africa-midterm-workshop?_ga=2.50908845.502412707.1652795004-1402479924.1607084245. Accessed 28 July 2022.

United Nations Environment Programme (2019a). *Global Chemicals Outlook II: From Legacies to Innovative Solutions - Implementing the 2030 Agenda for Sustainable Development*. https://wedocs.unep.org/20.500.11822/28113.

United Nations Environment Programme (2019b). *Guidance on the Global Monitoring Plan for Persistent Organic Pollutants – Updated Draft*. 26 February. UNEP/POPS/COP.9/INF/36. http://www.brsmeas.org/Decisionmaking/COPsandExCOPs/2019COPs/MeetingDocuments/tabid/7832/ctl/Download/mid/21620/language/en-US/Default.aspx?id=72&ObjID=26562.

United Nations Environment Programme (2021). *Guidance on the Global Monitoring Plan for Persistent Organic Pollutants*. 21 April. UNEP/POPS/COP.10/INF/42. http://www.brsmeas.org/2021COPs/MeetingDocuments/tabid/8810/language/en-US/Default.aspx.

United Nations Environment Programme (2023a). *Organization and Outcomes of Four Rounds of Interlaboratory Assessments on Persistent Organic Pollutants*. https://wedocs.unep.org/20.500.11822/44155

United Nations Environment Programme (2023b). *United Nations Environment Programme (2023d). Sectoral Report: Results of the 2016-2019 Human Milk Survey on Persistent Organic Pollutants. Geneva.*

United Nations Environment Programme (2024a). *Sectoral Report: Results of Air Monitoring of Persistent Organic Pollutants.*

United Nations Environment Programme (2024b). *Sectoral Report: Results of Water Monitoring of Persistent Organic Pollutants.*

United Nations Environment Programme (2024c). *Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Asian Region*.

United Nations Environment Programme (2024d). *Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Latin American and Caribbean Region*.

United Nations Environment Programme (2024e). *Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in the Pacific Islands Region*.

United Nations Environment Programme (n.d.). Global monitoring of persistent organic pollutants. https://www.unep.org/explore-topics/chemicals-waste/what-we-do/persistent-organic-pollutants/global-monitoring. Accessed 21 March 2023.

United Nations Environment Programme and Secretariat of the Stockholm Convention (2017). *Second Global Monitoring Report: Global Monitoring Plan for Persistent Organic Pollutants*. 23 January. UNEP/POPS/COP.8/INF/38. http://chm.pops.int/TheConvention/ConferenceoftheParties/Meetings/COP8/tabid/5309/Default.aspx.

van den Berg, M., Birnbaum, L.S., Denison, M., De Vito, M., Farland, W., Feeley, M. *et al.* (2006). The 2005 world health organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. *Toxicological Sciences* 93(2), 223–241. https://doi.org/10.1093/toxsci/kfl055.

van der Veen, I., Fiedler, H. and de Boer, J. (2023). Assessment of the per- and polyfluoroalkyl substances analysis under the Stockholm Convention – 2018/2019. *Chemosphere* 313, 137549. https://doi.org/10.1016/j.chemosphere.2022.137549.

Wania, F., Shen, L., Lei, Y.D., Teixeira, C. and Muir, D.C.G. (2003). Development and calibration of a resin-based passive sampling system for monitoring persistent organic pollutants in the atmosphere. *Environmental Science & Technology* 37(7), 1352–1359. https://doi.org/10.1021/es026166c.

Weiss, J., de Boer, J., Berger, U., Muir, D., Ruan, T., Torre, A. *et al.* (2015). *Global Monitoring Plan on Persistent Organic Pollutants: PFAS Analysis in Water for the Global Monitoring Plan of the Stockholm Convention - Set-up and Guidelines for Monitoring*. Geneva: United Nations Environment Programme. https://wedocs.unep.org/handle/20.500.11822/29682.

World Bank (n.d. a). DataBank. https://databank.worldbank.org/home.aspx. Accessed 17 July 2022.

World Bank (n.d. b). DataBank: World Development Indicators. https://databank.worldbank.org/reports.aspx?source=2&series=EN.POP.DNST&country=. Accessed 17 July 2022.

World Health Organization (2007). *Fourth WHO-Coordinated Survey of Human Milk for Persistent Organic Pollutants in Cooperation with UNEP - Guidelines for Developing a National Protocol*. https://www.slideshare.net/bibliotecavirtualam/fourth-who-coordinated-survey-of-human-milk-for-persistent-organic-pollutants-in-cooperation-with-unep.

World Health Organization (2011). Standards and operational guidance for ethics review of health-related research with human participants. https://apps.who.int/iris/rest/bitstreams/53316/retrieve.

9. APPENDIX

9.1. Responsible People in the Africa Project

Table S1: Africa: Members and the responsibilities of the national teams

Country	Responsibility	Person (name)	Affiliation	E-mail
Congo DR	Coordinator	Mr. Jean Claude Emene Elenga	Agence congolaise de l'Environnement	jcemene@yahoo.fr
	Air	Prof. Jean Kayembe Sungula	Université de Kinshasa, Faculté des Sciences, Département de Chimie	jeansungula@gmail.com
	Water			
	Human milk	Prof. José OKOND'AHOKA	Faculté de Médecine Vétérinaire Université Pédagogique Nationale (UPN)/KINSHASA	jose.okondahoka@upn.ac.cd
Egypt	Coordinator	Ms. Elham Refaat Abdel Aziz	Egyptian Environmental Affairs Agency	emorefaat@yahoo.com; azizelham26@gmail.com
	Air	Mr. Abdullah Saneyeldin Mohamed		abdo_sany@hotmail.com
	Water			
	Human milk			
Ethiopia	Coordinator	Mr. Habtamu Wodajo	Ethiopian Environment and Forest research institute Central Ethiopia Environment and Forest research Center, Gurd Shola	habtamuwodajosn@yahoo.com, habwodajo@yahoo.com
	Air			
	Water			
	Human milk	Mr. Mesaye Getachew	Environmental Public Health Research Team Ethiopian Public Health Institute (EPHI)	johnny.woldegabriel04@gmail.com, ephi@ethionet.et
Ghana	Coordinator	Dr. Sam Adu-Kumi	Environmental Protection Agency	sam.adu-kumi@epa.gov.gh, adukumisam@yahoo.com
	Air			
	Water			
	Human milk			
Kenya	Coordinator	Dr. Vincent Odongo Madadi	Department of Chemistry, University of Nairobi	vmadadi@uonbi.ac.ke
	Air	Prof. Shem Oyoo Wandiga		wandigas@uonbi.ac.ke
	Water	Mr. Charles W. Mirikau		cmirikau@uonbi.ac.ke
	Human milk	Dr. Leititia Kanja	Department of Public Health and Pharmacology, University of Nairobi	lkanja@uonbi.ac.ke
Mali	Coordinator	Mr. Bechir Simpara	Ministère de l'Environnement, de l'Assainissement et du Développement Durable	elbechirsimpara_2011@yahoo.fr
	Air	Mr. Boubacar Madio dit Aladiogo Maiga	Laboratoire Central Vétérinaire	aladiogo1@yahoo.fr, aladiogo2@yahoo.fr
	Water			
	Human milk	Dr. Seybou Guindo		seybouguindo@yahoo.fr
Mauritius	Coordinator	Mrs Sareeta Choytoo, Scientific Officer Until 2021: Mrs. Sheba Rojubally Cadinouche Scientific Officer	Ministry of Environment, Solid Waste Management and Climate Change	schoytoo@govmu.org
	Air			
	Water			
	Human milk			
Morocco	Coordinator	Mr. Mohammed El Bouch	Laboratoire National des Etudes et de Surveillance de la Pollution	elbouch21@yahoo.fr; elbouch@environnement.gov.ma
	Air	Mr. Otmani Anas		Otmani.anas@gmail.com
	Water	Mr. Mohamed kabriti		mkabriti@gmail.com
	Human milk	Mr. Elhamri Hecham	National Institute of Health	elhamrih@yahoo.fr
Nigeria	Coordinator	Mr. Charles K. Ikeah Mr. Olawale Akande	Federal Ministry of Environment	kcikeah@gmail.com a_olawale_2000@yahoo.com
	Air			
	Water			
	Human milk	Mr. Yunuss Abdul-Ganiyu		Abdul-Ganiyu.Yinnus@fedcs.gov.ng, ag-yunuss@yahoo.co.uk
Senegal	Coordinator	Ms. Aïta Sarr SECK	Direction de l'Environnement et des Etablissements Classés	aitasec@yahoo.fr
	Air	Ms. Sarr Marie Ndao		email: ndaomarie@yahoo.fr
	Water			
	Human milk	Dr. Aminata Toure		amitoure@hotmail.com

Table S1 (continued)

Country	Responsibility	Person (name)	Affiliation	E-mail
Tanzania	Coordinator	Ms. Asia Akule	Vice President's Office Division of Environment	asia.akule@vpo.go.tz
	Air	Ms. Edith Lyimo	Tanzania Bureau of Standards	edith_lyimo@yahoo.com
	Water			
	Human milk	Dr. Fedelice M.S Mafumiko		smafumiko@gmail.com
Togo	Coordinator	N'ladon Nadjo		nnadjonab@yahoo.fr, adjolo9@yahoo.fr
	Air	Prof. Komla Sanda		komla.sanda@gmail.com; danielkkoba@yahoo.fr
	Water			
	Human milk	Nyaku Afua	Direction des Laboratoires/Laboratoire de Contrôle Qualité et de Normalisation	hanvinatacha@yahoo.fr
Tunisia	Coordinator	Mrs. Chedia Baili Ben Jema	International Centre of Technology Environnemet	unite-cho@citet.nat.tn
	Air			
	Water			
	Human milk	Mr Youssef Zidi	Health ministry	josephzidi@yahoo.fr
Uganda	Coordinator	Jane Beebwa	Directorate of Government Analytical Laboratory (DGAL)	beebwajane@yahoo.com
	Air	Stanley Kizito		kizitostanley@gmail.com
	Water	Oscar Kibirango		stuartoscar1@gmail.com
	Human milk	Gerald Mutungi	Ministry of Health (MoH)	gnmutungi@yahoo.com
Zambia	Coordinator	Mr. David Kapindula	Environmental Management Agency	dkapindula@zema.org.zm; dkapindula@yahoo.com
	Air	Mr. David Kapindula Mr. Christopher Kanema		dkapindula@zema.org.zm ckanema@zema.org.zm
	Water			
	Human milk			

9.2. Locations of Air and Water Sampling Sites

Table S2: Locations of air sampling sites in the African region (PAS/PUF)

Country	Address and description (name of site)	Altitude (m)	Coordinates (decimal)	
			Latitude	Longitude
DR Congo	Kinshasa	443	-4.35	15.283
Egypt	New Cairo Development Administration Building – Eastern Cairo – Egypt	439	29.993	31.585
Ethiopia	central Ethiopia environment and forest Research center Nursery site in Addis Ababa city	2376	9.018	38.818
Ghana	Accra Meteorological Agency	72	5.65	-0.1667
Kenya	Meteorological station, Nairobi	1841	-1.2494	36.742
Mali	Bamako Centre	327	12.659	-7.9422
Morocco	Timdiqine, Ifrane, Pachalik d'Ifrane, Province d'Ifrane, 53002	1673	33.527	-5.1076
Mauritius		390	-20.297	57.498
Nigeria	Federal Ministry of Environment, Brown Building, 432 Independence Avenue, Central Business District, Abuja.	479	9.0387	7.467
Senegal	Ngoye: zone rurale	23	14.635	-16.4297
Tanzania	Vikuge, Kibaha district, Coast Region	161	-6.7883	38.8633
Togo	Kouma-Kondam, 140 km norht-west Lomé	614	6.95	0.5833
Tunisia	Tunis, Boulevard Leader Yasser Arafat, 1080 Charguia Tunis	4	36.8366	10.2114
Uganda	Soroti Flying School	1124	1.7208	33.6167
Zambia	Kenneth Kuanda - International Airport	1170	-15.323	28.447

Table S3: Geographical locations for water samples under UNEP/GMP2 African project

Country	Site name	Type	Coordinates (decimal)	
			Latitude	Longitude
Egypt	River Nile	Fresh	24.034	32.866
Ghana	Volta River	Fresh	6.125	0.123
Kenya	Sabaki, Malindi, Kenya	Ocean	-3.161	40.131
Senegal	River Senegal	Fresh	15.986	-16.515
Tunisia	Oued Medjerda, Andalusian kalaat bridge, Tunisia	Fresh	37.021	10.1408
Zambia	Kafue/Zambezi Confluence, RD491, Zambia	Fresh	-15.950	28.924

9.3. Monitoring Results from Expert Laboratories

9.3.1. Ambient Air

Table S4: PAS/PUFs: Concentration of chlorinated POPs (ng/PUF)

ISO3	Sample_ID	Drins	Chlordanes	DDTs	Heptachlors	HCHs	a_Endosulfan	Mirex	Toxaphene	PCB6	HCB	PeCBz	HCBD
COD	COD (2017-III)	30	3.5	895	0.69	5.3	11	<0.11	3.57	34	2.9	1.1	2.1
COD	COD (2017-IV)	48	2.7	580	0.76	10	12	<0.11	<LOQ	45	5.5	5	2.8
COD	COD (2018-I)	2.2	0.95	79	0.26	5.5	1.8	0.13	<LOQ	202	4.6	5.1	2.5
COD	COD (2018-I)	1.7	1.3	43	0.00	2.4	0.86	0.12	<LOQ	163	2.8	4.4	1.7
COD	COD (2018-II)	6.3	3.2	150	0.91	10	3.5	<0.02	<LOQ	259	4.2	1.7	0.98
COD	COD (2018-III)	6.9	1.8	208	0.96	1.2	<0.15	0.16	<LOQ	290	3.8	1.6	0.65
COD	COD (2018-IV)	11	5.7	69	0.58	4.9	<0.26	0.15	<LOQ	23	22	8.7	<0.28
COD	COD (2019-I)	3.3	0.46	64	0.00	4.7	1.1	<0.11	<LOQ	54	2.8	1.3	1.1
COD	COD (2019-II)	3.7	2.8	69	0.83	20	<0.39	0.13	<LOQ	21	8.5	5	<0.22
EGY	EGY (2017-I)	0.94	0.99	15	1.3	8.4	2.9	<0.11	0.43	8.7	5.9	2.3	0.86
EGY	EGY (2017-II)	1.9	1.0	17	1.1	9.7	<0.28	<0.11	0.67	6.6	3.6	2.2	2.1
EGY	EGY (2017-III)	2.4	1.1	20	1.2	17	<0.28	<0.11	<LOQ	6.9	6.4	3	2.1
EGY	EGY (2017-IV)	0.73	0.98	9.7	1.6	6.7	7.6	<0.11	<LOQ	7.2	23	31	3
EGY	EGY (2018-I)	1.6	0.61	9.3	0.77	4.5	<0.15	0.09	<LOQ	6.5	8.4	5.9	3.9
EGY	EGY (2018-II)	2.3	0.62	15	0.74	7.8	0.44	0.1	<LOQ	7.5	3.4	3.9	1
EGY	EGY (2018-III)	1.6	0.5	20	0.89	8.9	<0.15	0.13	0.26	7.4	3.4	1.8	2.1
EGY	EGY (2018-IV)	0.00	0.08	9.9	0.84	5.2	12	<0.1	0.21	7.1	22	22	3.5
ETH	ETH (2017-II)	8.2	4.0	18	5.8	6.8	25	<0.11	<LOQ	2.2	6.4	2	1
ETH	ETH (2017-III)	14	3.7	21	5.6	9.3	58	<0.11	<LOQ	2.5	6.5	1.4	1.6
ETH	ETH (2017-IV)	2.7	2.4	12	3.8	2.2	11	<0.11	<LOQ	1.2	5.9	2	1.8
ETH	ETH (2018-I)	6.6	4.4	20	5.6	6.7	15	0.11	<LOQ	1.4	6.8	2.2	1.7
ETH	ETH (2018-II)	10	4.2	16	6.7	8.9	11	0.09	0.17	1.8	7.4	2.4	2.1
ETH	ETH (2018-III)	17	0.63	77	1.0	7.1	18	0.1	<LOQ	2.8	5	1.2	1.8
ETH	ETH (2018-IV)	3.6	1.7	12	2.9	4.1	7.2	<0.1	<LOQ	1.7	5.8	1.7	1.7
ETH	ETH (2019-I)	5.8	3.3	14	3.8	3.5	4.1	0.13	<LOQ	2.0	5.5	1.8	1.5
GHA	GHA (2017-I)	6.0	2.1	13	2.3	1.5	110	<0.11	0.42	6.0	2.3	1.4	0.91
GHA	GHA (2017-II)	4.5	2.0	10	2.1	1.2	40	<0.11	<LOQ	5.2	3.4	0.95	1.3
GHA	GHA (2017-III)	3.7	1.9	8.9	2.0	1.0	40	<0.11	<LOQ	4.7	2.3	0.61	0.67
GHA	GHA (2017-IV)	4.4	1.6	8.1	1.6	1.2	140	<0.11	<LOQ	5.0	3.9	2.1	0.93
GHA	GHA (2018-I)	3.2	2.0	12	2.8	3.2	43	0.1	<LOQ	5.5	2.2	1.6	0.69
GHA	GHA (2018-II)	4.3	0.98	8.4	2.1	0.94	71	0.1	<LOQ	4.6	2.8	1.1	0.64
GHA	GHA (2018-III)	5.8	1.7	12	2.5	1.6	49	0.12	<LOQ	5.8	2.3	2	1
GHA	GHA (2018-III)	2.8	2.4	10	1.9	1.8	52	<0.11	<LOQ	5.2	2	1.7	1.7
GHA	GHA (2018-IV)	3.1	1.1	8.0	1.3	1.3	58	<0.1	0.17	4.5	3.4	4.7	0.44
KEN	KEN (2017-I)	23	2.8	16	0.12	1.4	0.92	<0.1	0.83	3.0	5.1	0.99	1.3
KEN	KEN (2017-II)	54	12	69	1.4	6.8	<0.26	0.22	0.87	7.6	12	2.7	1.5

Table S4 (continued)

ISO3	Sample_ID	Drins	Chlordanes	DDTs	Heptachlors	HCHs	a_Endosulfan	Mirex	Toxaphene	PCB6	HCB	PeCBz	HCBD
KEN	KEN (2017-III)	15	1.9	14	0.17	1.8	<0.26	<0.1	2.14	3.7	4.4	1.2	0.8
KEN	KEN (2017-IV)	29	3.3	14	0.67	1.3	0.72	<0.11	0.4	2.7	4.6	1.1	1.3
KEN	KEN (2018-I)	30	3.8	23	0.89	1.3	0.81	0.13	0.46	2.2	4.3	0.92	1.5
KEN	KEN (2018-II)	24	3.3	13	0.82	1.4	<0.15	0.11	<LOQ	2.5	3.9	1.2	1.1
KEN	KEN (2018-III)	12	1.3	9.0	0.85	1.2	<0.15	0.1	<LOQ	4.4	4.4	1.2	1.3
KEN	KEN (2018-IV)	27	3.6	14	0.15	1.3	0.35	0.11	0.2	2.4	4.3	0.95	<0.28
MAR	MAR (2017-II)	0.54	1.1	8.1	1.3	2.0	2.6	<0.11	<LOQ	4.0	11	1.4	3.5
MAR	MAR (2017-III)	0.75	0.97	9.4	1.2	2.0	1.5	<0.11	<LOQ	5.8	4	0.47	2.2
MAR	MAR (2017-IV)	1.4	1.2	13	1.4	3.1	2	<0.11	<LOQ	7.2	13	1.6	3.5
MAR	MAR (2018-I)	1.2	0.93	9.0	1.2	2.0	<0.15	0.11	0.21	3.3	17	2.8	4.2
MAR	MAR (2018-II)	1.5	2.0	13	1.4	3.7	1.4	0.12	0.22	5.0	11	1.2	7.6
MAR	MAR (2018-III)	2.2	2.2	18	1.5	4.8	1.6	0.14	0.24	8.4	12	1.2	5.5
MLI	MLI (2017-I)	1.2	0.84	27	0.93	0.31	1.3	<0.11	1.7	3.0	2.5	0.78	2.2
MLI	MLI (2017-II)	6.4	2.1	97	3.0	2.1	4.2	0.22	0.44	8.3	3.3	0.75	1.2
MLI	MLI (2017-III)	6.4	1.9	89	2.2	2.2	3.4	0.27	<LOQ	5.9	2.7	0.77	1
MLI	MLI (2017-IV)	1.4	0.74	23	0.94	0.42	1.2	<0.11	0.16	3.1	6.4	1.9	2.6
MLI	MLI (2018-I)	2.1	0.99	32	1.2	0.64	0.79	0.15	<LOQ	3.3	3.7	1	2.5
MLI	MLI (2018-II)	4.6	1.7	77	1.7	2.2	1	0.24	<LOQ	6.3	2.9	0.71	2.5
MLI	MLI (2018-III)	7.4	2.0	95	2.6	2.6	3.3	0.37	0.16	7.6	4.5	1.1	1.6
MLI	MLI (2018-IV)	1.2	0.81	24	0.49	0.87	0.74	<0.1	<LOQ	3.6	2	1.1	2.2
MUS	MUS (2017-I)	3.7	0.93	18	0.42	3.2	0.44	<0.11	<LOQ	2.5	2.7	0.38	2
MUS	MUS (2017-II)	3.0	0.95	15	0.44	3.1	0.27	<0.11	<LOQ	2.4	3.5	0.55	1.4
MUS	MUS (2017-III)	2.4	0.97	9.5	0.47	2.6	0.41	<0.11	<LOQ	2.1	3.6	0.56	2.4
MUS	MUS (2017-IV)	3.3	0.00	14	0.00	5.2	<0.3	0.12	<LOQ	2.1	3.9	2.3	2
MUS	MUS (2018-I)	4.3	0.64	23	0.59	3.8	<0.15	0.12	<LOQ	1.8	3.3	0.73	1.2
MUS	MUS (2018-II)	3.5	0.55	9.6	0.56	2.8	<0.15	0.09	<LOQ	1.4	3.5	1.2	1.4
MUS	MUS (2018-III)	2.7	0.53	5.9	0.13	3.2	<0.22	<0.08	<LOQ	1.4	4	1.6	1.6
MUS	MUS (2018-IV)	3.3	0.52	14	0.00	3.8	<0.39	0.12	<LOQ	2.5	4.1	1.3	1.7
NGA	NGA (2017-IV)	0.00	8.9	4.4	1.8	5.1	2	<0.11	<LOQ	4.6	4.5	3	2.1
NGA	NGA (2018-I)	0.00	7.1	3.4	1.1	4.4	<0.41	<0.11	<LOQ	4.7	2.4	1.9	1.8
NGA	NGA (2018-II)	0.00	6.6	3.3	1.1	3.5	1.7	<0.11	<LOQ	3.7	2.3	1.5	1.2
NGA	NGA (2018-III)	0.00	6.0	3.7	1.2	3.7	<0.41	<0.11	<LOQ	2.9	3.3	1.4	1.2
NGA	NGA (2018-IV)	0.00	6.5	4.1	1.6	4.7	0.93	<0.11	<LOQ	4.2	4.7	2.8	1
NGA	NGA (2019-I)	0.00	8.5	4.7	1.8	2.4	4	<0.11	<LOQ	4.8	2.3	1.7	2
NGA	NGA (2019-II)	0.00	6.5	4.6	1.2	3.3	5.9	<0.11	<LOQ	3.1	4.1	1.7	1.6
NGA	NGA (2019-III)	0.00	8.2	5.2	1.7	3.8	1.8	<0.11	<LOQ	3.2	4.5	2.7	2.3
SEN	SEN (2017-I)	0.00	0.44	13	0.17	15	<0.26	<0.1	<LOQ	1.7	3.5	0.72	<0.28
SEN	SEN (2017-II)	1.8	1.2	15	0.96	8.8	0.63	<0.11	<LOQ	2.5	4.2	0.7	4.4
SEN	SEN (2017-III)	1.5	0.72	17	0.60	8.1	0.89	<0.11	1.3	2.0	3	0.38	2.3
SEN	SEN (2017-IV)	0.00	0.00	5.5	0.59	4.4	<0.29	0.12	<LOQ	0.83	5	1.3	3.9
SEN	SEN (2018-I)	1.1	0.65	8.9	0.98	9.4	<0.15	0.1	0.18	1.7	4.6	2.7	3.6
SEN	SEN (2018-II)	2.1	0.79	13	1.0	5.9	<0.15	0.11	0.2	2.5	3.9	0.98	3.5
SEN	SEN (2018-III)	0.78	1.5	10	0.95	3.5	0.9	0.12	0.17	2.1	3	0.56	2.3
SEN	SEN (2018-IV)	0.00	0.34	4.9	0.19	3.1	<0.26	<0.1	<LOQ	1.2	2.7	1.5	1.1
TGO	TGO (2017-I)	0.00	0.30	5.8	0.16	2.1	3.7	<0.1	0.46	1.5	2.8	0.7	0.84
TGO	TGO (2017-II)	0.00	0.00	6.1	0.14	1.9	3.3	<0.1	<LOQ	1.3	3.4	0.45	1.4
TGO	TGO (2017-III)	0.00	0.00	4.8	0.61	2.3	5.3	<0.11	<LOQ	1.4	4.4	0.77	1.3
TGO	TGO (2017-IV)	0.00	0.00	5.7	0.00	1.8	3.7	<0.11	<LOQ	1.5	2.4	0.38	0.92
TGO	TGO (2018-I)	1.1	0.18	5.4	0.11	2.3	3.2	0.11	<LOQ	1.4	3.2	0.68	2.4
TGO	TGO (2018-II)	0.87	0.42	5.6	0.06	1.7	2.1	0.13	<LOQ	1.5	2.6	0.42	1.8

Table S4 (continued)

ISO3	Sample_ID	Drins	Chlordanes	DDTs	Heptachlors	HCHs	a_Endosulfan	Mirex	Toxaphene	PCB6	HCB	PeCBz	HCBD
TGO	TGO (2018-III)	0.00	0.00	4.7	0.85	2.3	4.7	0.11	<LOQ	2.1	4	0.77	1.6
TGO	TGO (2018-IV)	0.62	0.51	7.0	0.20	2.9	3.1	<0.1	0.17	1.6	2.2	0.58	1.3
TUN	TUN (2017-I)	2.0	0.41	7.3	2.5	4.3	<0.26	<0.1	<LOQ	41	16	2.9	7.7
TUN	TUN (2017-II)	1.5	0.33	7.1	0.52	3.1	1.5	<0.1	<LOQ	126	5.2	0.86	1.5
TUN	TUN (2017-III)	1.8	0.33	7.0	1.7	3.3	1.3	<0.1	0.51	71	7.5	1.3	4.2
TUN	TUN (2017-IV)	1.4	0.93	6.1	1.4	2.7	0.82	<0.11	0.19	33	12	2.3	7.5
TUN	TUN (2018-I)	1.8	0.68	5.4	1.9	3.8	<0.15	0.11	0.21	22	12	1.7	3.9
TUN	TUN (2018-II)	1.7	0.50	4.6	1.3	3.1	0.59	0.09	0.22	41	6.8	0.86	2.3
TUN	TUN (2018-III)	3.3	0.65	9.4	1.8	5.1	1	0.11	0.24	66	7.7	1.4	3.7
TUN	TUN (2018-IV)	1.4	0.69	5.2	2.4	3.6	<0.22	<0.08	0.18	19	13	2.5	6.4
TZA	TZA (2018-IV)	8.5	4.1	113	6.5	100	<0.24	<0.1	2.3	1.1	2.4	0.53	1.6
TZA	TZA (2019-I)	10	6.7	229	8.2	180	1.3	<0.11	2.1	0.54	1.8	0.33	0.8
TZA	TZA (2019-II)	1.7	0.00	16	0.00	12	2.6	<0.11	<LOQ	0.44	1.5	0.29	0.87
TZA	TZA (2019-III)	1.6	1.5	15	1.1	50	<0.39	<0.11	0.32	1.1	1.9	0.51	0.96
TZA	TZA (2019-IV)	6.3	3.0	86	4.9	95	<0.39	0.12	0.7	1.0	3	0.52	0.87
UGA	UGA (2017-I,II,III)	7.8	3.5	56	2.0	0.59	4.5	0.13	0.95	12	2	0.3	1.5
UGA	UGA (2017-IV)	1.5	1.4	12	0.65	0.37	2	0.14	<LOQ	5.0	2.6	0.77	2.2
UGA	UGA (2018-I)	3.6	1.8	19	1.5	1.6	1.4	0.12	0.25	5.1	2.6	0.56	1.2
UGA	UGA (2018-II)	4.6	1.8	25	1.8	1.0	0.35	0.12	0.27	5.2	2.2	0.47	1.6
UGA	UGA (2018-III+IV)	2.9	1.8	23	0.49	0.54	2.4	<0.08	<LOQ	3.5	1.1	0.54	1.2
UGA	UGA (2019-I)	1.1	0.00	5.7	0.57	0.97	<0.3	<0.11	0.18	1.1	0.72	0.49	1.6
ZMB	ZMB (2017-I)	18	23	38	1.1	56	2.4	0.12	0.22	3.7	2.6	0.92	<0.28
ZMB	ZMB (2017-II)	5.5	10	20	0.12	3.3	0.81	<0.1	<LOQ	2.0	4.3	1.3	<0.28
ZMB	ZMB (2017-III)	4.2	5.7	22	0.21	3.3	1.1	<0.1	<LOQ	4.9	3.3	1	5
ZMB	ZMB (2017-IV)	27	19	47	1.5	30	2.2	<0.11	<LOQ	11	3	0.95	2.4
ZMB	ZMB (2018-I)	26	22	51	1.3	4.6	1.1	0.18	<LOQ	6.5	3.2	0.92	15
ZMB	ZMB (2018-II)	13	9.8	28	0.87	4.3	2.6	0.14	<LOQ	2.9	4.1	0.87	1.8
ZMB	ZMB (2018-III)	7.8	5.8	16	0.73	1.7	0.47	0.12	<LOQ	2.6	2.2	0.7	2.4
ZMB	ZMB (2018-IV)	21	15	53	0.16	2.8	<0.22	<0.08	<LOQ	4.2	2	0.79	2.2

Table S5: PAS/PUFs: Concentration of dl-POPs (pg TEQ/xPUF)

Country ISO-3	Sample ID	Unit	TEQ_DF	TEQ_PCB
COD	COD (2017-II)	pg/2 PUF	52.7	12.8
COD	COD (2017-III)	pg/2 PUF	49.2	13.4
COD	COD (2017-IV)	pg/2 PUF	35.2	8.5
COD	COD (2018-I+II+III+IV)	pg/4 PUF	64.4	18.6
COD	COD (2019-I+II)	pg/4 PUF	88.5	34.7
EGY	EGY (2017-I)	pg/2 PUF	106.8	31.0
EGY	EGY (2017-II)	pg/2 PUF	45.8	14.8
EGY	EGY (2017-III)	pg/2 PUF	84.0	18.0
EGY	EGY (2017-IV)	pg/2 PUF	127.8	27.0
EGY	EGY (2018-I)	pg/2 PUF	123.6	29.0
EGY	EGY (2018-II)	pg/2 PUF	54.1	13.1
EGY	EGY (2018-III)	pg/2 PUF	26.0	11.9
EGY	EGY (2018-IV)	pg/2 PUF	138.3	32.7
ETH	ETH (2017-II+III+IV)	pg/3 PUF	6.1	1.8
ETH	ETH (2018-I+II+III+IV)	pg/4 PUF	15.1	1.5
GHA	GHA (2017-I)	pg/2 PUF	68.5	13.8
GHA	GHA (2017-II)	pg/2 PUF	54.9	8.7
GHA	GHA (2017-III)	pg/2 PUF	70.7	13.4
GHA	GHA (2017-IV)	pg/2 PUF	49.2	11.3
GHA	GHA (2018)	pg/4 PUF	138.7	30.5
KEN	KEN (2017-I+II+III+IV)	pg/4 PUF	33.6	8.1
KEN	KEN (2018)	pg/4 PUF	37.3	9.4
MAR	MAR (2017-II+III+IV)	pg/3 PUF	33.6	0.1
MAR	MAR (2018-I+II+III)	pg/3 PUF	2.2	2.1
MLI	MLI (2017-I)	pg/2 PUF	155.4	16.5
MLI	MLI (2017-II)	pg/2 PUF	91.8	15.2
MLI	MLI (2017-III)	pg/2 PUF	9.2	2.9
MLI	MLI (2017-IV)	pg/2 PUF	96.0	10.8
MLI	MLI (2018-I+II+III+IV)	pg/4 PUF	66.0	12.6
MUS	MUS (2017-I)	pg/2 PUF	0.8	1.0
MUS	MUS (2017-II)	pg/2 PUF	0.7	0.4
MUS	MUS (2017-III)	pg/2 PUF	1.8	0.5
MUS	MUS (2017-IV)	pg/2 PUF	2.2	1.0
MUS	MUS (2017-I+II+III+IV)	pg/8 PUF	7.0	2.3
MUS	MUS (2018-I+II+III+IV)	pg/4 PUF	7.0	1.3
NGA	NGA (2017-IV)	pg/2 PUF	18.7	4.3
NGA	NGA (2018-I+II+III+IV)	pg/8 PUF	67.6	21.3
NGA	NGA (2019-I+II+III+IV)	pg/8 PUF	79.8	19.8
SEN	SEN (2017-I)	pg/1 PUF	9.9	0.3
SEN	SEN (2017-II)	pg/1 PUF	2.3	0.8
SEN	SEN (2017-III)	pg/1 PUF	4.4	0.1
SEN	SEN (2017-IV)	pg/2 PUF	0.1	0.0
SEN	SEN (2018-I+II+III)	pg/6 PUF	18.2	4.3
TZA	TZA (2018-IV)	pg/2 PUF	1.6	0.9
TZA	TZA (2019-I+II)	pg/4 PUF	2.3	0.8
TZA	TZA (2019-III+IV)	pg/4 PUF	3.2	0.9
TGO	TGO (2017-I)	pg/2 PUF	4.7	1.5
TGO	TGO (2017-II)	pg/2 PUF	1.8	1.2
TGO	TGO (2017-III)	pg/2 PUF	2.6	1.0
TGO	TGO (2017-IV)	pg/2 PUF	2.5	1.0

Table S5 (continued)

Country ISO-3	Sample ID	Unit	TEQ_DF	TEQ_PCB
TGO	TGO (2017-I+II+III+IV)	pg/8 PUF	13.3	5.1
TGO	TGO (2018-I+II+III+IV)	pg/4 PUF	8.6	2.6
TUN	TUN (2017-I)	pg/2 PUF	3.6	6.4
TUN	TUN (2017-IV)	pg/2 PUF	3.5	6.4
TUN	TUN (2017-I+II+III+IV)	pg/6 PUF	10.1	25.9
TUN	TUN (2018-I)	pg/2 PUF	8.1	4.3
TUN	TUN (2018-II)	pg/2 PUF	4.6	8.4
TUN	TUN (2018-III)	pg/2 PUF	6.4	12.1
TUN	TUN (2018-IV)	pg/2 PUF	4.5	4.1
UGA	UGA (2017-I+II+III+IV)	pg/4 PUF	17.2	4.1
UGA	UGA (2018+2019-I+II+III+I)	pg/5 PUF	23.5	6.3
ZMB	ZMB (2017-I+II+III+IV)	pg/4 PUF	8.7	14.0
ZMB	ZMB (2018-I+II+III+IV)	pg/4 PUF	11.8	6.8

Table S6: PAS/PUFs: Concentration of brominated flame retardants (ng/PUF)

ISO3	Sample_ID	PBDE8	HBCDs	PBB153
COD	COD (2017-III)	1.9	4.1	<0.08
COD	COD (2017-IV)	3.6	0.44	0.08
COD	COD (2018-I)	2.4	0.22	<0.08
COD	COD (2018-II)	9.8	2.0	0.33
COD	COD (2018-III)	9.2	4.6	0.37
COD	COD (2018-IV)	16	2.3	0.87
COD	COD (2019-I)	9.5	2.1	0.46
COD	COD (2019-II)	1.3	0.38	<0.08
EGY	EGY (2017-I)	0.98	1.8	<0.08
EGY	EGY (2017-II)	1.3	1.5	<0.08
EGY	EGY (2017-III)	2.4	7.5	<0.08
EGY	EGY (2017-IV)	0.20	1.7	<0.08
EGY	EGY (2018-I)	1.2	<LOQ	<0.08
EGY	EGY (2018-II)	1.1	6.1	<0.08
EGY	EGY (2018-III)	0.00	1.4	<0.08
EGY	EGY (2018-IV)	0.68	4.1	<0.08
ETH	ETH (2017-II)	0.00	0.24	<0.08
ETH	ETH (2017-III)	0.00	0.72	<0.08
ETH	ETH (2017-IV)	0.55	0.37	<0.08
ETH	ETH (2018-I)	0.63	0.35	<0.08
ETH	ETH (2018-II)	0.00	0.40	<0.08
ETH	ETH (2018-III)	0.00	0.29	<0.08
ETH	ETH (2018-IV)	0.00	0.50	<0.08
ETH	ETH (2019-I)	0.00	1.9	<0.08
GHA	GHA (2017-I)	4.8	0.81	<0.08
GHA	GHA (2017-II)	4.8	0.81	<0.08
GHA	GHA (2017-III)	4.8	0.32	<0.08
GHA	GHA (2017-IV)	4.0	0.41	<0.08
GHA	GHA (2018-I)	5.0	0.39	<0.08
GHA	GHA (2018-II)	9.8	0.65	0.22
GHA	GHA (2018-III)	5.5	0.37	0.09
GHA	GHA (2018-IV)	7.4	0.26	0.08
KEN	KEN (2017-I)	0.17	0.10	<0.08
KEN	KEN (2017-II)	0.45	0.20	<0.08

Table S6 (continued)

ISO3	Sample_ID	PBDE8	HBCDs	PBB153
KEN	KEN (2017-III)	0.30	0.26	<0.08
KEN	KEN (2017-IV)	1.1	<LOQ	<0.08
KEN	KEN (2018-I)	0.72	0.07	<0.08
KEN	KEN (2018-II)	0.22	0.31	<0.08
KEN	KEN (2018-III)	0.91	0.03	<0.08
KEN	KEN (2018-IV)	0.54	<LOQ	<0.08
MAR	MAR (2017-II)	0.00	0.28	<0.08
MAR	MAR (2017-III)	0.00	0.21	<0.08
MAR	MAR (2017-IV)	0.00	0.24	<0.08
MAR	MAR (2018-I)	0.00	1.9	<0.08
MAR	MAR (2018-II)	0.00	0.30	<0.08
MAR	MAR (2018-III)	0.00	0.28	<0.08
MLI	MLI (2017-I)	1.3	0.13	<0.08
MLI	MLI (2017-II)	2.2	0.16	<0.08
MLI	MLI (2017-III)	1.8	0.13	<0.08
MLI	MLI (2017-IV)	0.92	0.11	<0.08
MLI	MLI (2018-I)	1.4	0.28	<0.08
MLI	MLI (2018-II)	1.7	0.21	<0.08
MLI	MLI (2018-III)	0.73	0.31	<0.08
MLI	MLI (2018-IV)	1.2	0.27	<0.08
MUS	MUS (2017-I)	0.00	0.05	<0.08
MUS	MUS (2017-II)	0.00	<LOQ	<0.08
MUS	MUS (2017-III)	0.00	<LOQ	<0.08
MUS	MUS (2017-IV)	0.00	0.22	<0.08
MUS	MUS (2018-I)	0.00	0.04	<0.08
MUS	MUS (2018-II)	0.00	1.9	<0.08
MUS	MUS (2018-III)	0.00	0.08	<0.08
MUS	MUS (2018-IV)	0.00	0.49	<0.08
NGA	NGA (2017-IV)	3.9	2.9	<0.08
NGA	NGA (2018-I)	4.5	2.4	<0.08
NGA	NGA (2018-II)	8.1	3.3	<0.08
NGA	NGA (2018-III)	2.3	2.0	<0.08
NGA	NGA (2018-IV)	3.3	9.3	<0.08
NGA	NGA (2019-I)	4.2	1.3	<0.08
NGA	NGA (2019-II)	2.2	2.4	<0.08
NGA	NGA (2019-III)	3.6	2.2	<0.08
SEN	SEN (2017-I)	0.00	0.51	<0.08
SEN	SEN (2017-II)	0.21	0.83	<0.08
SEN	SEN (2017-III)	0.00	v	<0.08
SEN	SEN (2017-IV)	0.00	0.10	<0.08
SEN	SEN (2018-I)	0.00	5.1	<0.08
SEN	SEN (2018-II)	0.28	0.51	<0.08
SEN	SEN (2018-III)	0.00	0.20	<0.08
SEN	SEN (2018-IV)	0.00	0.35	<0.08
TGO	TGO (2017-I)	0.19	1.7	<0.08
TGO	TGO (2017-II)	0.00	0.04	<0.08
TGO	TGO (2017-III)	0.00	0.43	<0.08
TGO	TGO (2017-IV)	0.00	1.3	<0.08
TGO	TGO (2018-I)	0.17	14	<0.08
TGO	TGO (2018-II)	0.16	5.2	<0.08

Table S6 (continued)

ISO3	Sample_ID	PBDE8	HBCDs	PBB153
TGO	TGO (2018-III)	0.16	9.2	<0.08
TGO	TGO (2018-IV)	0.00	8.8	<0.08
TUN	TUN (2017-I)	0.80	0.89	<0.08
TUN	TUN (2017-II)	5.5	0.70	<0.08
TUN	TUN (2017-III)	3.2	0.46	<0.08
TUN	TUN (2017-IV)	0.32	0.62	<0.08
TUN	TUN (2018-I)	0.32	0.57	<0.08
TUN	TUN (2018-II)	2.3	0.28	<0.08
TUN	TUN (2018-III)	2.6	0.18	<0.08
TUN	TUN (2018-IV)	0.58	0.57	<0.08
TZA	TZA (2018-IV)	0.00	39	<0.08
TZA	TZA (2019-I)	0.21	2.7	<0.08
TZA	TZA (2019-II)	0.00	<LOQ	<0.08
TZA	TZA (2019-III)	1.2	<LOQ	<0.08
TZA	TZA (2019-IV)	0.92	0.37	<0.08
UGA	UGA (2017-I,II,III)	0.16	0.04	<0.08
UGA	UGA (2017-IV)	0.00	0.16	<0.08
UGA	UGA (2018-I)	0.60	<LOQ	<0.08
UGA	UGA (2018-II)	0.62	<LOQ	<0.08
UGA	UGA (2018-III+IV)	1.4	30	<0.08
UGA	UGA (2019-I)	0.20	0.96	<0.08
ZMB	ZMB (2017-I)	0.23	0.11	<0.08
ZMB	ZMB (2017-II)	0.34	1.2	<0.08
ZMB	ZMB (2017-III)	1.3	1.1	0.13
ZMB	ZMB (2017-IV)	0.90	9.1	0.08
ZMB	ZMB (2018-I)	0.00	2.8	<0.08
ZMB	ZMB (2018-II)	1.2	27	<0.08
ZMB	ZMB (2018-III)	0.70	10	<0.08
ZMB	ZMB (2018-IV)	0.32	30	<0.08

Table S7: PAS/PUFs: Concentration of PFAS (pg/x PUF) Values <LOQ are shown in light orange color; NR indicates that quantification was not possible due to interferences

ISO-3	Sample ID	Unit	ΣPFOS	L-PFOA	L-PFHxS	FOSA
COD	COD (2017-II)	pg/1 PUF	319	180	<12	NR
COD	COD (2017-II+III+IV)	pg/3 PUF	442	440	<12	338
COD	COD (2017-III)	pg/1 PUF	168	201	<12	NR
COD	COD (2017-IV)	pg/1 PUF	155	NR	<12	NR
COD	COD (2018-I)	pg/1 PUF	201	263	<12	<25
COD	COD (2018-I+II+III+IV)	pg/4 PUF	NR	1,100	<12	NR
COD	COD (2018-II)	pg/1 PUF	380	299	44	<25
COD	COD (2018-III)	pg/1 PUF	176	150	<12	<25
COD	COD (2018-IV)	pg/1 PUF	98	109	<12	<25
COD	COD (2019-I)	pg/1 PUF	332	NR	24	NR
COD	COD (2019-I+II)	pg/2 PUF	NR	NR	NR	NR
COD	COD (2019-II)	pg/1 PUF	68	NR	19	NR
EGY	EGY (2017-I)	pg/1 PUF	1,331	1,194	<12	NR
EGY	EGY (2017-I+II+III+IV)	pg/4 PUF	4,088	2,402	<12	NR
EGY	EGY (2017-II)	pg/1 PUF	577	597	<12	NR
EGY	EGY (2017-III)	pg/1 PUF	NR	NR	<12	NR
EGY	EGY (2017-IV)	pg/1 PUF	2,480	480	<12	NR
EGY	EGY (2018-I+II+III+IV)	pg/4 PUF	NR	2,513	NR	<25

Table S7 (continued)

ISO-3	Sample ID	Unit	ΣPFOS	L-PFOA	L-PFHxS	FOSA
EGY	EGY (2018-II)	pg/1 PUF	595	720	59	NR
EGY	EGY (2018-III)	pg/1 PUF	396	454	67	NR
EGY	EGY (2018-IV)	pg/1 PUF	414	605	40	NR
ETH	ETH (2017-II)	pg/1 PUF	90	107	<12	NR
ETH	ETH (2017-II+III+IV)	pg/3 PUF	199	244	<12	127
ETH	ETH (2017-III)	pg/1 PUF	66	63	<12	<25
ETH	ETH (2017-IV)	pg/1 PUF	98	128	<12	NR
ETH	ETH (2018-I)	pg/1 PUF	112	94	<12	<25
ETH	ETH (2018-I+II+III+IV)	pg/4 PUF	228	402	<12	NR
ETH	ETH (2018-II)	pg/1 PUF	45	90	<12	<25
ETH	ETH (2018-III)	pg/1 PUF	56	126	<12	<25
ETH	ETH (2018-IV)	pg/1 PUF	<12	<13	<12	<25
ETH	ETH (2019-I)	pg/1 PUF	60	105	<12	35
GHA	GHA (2017-I)	pg/1 PUF	238	182	<12	NR
GHA	GHA (2017-I+II+III+IV)	pg/4 PUF	653	557	42	1,004
GHA	GHA (2017-II)	pg/1 PUF	227	142	<12	NR
GHA	GHA (2017-III)	pg/1 PUF	215	191	<12	<25
GHA	GHA (2017-IV)	pg/1 PUF	165	264	<12	NR
GHA	GHA (2018-I)	pg/1 PUF	122	171	<12	<25
GHA	GHA (2018-I+II+III+IV)	pg/4 PUF	587	611	39	NR
GHA	GHA (2018-II)	pg/1 PUF	125	125	<12	<25
GHA	GHA (2018-III)	pg/1 PUF	<12	150	<12	<25
GHA	GHA (2018-IV)	pg/1 PUF	140	NR	<12	<25
KEN	KEN (2017-I)	pg/1 PUF	NR	NR	<12	NR
KEN	KEN (2017-I+II+III+IV)	pg/4 PUF	2,055	558	<12	215
KEN	KEN (2017-II)	pg/1 PUF	NR	NR	<12	NR
KEN	KEN (2017-III)	pg/1 PUF	141	181	56	NR
KEN	KEN (2017-IV)	pg/1 PUF	NR	NR	21	NR
KEN	KEN (2018-I)	pg/1 PUF	53	129	13	<25
KEN	KEN (2018-I+II+III+IV)	pg/4 PUF	325	454	<12	95
KEN	KEN (2018-II)	pg/1 PUF	50	73	13	<25
KEN	KEN (2018-III)	pg/1 PUF	89	104	16	<25
KEN	KEN (2018-IV)	pg/1 PUF	60	88	13	<25
MAR	MAR (2017-II)	pg/1 PUF	88	128	<12	NR
MAR	MAR (2017-II+III+IV)	pg/3 PUF	250	442	<12	224
MAR	MAR (2017-III)	pg/1 PUF	447	232	<12	NR
MAR	MAR (2017-IV)	pg/1 PUF	82	201	<12	NR
MAR	MAR (2018-I)	pg/1 PUF	63	60	<12	<25
MAR	MAR (2018-I+II+III)	pg/3 PUF	190	432	<12	66
MAR	MAR (2018-II)	pg/1 PUF	60	123	16	NR
MAR	MAR (2018-III)	pg/1 PUF	117	197	17	NR
MLI	MLI (2017-I)	pg/1 PUF	237	287	<12	<25
MLI	MLI (2017-I+II+III+IV)	pg/4 PUF	974	742	72	240
MLI	MLI (2017-II)	pg/1 PUF	447	326	<12	NR
MLI	MLI (2017-III)	pg/1 PUF	171	139	<12	<25
MLI	MLI (2017-IV)	pg/1 PUF	253	186	<12	NR
MLI	MLI (2018-I)	pg/1 PUF	192	227	24	<25
MLI	MLI (2018-I+II+III+IV)	pg/4 PUF	703	787	<12	<25
MLI	MLI (2018-II)	pg/1 PUF	216	225	27	NR
MLI	MLI (2018-III)	pg/1 PUF	93	96	15	<25

Table S7 (continued)

ISO-3	Sample ID	Unit	PFOS	L-PFOA	L-PFHxS	FOSA
MLI	MLI (2018-IV)	pg/1 PUF	95	135	20	<25
MUS	MUS (2017-I)	pg/1 PUF	24	69	<12	NR
MUS	MUS (2017-I+II+III+IV)	pg/4 PUF	185	293	<12	158
MUS	MUS (2017-II)	pg/1 PUF	61	81	<12	NR
MUS	MUS (2017-III)	pg/1 PUF	113	80	<12	NR
MUS	MUS (2017-IV)	pg/1 PUF	<12	85	<12	NR
MUS	MUS (2018-I)	pg/1 PUF	34	62	<12	<25
MUS	MUS (2018-I+II+III+IV)	pg/4 PUF	185	252	<12	<25
MUS	MUS (2018-II)	pg/1 PUF	45	53	<12	<25
MUS	MUS (2018-III)	pg/1 PUF	32	57	14	<25
MUS	MUS (2018-IV)	pg/1 PUF	38	<13	<12	<25
NGA	NGA (2017-IV)	pg/1 PUF	67	NR	<12	<25
NGA	NGA (2018-I)	pg/1 PUF	<12	NR	<12	<25
NGA	NGA (2018-I+II+III+IV)	pg/4 PUF	NR	NR	<9.9	<25
NGA	NGA (2018-II)	pg/1 PUF	<12	151	<12	<25
NGA	NGA (2018-III)	pg/1 PUF	48	NR	<12	<25
NGA	NGA (2018-IV)	pg/1 PUF	58	NR	<12	<25
NGA	NGA (2019-I)	pg/1 PUF	87	259	<12	<25
NGA	NGA (2019-I+II+III)	pg/3 PUF	215	NR	<12	<25
NGA	NGA (2019-II)	pg/1 PUF	67	NR	<12	<25
NGA	NGA (2019-III)	pg/1 PUF	<12	NR	<12	<25
SEN	SEN (2017-I)	pg/1 PUF	726	833	<12	NR
SEN	SEN (2017-I+II+III+IV)	pg/4 PUF	848	1,584	<12	NR
SEN	SEN (2017-II)	pg/1 PUF	72	315	NR	NR
SEN	SEN (2017-III)	pg/1 PUF	252	129	<12	NR
SEN	SEN (2017-IV)	pg/1 PUF	237	327	<12	NR
SEN	SEN (2018-I)	pg/1 PUF	343	435	21	NR
SEN	SEN (2018-I+II+III+IV)	pg/4 PUF	984	1,213	<12	<25
SEN	SEN (2018-II)	pg/1 PUF	226	258	19	<25
SEN	SEN (2018-III)	pg/1 PUF	108	106	14	<25
SEN	SEN (2018-IV)	pg/1 PUF	346	289	25	<25
TGO	TGO (2017-I)	pg/1 PUF	48	173	<12	NR
TGO	TGO (2017-I+II+III+IV)	pg/4 PUF	260	381	<12	293
TGO	TGO (2017-II)	pg/1 PUF	38	107	<12	NR
TGO	TGO (2017-III)	pg/1 PUF	73	89	<12	NR
TGO	TGO (2017-IV)	pg/1 PUF	105	117	<12	54
TGO	TGO (2018-I)	pg/1 PUF	63	158	16	34
TGO	TGO (2018-I+II+III+IV)	pg/4 PUF	256	507	<12	NR
TGO	TGO (2018-II)	pg/1 PUF	75	105	15	<25
TGO	TGO (2018-III)	pg/1 PUF	50	75	<12	NR
TGO	TGO (2018-IV)	pg/1 PUF	41	65	13	NR
TUN	TUN (2017-I)	pg/1 PUF	202	217	<12	NR
TUN	TUN (2017-I+II+III+IV)	pg/4 PUF	645	891	51	330
TUN	TUN (2017-II)	pg/1 PUF	NR	525	<12	NR
TUN	TUN (2017-III)	pg/1 PUF	145	290	<12	NR
TUN	TUN (2017-IV)	pg/1 PUF	99	166	<12	<25
TUN	TUN (2018-I)	pg/1 PUF	125	146	18	NR
TUN	TUN (2018-I+II+III+IV)	pg/4 PUF	NR	1,088	<12	NR
TUN	TUN (2018-II)	pg/1 PUF	123	195	16	NR
TUN	TUN (2018-III)	pg/1 PUF	122	325	20	NR

Table S7 (continued)

ISO-3	Sample ID	Unit	ΣPFOS	L-PFOA	L-PFHxS	FOSA
TUN	TUN (2018-IV)	pg/1 PUF	102	126	20	NR
UGA	UGA (2017-I+II+III)	pg/1 PUF	96	221	<12	NR
UGA	UGA (2017-I+II+III+IV)	pg/4 PUF	183	301	<12	NR
UGA	UGA (2017-IV)	pg/1 PUF	59	103	<12	NR
UGA	UGA (2018-I)	pg/1 PUF	88	149	16	NR
UGA	UGA (2018-I+II+III)	pg/3 PUF	NR	NR	NR	NR
UGA	UGA (2018-II)	pg/1 PUF	43	63	12	NR
UGA	UGA (2018-III)	pg/1 PUF	75	147	19	NR
UGA	UGA (2019-I)	pg/1 PUF	77	156	<12	NR
ZMB	ZMB (2017-I)	pg/1 PUF	2,239	169	237	<25
ZMB	ZMB (2017-I+II+IV)	pg/3 PUF	58,326	4,011	9,608	4,135
ZMB	ZMB (2017-II)	pg/1 PUF	6,689	545	1,198	<25
ZMB	ZMB (2017-IV)	pg/1 PUF	24,181	1,596	2,750	NR
ZMB	ZMB (2018-I)	pg/1 PUF	10,024	430	782	992
ZMB	ZMB (2018-I+II+III+IV)	pg/3 PUF	86,534	7,865	14,278	NR
ZMB	ZMB (2018-II)	pg/1 PUF	25,479	1,712	2,893	1,872
ZMB	ZMB (2018-III)	pg/1 PUF	26,259	1,760	3,521	1,894
ZMB	ZMB (2018-IV)	pg/1 PUF	35,966	3,182	7,879	1,344

9.3.2. Water

Table S8: Concentration of PFAS in water: L-PFOS, br-PFOS, ΣPFOS, PFOA and PFHxS in (ng L^{-1}) for African samples collected under the UNEP project in the years from 2017 to 2019.

Sample_ID	Year	Season	PFOS	PFOA	PFHxS	L_PFOS	br_PFOS
Water sampling network							
EGY (2017-I)	Y2017	I	0.27	0.27	0.03	0.15	0.12
EGY (2017-II)	Y2017	II	0.34	0.46	0.05	0.15	0.19
EGY (2017-III)	Y2017	III	0.40	0.47	0.05	0.24	0.16
EGY (2017-IV)	Y2017	IV	0.48	0.93	0.04	0.33	0.15
EGY (2018-II)	Y2018	II	0.27	0.49	0.05	0.14	0.13
EGY (2018-III)	Y2018	III	0.19	0.36	0.06	0.07	0.12
EGY (2018-IV)	Y2018	IV	0.38	0.72	0.15	0.22	0.16
GHA (2017-I)	Y2017	I	0.27	0.31	0.07	0.21	0.06
GHA (2017-II)	Y2017	II	0.44	0.24	0.03	0.34	0.10
GHA (2017-III)	Y2017	III	1.21	0.31	0.08	0.95	0.26
GHA (2017-IV)	Y2017	IV	0.23	0.39	0.04	0.16	0.07
GHA (2018-I)	Y2018	II	0.00	0.23	0.03	0.00	0.00
GHA (2018-II)	Y2018	III	0.23	0.22	0.04	0.15	0.07
GHA (2018-III)	Y2018	IV	0.22	0.21	0.03	0.14	0.08
KEN (2017-I)	Y2017	I	1.52	0.59	0.39	1.04	0.48
KEN (2017-II)	Y2017	II	2.18	3.40	1.20	1.30	0.89
KEN (2017-III)	Y2017	III	2.06	2.17	1.54	0.78	1.28
KEN (2017-IV)	Y2017	IV	1.95	4.02	1.63	1.20	0.75
KEN (2018-I)	Y2018	I	0.81	0.94	0.35	0.46	0.35
KEN (2018-II)	Y2018	II	0.62	1.02	0.77	0.22	0.40
KEN (2018-III)	Y2018	III	1.94	2.13	1.17	0.64	1.30
KEN (2018-IV)	Y2018	IV	0.91	1.00	0.33	0.52	0.40
SEN (2017-I)	Y2017	I	0.08	0.07	0.00	0.08	0.00
SEN (2017-II)	Y2017	II	0.45	0.08	0.00	0.40	0.06
SEN (2017-III)	Y2017	III	0.55	0.21	0.03	0.41	0.15

Table S8 (continued)

Sample_ID	Year	Season	PFOS	PFOA	PFHxS	L_PFOS	br_PFOS
Water sampling network							
SEN (2017-IV)	Y2017	IV	0.12	0.05	0.00	0.08	0.04
SEN (2018-II)	Y2018	II	0.07	0.13	0.00	0.04	0.03
SEN (2018-III)	Y2018	III	0.36	0.12	0.03	0.21	0.15
TUN (2017-I)	Y2017	I	0.59	1.03	0.09	0.38	0.21
TUN (2017-II)	Y2017	II	0.62	0.92	0.08	0.34	0.28
TUN (2017-III)	Y2017	III	0.64	1.24	0.08	0.46	0.19
TUN (2017-IV)	Y2017	IV	0.60	1.31	0.11	0.38	0.22
TUN (2018-I)	Y2018	I	0.60	1.46	0.11	0.31	0.29
TUN (2018-II)	Y2018	II	0.36	0.76	0.13	0.25	0.11
TUN (2018-III)	Y2018	III	0.94	1.60	0.11	0.83	0.11
TUN (2018-IV)	Y2018	IV	0.73	1.01	0.09	0.47	0.26
ZMB (2017-I)	Y2017	I	0.68	0.35	0.23	0.54	0.14
ZMB (2017-II)	Y2017	II	2.64	0.22	0.21	2.11	0.54
ZMB (2017-III)	Y2017	III	0.55	0.14	0.00	0.44	0.11
ZMB (2017-IV)	Y2017	IV	0.13	0.13	0.00	0.09	0.04
ZMB (2018-I)	Y2018	I	0.14	0.14	0.04	0.09	0.05
ZMB (2018-II)	Y2018	II	0.12	0.12	0.05	0.08	0.04
ZMB (2018-III)	Y2018	III	0.06	0.12	0.03	0.06	0.00
ZMB (2018-IV)	Y2018	IV	0.07	0.10	0.00	0.04	0.04
National samples							
NGA	Y2019		0.34	0.24	0.08		
UGA/12/MTM	Y2019		0.10	0.24	0.00		
UGA-A (2019-1)	Y2019		0.44	0.56	0.09		
UGA-A (2019-2)	Y2019		0.45	1.86	0.13		
UGA-A (2019-3)	Y2019		0.03	0.12	0.00		
UGA-A (2019-4)	Y2019		0.04	0.11	0.00		

9.3.3. Human Milk

Table S9: Concentration of quantified chlorinated and brominated POPs in human milk (ng/g lipid) for African national pools

	COD	EGY	ETH	GHA	KEN	MLI	MUS	MAR	NGA	SEN	TZA	TGO	TUN	UGA	ZMB
Chlordanes	1.17	0	1.16	1.04	0.58	2.38	0	7.54	3.34	6.07	0.50	4.28	0	0	3.31
Dieldrin	0.83	0	0	1.43	1.34	1.66	0.502	1.79	1.15	1.94	2.11	0.89	1.03	0.561	2.03
DDTs	177	15.2	6560	69.1	75.8	493	506	215	89.0	173	341	568	86.6	96.0	503
HCHs	1.43	21.0	0	1.46	1.57	4.30	5.27	2.62	2.20	13.5	2.00	2.00	8.06	0	2.69
cis_Hepo	0	0	0	0	0	0.62	0	3.20	0	0.56	0	0	0.52	0	0
Mirex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HCB	1.53	2.29	1.67	3.51	1.73	2.58	2.72	3.4	3.67	3.37	1.26	1.91	3.24	1.67	1.4
SCCP	50.2	NA	70.0	77.0	56.0	69.0	111	66.0	51.0	102	121	39.8	51.0	46.4	112
PCB6	14.0	3.71	0.897	13.7	2.47	14.1	5.87	60.7	14.5	90.3	3.39	22.3	53	2.46	5.08
PBDE6	2.31	0.45	0.39	2.25	1.56	1.38	0.53	0.61	1.45	1.80					
														0.30	0.36
HBCD_a	0.20	0.80	0	0.30	0	0	0.30	0	0.70	0.10	0	0.50	0	0	0
Toxaphenes															

Table S10: Concentration of dl-POPs in human milk (pg/g lipid) for African national pools collected under the UNEP project from 2016 to 2019

			ETH	GHA	KEN	MLI	MUS	MAR	NGA	SEN	TZA	TGO	TUN	UGA	ZMB
TEQ_DF	9.97	5.59	1.02	2.68	1.52	2.90	1.54	2.95	2.51	5.74	1.68	3.31	2.24	1.24	1.37
TEQ_PCB	0.89	3.45	0.27	1.20	0.57	0.95	0.55	3.70	0.93	2.62	0.47	1.10	2.57	0.35	0.46

Table S11: Concentration of PFAS in human milk (pg/g f.w.) for African national pools collected under the UNEP project from 2016 to 2019

	COD	EGY	ETH	GHA	KEN	MLI	MUS	MAR	NGA	SEN	TZA	TGO	TUN	UGA	ZMB
PFOS	0	NA	9.11	15.6	0	21.9	12.8	13.6	10.4	10.2	7.50	12.8	19.8	0	0
PFOA	12.2	NA	6.20	11.3	10.4	12.8	18.0	15.7	14.3	13.6	11.0	17.7	18.1	8.37	8.62

UN environment programme

United Nations Avenue, Gigiri
P O Box 30552, 00100 Nairobi, Kenya
Tel +254 720 200200
unep-info@un.org
www.unep.org