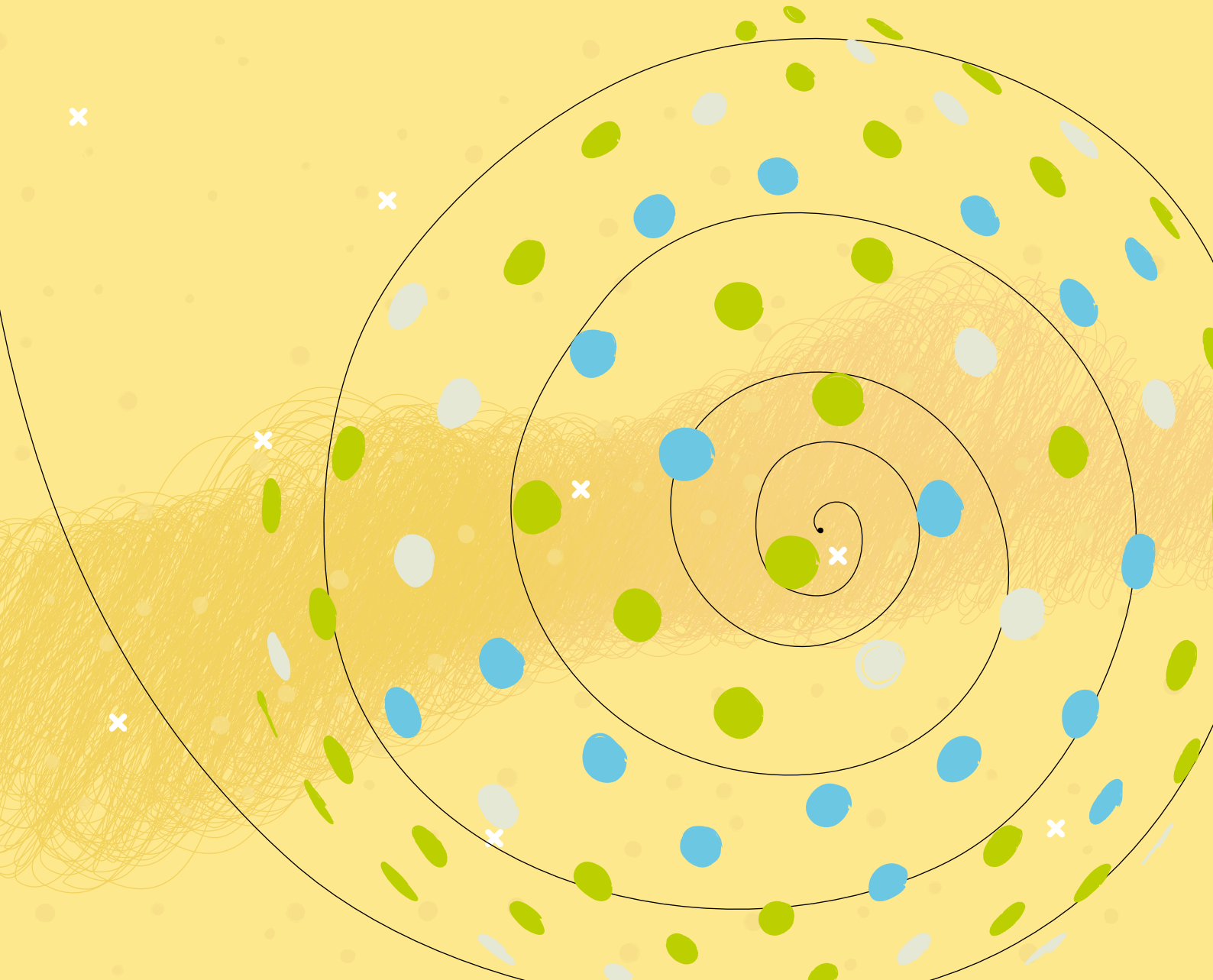
UN environment programme

Regional Report

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



ISBN: 978-92-807-4148-3

Job number: DTI/2638/GA

Disclaimer

Suggested citation: United Nations Environment Programme. (2024). *Implementation of the POPs Monitoring Plan under the Stockholm Convention in the Asian Region*. Geneva:

DOI: https://doi.org/10.59117/20.500.11822/45421

URL: https://wedocs.unep.org/20.500.11822/45421

ACKNOWLEDGEMENTS

This report was coordinated by the United Nations Environment Programme (UNEP), in the framework of the project title "Implementation of the POPs Monitoring Plan under the Stockholm Convention in Asian Region"; Project GEF ID 4894.

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

UNEP appreciates the information provided by project countries, Cambodia, the Philippines and Thailand to section 4.2. Results generated by national laboratories and; Cambodia, Lao PDR, Mongolia, Philippines, Thailand and Viet Nam to Section 7. Sustainability Plans. These two sections are based on the information included in the national reports submitted by each 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.

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UNEP, Chemicals and Health Branch, Geneva, Switzerland. 67 pp.

ABBREVIATIONS

AAS	Active air sampler
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

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SECTION 1

Introduction

Photo: ©Unsplash / Muhammad Haikal Sjukri

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). POPs can also have adverse effects on human populations leading to a variety of health problems. 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, during pregnancy and lactation women and children are susceptible as 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 POPs and coordinated by the United Nations Environment Programme (UNEP). The report covers the period of the UNEP/GEF GMP2 project implemented in seven countries in the Asian region between 2016 and 2021 (UNEP 2015a); it does not include the Pacific Islands region, which had a self-standing project and final regional report (UNEP 2015b; UNEP 2024a).

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 had the POPs listed until 2013 included (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 all POPs listed. In addition, agreement was reached to also include perfluorohexanesulfonic acid (PFHxS), which was recommended for listing by the POPs review committee 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) (see lower part of Table 1).

Table 1: Recommended analytes (UNEP 2019b)

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 PCDD/PCDF (17 congeners)
	Toxaphene	Congeners P26, P50, P62
COP-4	Chlordecone	Chlordecone
	alpha-hexachlorocylcohexane	a-HCH
	beta-hexachlorocylcohexane	b-HCH
	Lindane	g-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	a-HBCD, b-HBCD, g-HBCD
COP-7	Hexachlorobutadiene	HCBD
	Polychlorinated naphthalenes (PCN)	[PCN]
	Pentachlorophenol	[PCP, PCA]
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/analyte 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 collection of human milk is a non-invasive sampling method and thus, has many practical and procedural advantages over the collection of other biological samples, such as blood or adipose tissue. The biomonitoring component of the GMP has been put in place by 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 (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 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; UNEP 2019b; Fiedler *et al*. 2020a) for PFOS and PFOA; not for the other POPs. The GMP guidance document as "Updated draft", (UNEP 2019b), 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.

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SECTION 2

Characteristics of the participating countries

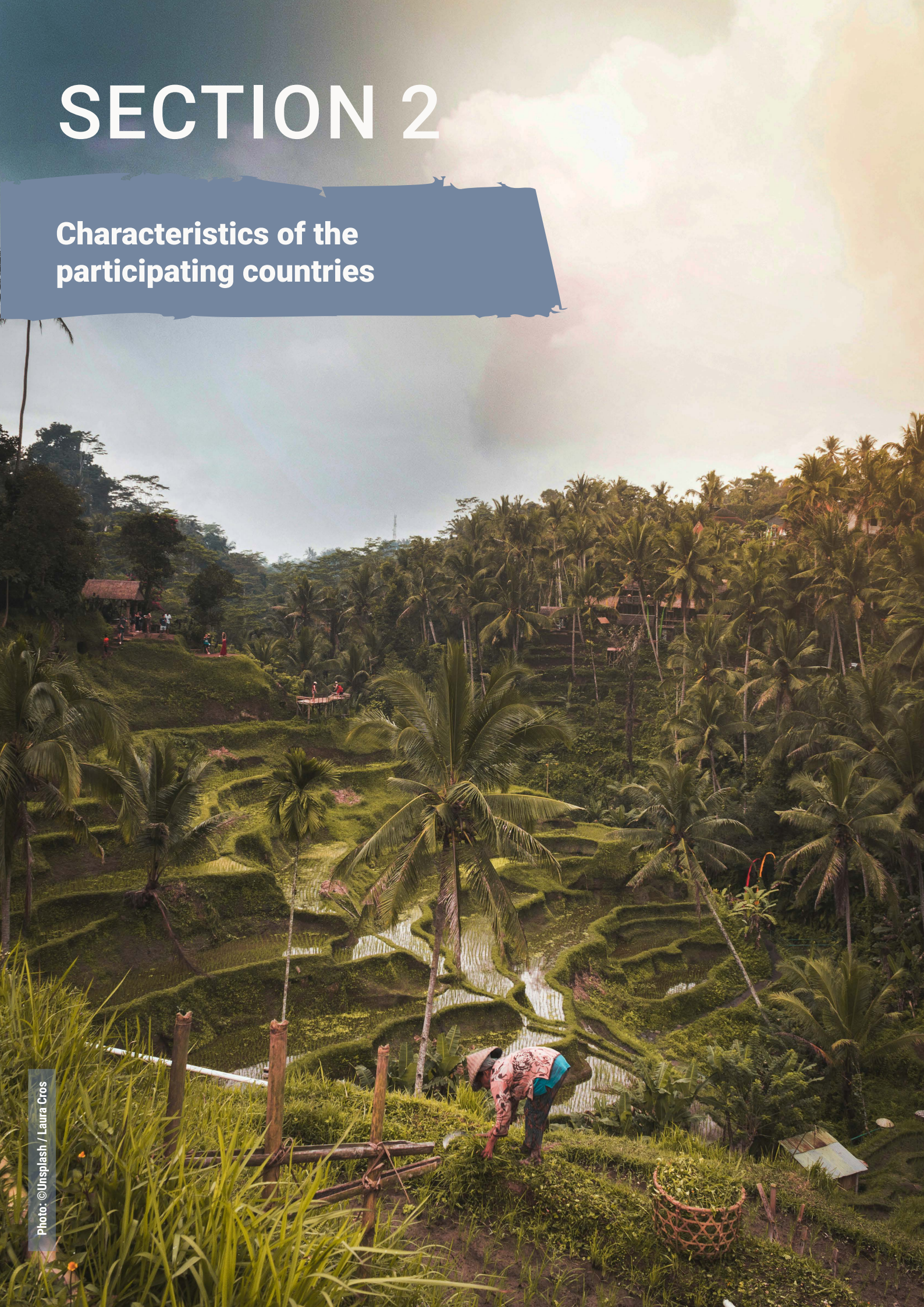


Photo: ©Unsplash / Laura Cros

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, LM, UM, H) as the gross national income (GNI) per capita in US$ according to the Atlas methodology (World Bank n.d. a). Economically, six countries are lower-middle income countries (WBC classification 'LM') and only Thailand belongs to the upper-middle income group (WBC classification 'UM').

The countries in the Asian region differ largely as to population and population density, which is defined as population density per square kilometer per square kilometer of land area (population/km²). Mongolia is the least densely populated country (PD_Code A, having less than 30.6 inhabitants per km²) whereas the Philippines, Thailand and Viet Nam are more densely populated (PD_Code C, having between 100 inhabitants per km² and 499.99 inhabitants per km² (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.

Photo: ©Pixabay / Sasint

SECTION 3

National activities with respect to sampling and POPs analysis

Photo: ©Unsplash / National Cancer Institute

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, Masaryk University, equipped all participating countries with PAS and preconditioned PUFs as shown below:

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

Table 2: 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, pentachlorobenzene, 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, pentachlorobenzene, 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 are 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).

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 2017c; 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 2.

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. Exposure periods were designated as follows

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

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

Photographic impressions of the air sampling sies with the PAS exposed are shown below; no photo was provided by Indonesia.

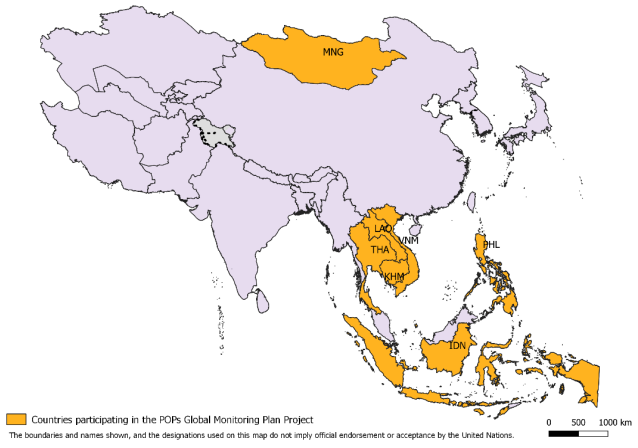


Figure 1: Geographical sketch of countries participating in the UNEP/GMP2 Asia project

Sampling site for air with PAS/PUF: Cambodia, © Ministry of Environment (Cambodia)

Sampling site for air with PAS/PUF: Lao PDR, © Ministry of Natural Resources and Environment (Lao PDR)

Sampling site for air with PAS/PUF: Mongolia, © Mongolian Academy of Sciences

Sampling site for air with PAS/PUF: Philippines, © Department of Environment and Natural Resources (Philippines)

Sampling site for air with PAS/PUF: Thailand, © Thammasat University

Sampling site for air with PAS/PUF: Viet Nam, © Ministry of Natural Resources and Environment (Viet Nam)

3.1.2. Core matrix air with active sampler

Following the recommendation in the GMP guideline (UNEP 2019b), one site in each Mongolia and Viet Nam were selected to host an active air sampler (AAS).

Sampling site for air with AAS: Mongolia, © Mongolian Academy of Sciences

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 2019b); PFOA, its salts and PFOA-related compounds have been listed in Annex A with specific exemptions in 2019 (Secretariat of the Stockholm Convention 2019c). 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 perfluorinated compounds (PFAS) only (UNEP 2019b; 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 two were from the Asian region, Mongolia and Viet Nam. The identification of the sampling sites is provided in Appendix in Table S 3. The graphical sketch of the water sampling sites is shown in Figure 2.

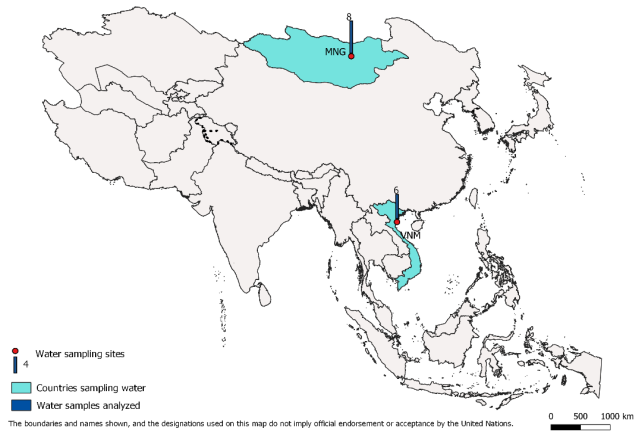


Figure 2: Geographical sketch of water sampling locations under UNEP/GMP2 Asia project

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; Asia contributed with 14 samples, which corresponds to 80 % realization of the planned activities (two countries with four samples per year during two years; thus, a total of eight samples per country).

The water samples received by the expert laboratory were as shown in Table 3

Table 3: Number of water samples available

Year	MNG	VNM	Overall
2017	4	2	6
2018	4	3	7
2019	-	1	1
Tolal	8	6	14

Photographic impressions of the water sampling site in Mongolia is shown below. For the Viet Nam site, no photo was received.

Sampling site for water: Mongolia

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. x
- 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 for analysis of brominated and chlorinated POPs. After arrival, CVUA took one aliquot of 10 mL and shipped to MTM Research Centre at Örebro University for PFAS analysis. The results are reported *per* national pool.

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 by participating country.

Cambodia

The coordination scheme is setting up to facilitate the project implementation for activities B - Human milk POPs sampling. There are four main key agencies cooperating together to ensure the completion of project activities listed from identifying the sampling site, examinating the site, conducting the site sampling, collecting the samples, sending the samples, analyzing and report the result. The four key agencies cooperating and significantly involve in the project implementation include: The department of Hazardous Substance Management, Laboratory, Tboung Khmum Provincial Department of Health, and project international laboratories (CVUA Freiburg, Germany and MTM Örebro University, Sweden).

Tboungkhmum province is selected for conducting POPs Human Milk Sampling. In particular, there are 3 referral hospitals (Ou Reang Ov, Preah Norodom SIHANOUK Tboungkhmum and Ponhean Kraek) are selected to cooperate and assist in the mother milk collection. Those referral hospitals have a high record on providing health services to people in the province. In the sampling process, there are 50 human milk donors needed for the survey.

The sample is collected directly to the collecting sampling bottles and stored in the cooler box at about 4 °C, then the sample is transferred to keep in the freezer at -20 °C.

By facilitated from healthcare workers of the three provincial referral hospitals of Tboungkhmum province. There are 50 mothers identified as human milk donors. Each mother is requested to provide 50 ml of milk for the sampling. The technical team of laboratory with cooperated from healthcare workers started human milk sampling from May to June 2019.

From each of the 50 human milk samples, the 25 mL were kept separately for national analysis and 25 mL each were combined into the national pool sample.

Mongolia

The human milk sampling survey was conducted following a protocol originally developed by WHO (2007) and modified by UNEP (2017a). One national pool as a representative sample was prepared by collecting 50 mL of breast milk from 50 primiparae.

Selection of donor was done after giving birth as the chosen method. The procedure of preparation of collecting milk samples such as selecting donors and interviewing possible candidates took almost three months. A total of 212 mothers were interviewed and finally, 65 mothers were chosen as possible candidates fulfilling the criteria given in the SOP for the sampling of human breast milk. However, finally, when collecting milk samples, 50 mothers were included in this human milk survey.

The sample collection was done from February to May 2018. The donor mothers were selected from seven different districts in the Ulaanbaatar area. Only one donor mother was selected from the countryside that was from Zavkhan aimag (west part of Mongolia).

Before taking the sample, the project team had some awareness-raising lectures on the importance of breastfeeding, although most mothers have the intention to support breastfeeding in Mongolia. Then, the donors were asked to give their written consent on the standard Informed Consent Form. Afterwards, donors were instructed to collect a minimum of 50 mL of milk by hand expression and milk samples were inserted into the clean glass jar.

After the collection of individual samples from 50 mothers, the samples were stored in the refrigerator. The ethics commission meeting took another two months to get approval. Finally, the pooled sample was sent to the expert laboratory in August 2018.

Although we have followed all the instructions given in the guidelines for organization, sampling, and analysis prepared by UNEP, due to the shipment condition, the pooled samples that arrived at the expert lab was no longer frozen. According to the expert laboratory, the sample didn't look spoiled and was processed.

Thailand

The human milk sampling activities was carried out by the support of the Department of Health and taking into account the concerns of the National Sub-committee at its meeting 1/2016 in April 2016, regarding the public dissemination of their results.

In brief: Human milk samples were collected by the cooperation of 12 health centers under the Department of Health across the country, five samples from each health center. The 12 health centers were located in the following provinces: 1) Chiang Mai 2) Phitsanulok 3) Nakhon Sawan 4) Saraburi 5) Ratchaburi 6) Chonburi 7) Khon Kaen 8) Udon Thani 9) Nakhon Ratchasima 10) Ubon Ratchathani 11) Nakhon Si Thammarat, and 12) Yala. Donor mothers were selected through a human milk survey, potential donor interview, donor selection and human milk sampling were done according to the UNEP guideline (UNEP 2017a).

Table 4: Overview of the human milk survey process in Thailand

Sampling	Analytical procedures	QA/QC
Collected from primiparous breast-feeding women in Thailand Based on WHO protocol Strategy for selecting donors Interview potential donors, and consider diet, rural and urban residence and avoiding occupational exposure, proximity to potential POPs releasing activities	**Organochlorine pesticides:** Cleanup in a Florisil column GC/MS PCB: Cleanup in a Florisil column GC-ECD **For dl-PCBPCB:** HRGC/HRMS-SIM Hexane extraction and purification by a multistage column of silica gel. Addition of 13C-labeled substances as surrogate standard substances	Inter-laboratory quality assessment studies

Viet Nam

The sampling followed the guideline of UNEP, thus, only primiparae were included.

- For the national pooled sample of human milk collected in Viet Nam, human breast milk samples were collected from 11 cities and provinces from north to south of Viet Nam.
- In Viet Nam, with population over 90 million, 55 individual samples are collected from 11 cities and provinces. The selection of location is based on the key socio-economic zones throughout the countries.
- For the national pool, 20 mL from each of the 55 individual samples were pooled to one national representative sample and sent to the expert laboratories for analysis.
- The total volume of the pooled samples was 1 100 mL.

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. Cambodia

The coordination scheme was set-up to facilitate the project implementation for activities C. National Sample Analysis. There are three main key agencies cooperating to ensure the completion of this project activities. The three key agencies cooperating and significantly involving to the project implementation include: The department of Hazardous Substance Management, Laboratory of Ministry of Environment and Laboratory of Institute of Technology of Cambodia.

Figure 3: National sample analysis coordination scheme

The main cooperation work of those agencies is described as follows:

- The department of Hazardous Substance Management works closely with the laboratories and donors to ensure the successful project implementation according to the setting objective and timeframe. To be specific, the department is in charge of administration, finance, cooperation and facilitating with stakeholders, reporting to donor and overall project coordination.
- Laboratory of Ministry of Environment cooperates with Institute of Technology of Cambodia in the analysis of PUF disk from air sampling.

Analytical method for PUFs: Pesticide extraction followed a method described by Lammel et al. 2007 and Yusa et al. 2009. The PUF disk was extracted by Soxhlet with200 mL acetone for 8 h. The thimble was then further extracted by sonication with 150 mL of n-hexane for another 30 min. The extraction solvents were combined and evaporated to

dryness using rotary evaporator. One milliliter of n-hexane was added to dissolve the extract and subject to GC-MS analysis. The column used was DB-5ms with the length of 30 m, thickness 0.25 µm and diameter 0.25 mm. One microliter of sample was injected to GC-MS by auto injector using spitless mode. After that, the column oven temperature was programmed from 40 °C to 310 °C by holding for 2 min at 40 °C, increased the temperature to 310 °C with a rate of 8 °C/min, and then held for 5 minutes. The carrier gas was ultra-pure helium at the total flow of 50 mL/min while the column flow was 1.23 mL/min. The ion source temperature was 200 °C and the temperature of the interface was 300 °C. All pesticides were identified by retention time and specific ions and quantified by the external standard method. The analytical spectrum included many substances that are not listed in the Stockholm Convention. From the POPs listed in the Annex A of the Stockholm Convention, only HCB was quantified in two PUFs, namely 2018-II and 2018-III at 40 ng/PUF and 47 ng/PUF. All other samples were below the LOQ of 15 ng/PUF.

3.2.2. Thailand

dl-POPs analysis

PCDD/PCDF and dl-PCB were analyzed by the Department of Environmental Quality Promotion (DEQP), Thailand using the in-house method WI-9-1-D1001 based on the manual by the Ministry of Environment, Japan (2008) for examining dioxins in ambient air.

- Extraction step: Polyurethane foam was pressed into a thimble and spiked with the clean-up label compound (13C) and Soxhlet extracted with 500 mL of toluene for 20 hours.
- Concentrate the extractant by rotary evaporator until 5 mL.
- Clean-up step: the concentrated solution was cleaned up with multilayer column and activated carbon column
- Concentrate the cleanup solution to 100 µL and add syringe spike label compound (13C) as internal standard and injection to GC/HRMS.

Results were reported for two samples from 2019 with no PCDD or PCDF congener above LOQ. For dl-PCB results, see the Thailand national report.

PFAS analysis

Analysis of PFOS was performed by Mahidol University (MU), Thailand.

Sample extraction: Each polyurethane foam filter (PUFs) was weighted and cut into small pieces. Then, the sample was transferred into a 33 mL stainless steel extraction cell of Dionex™ ASE™ 200 accelerated solvent extraction system (ASE). The cell was filled with stainless steel ball and put into ASE cell tray for extraction using methanol (HPLC grade). The ASE conditions were pressure 2000 psi, temperature 100 °C, pre-heat 5 min, heat 5 min and static 10 min, flush 40 % and purge time 120 s with 3 extraction cycles.

Sample pretreatment and clean up: After the extraction, the sample was dried using water bath and reconstituted with ultrapure water (Milli-Q) 400 mL. All samples were concentrated by solid phase extraction (SPE) using Presep-C Agri (short) cartridges. The cartridges were pre-conditioned using the sequence of 3 mL methanol (HPLC grade), 2 mL acetonitrile (HPLC grade) and 5 mL ultrapure water (Milli-Q), respectively, before loading the sample. The samples were eluted with methanol (HPLC grade) and purged until dried using block heating bath associated with high purity nitrogen gas purge. Finally, the samples were reconstituted with 1 mL 40% acetonitrile and transferred to the vial before analyzing by liquid chromatography coupled with tandem mass spectrometry (LC/MS/MS).

Sample analysis: The samples were analyzed using Agilent 1200SL HPLC coupled with Agilent 6400 tandem mass spectrometry (MS/MS) and operated by electrospray ionization (ESI) negative mode. The column was Eclipse plus C18 (2.1 mm×100 mm, 1.8 µm) from Agilent Technologies, USA. The mobile phases consisted of buffer solution 10 mM ammonium acetate in ultra-pure water and acetonitrile at 0.25 mL/min flow rate. The PFOS precursor ion (m/z) and the product ion (m/z) were 499>80 and the injection volume was 10 µL. The results are summarized below.

Table 5: Summary of results from the analysis of PFOS by Mahidol University in Thailand

POPs	Unit	Concentration						
		2017-IV	2018-I	2018-II	2018-III	2018-IV	2019-I	2019-II
L-PFOS	ng/PUF	-	-	0.078	ND	0.268	ND	ND
br-PFOS	ng/PUF	-	-	0.577	0.556	0.848	0.459	0.579
ΣPFOS	ng/PUF	-	-	0.655	0.556	1.116	0.459	0.579

3.2.3. Philippines

Two of the eight PUFs from the passive air samplers that were collected for each sampling event, were designated to be analyzed by the EMB Central Office Laboratory; one for selected organochlorine pesticides (OCPs) and the other for PCB.

The EMB Central Office Laboratory performed analysis of PCB using its established methodology based on the methods of the United States Environmental Protection Agency (US EPA), determining 19 PCB congeners, including the three indicator PCB, namely, PCB 138, PCB 153, and PCB 180. The national laboratory was not able to quantify any of the three PCB congeners in any PUF.

The national laboratory analyzed almost all OCPs, HCB, PeCBz and HCBD but only a few compounds had amounts above the LOQ (see Table 6). From the HCHs, lindane was quantified once (4.5 ng/PUF), none of the DDT could be quantified. The highest detection frequency had chlordane.

Table 6: Summary of results from the analysis of PCB by EMB Central Office Laboratory in the Philippines

OCP	PHL (2018-I)	PHL (2018-II)	PHL (2018-III)	PHL (2019-I)	PHL (2019-II)	PHL (2019-III)
Lindane (g-HCH)	< 2.0	4.50	< 2.0	< 2.0	< 2.0	< 2.0
α-Endosulfan	< 2.0	2.1	< 2.0	4.70	4.2	< 30
cis-chlordane	< 2.0	2.0	< 2.0	2.80	4.1	< 30
trans-chlordane	4.20	5.00	< 2.0	11.1	< 2.0	< 30

SECTION 4

Results from expert laboratories

Photo: ©UNEP / Victor Estellano

4. RESULTS FROM EXPERT LABORATORIES

Chemical analysis was performed by the national POPs laboratories assigned by the national coordinator in each country (for results, see section 4.2) and so-called 'expert laboratories' with the following assignments according to POPs group and matrix. In the Asian project, these included:

- 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 printed 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, 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 2015c).

4.1. Chemical analysis and reporting of results

Generic protocols for the analysis of POPs had been developed in a previous GEF project for organochlorine pesticides and indicator PCB (PCB_6) (UNEP 2014a), polybrominated diphenyl ethers (PBDEs) (UNEP 2014b), and perfluoroalkane substances (UNEP 2015d). 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 dioxin like-POPs (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 TEQs are reported for the combined PCDD/PCDF, namely for seven 2,3,7,8-substituted PCDD and ten 2,3,7,8-substituted PCDF (expressed as TEQ_DF) and TEQ for 12 non-ortho and mono-ortho PCB (expressed as TEQ_PCB). Concentrations for dl-POPs were reported in picogram per PUF (pg TEQ/PUF) for PAS/PUF air samples, femtogram *per* cubic meter (fg TEQ/m^3) for AAS samples, and picogram *per* gram lipid (pg/g lipid) for human milk.

In order to compare, results should be reported according to number of PUFs (and exposed period); thus, when four PUFs were combined, the amount should be divided by a factor of 4 to receive the amount *per* one PUF and one period. 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 49 datasets as shown in Table 7; the summary of results per group of chlorinated POPs (Cl-POPs) (as sums of isomers or congeners) are shown in Table 8. Graphical sketches provide the summary and comparison of results of chemical analyses for Cl-POPs as Figure 4. All data refer to 1 PUF and 3 month of exposure time and are given in ng/PUF.

Table 7: Number of PUFs per country and year, analyzed for Cl-POPs

	2017 (N=8)	2018 (N=27)	2019 (N=14)	Overall (N=49)
KHM	0	4	2	6
IDN	0	4	4	8
LAO	1	4	2	7
MNG	3	4	1	8
PHL	0	3	2	5
THA	1	4	2	7
VNM	3	4	1	8

The highest mean value was found for HCBD, a relatively newly listed POPs (Figure 4 and Table 8). The high value was due to the data generated in Mongolia (range: 3.00 ng/PUF-334 ng/PUF; mean value = 75.7 ng/PUF), which were much higher than in all other countries. The median value for HCBD was moderate (3.0 ng/PUF). The highest median value was found for DDT with the highest amounts found in Cambodia, followed by Viet Nam and Indonesia. For chlordane and HCHs the mean values were substantially higher than their respective median values. For PCB_6, closeness of mean and median values indicates similar levels in all countries. Striking are the high values in Mongolia, which had much higher values for HCHs and HCB than the other Asian countries. For other POPs, there is often one country that exhibits high values, such as LAO for chlordane, VNM for α-endosulfan, MNG for PeCBz.

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

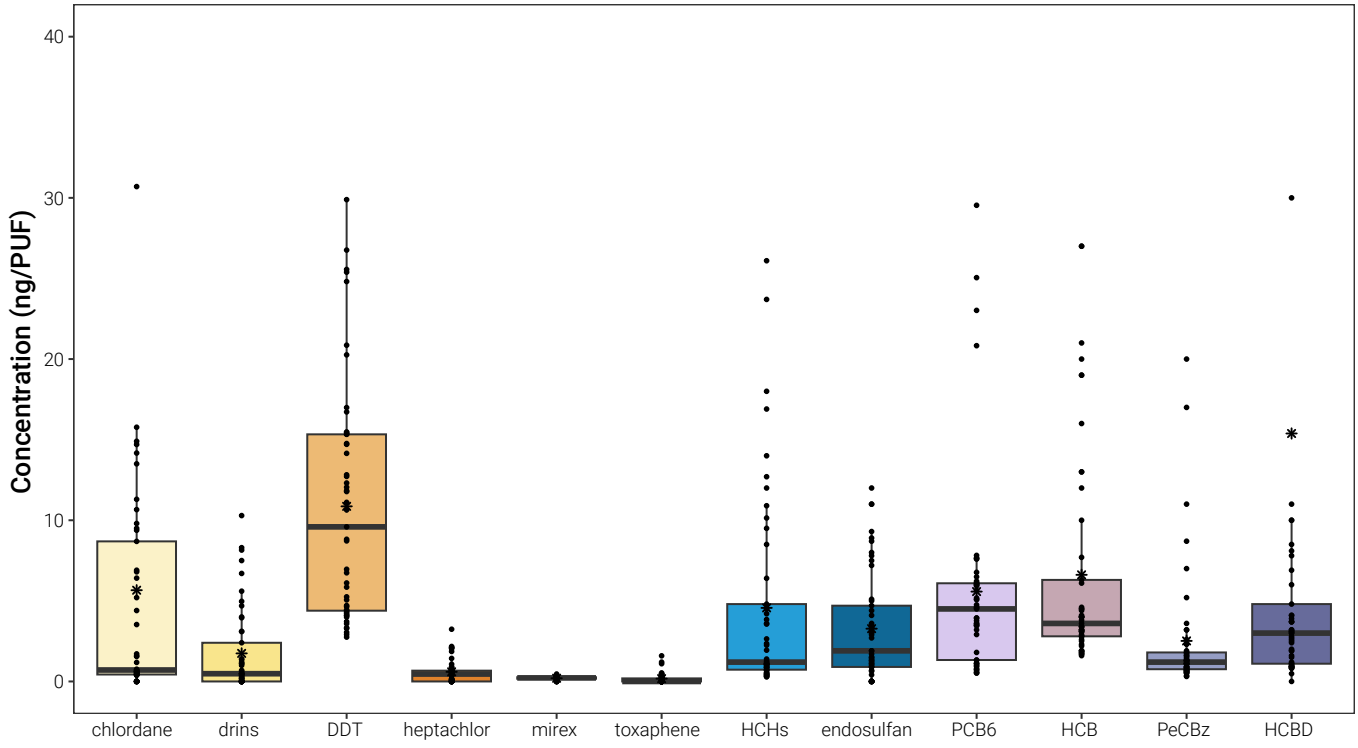


Figure 4: PAS/PUF: Box plots for chlorinated POPs in PAS/PUFs: summary across all samples (n=49). Y-axis zoomed to 40 ng/PUF

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

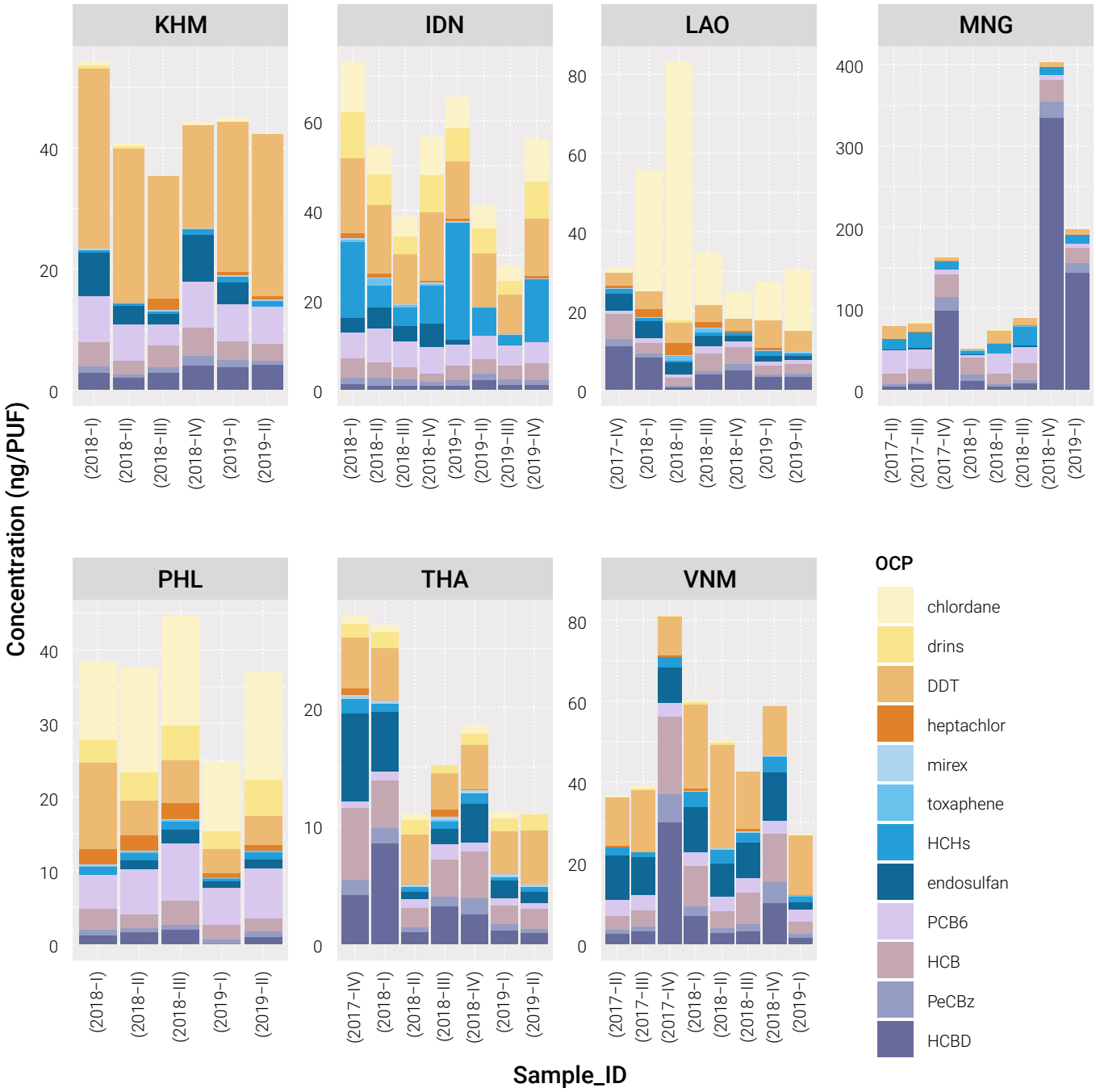


Figure 5: PAS/PUF: Stacked bar graphs for chlorinated POPs by country and sample (n=49)

Table 8: Chlorinated POPs in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (ng/PUF). note: 0 = LOQ

POPs	Central tendencies	KHM (N=6)	IDN (N=8)	LAO (N=7)	MNG (N=8)	PHL (N=5)	THA (N=7)	VNM (N=8)	Overall (N=49)
chlordane	Mean (SD)	0.393 (0.328)	6.98 (2.66)	20.5 (21.9)	0.724 (0.679)	12.8 (2.52)	0.441 (0.311)	0.314 (0.268)	5.66 (10.8)
	Median [Min, Max]	0.495 [0, 0.760]	6.66 [3.53, 11.3]	13.5 [1.55, 65.7]	0.445 [0, 1.71]	14.2 [9.50, 14.9]	0.600 [0, 0.710]	0.420 [0, 0.620]	0.710 [0, 65.7]
drins	Mean (SD)	0.163 (0.253)	6.71 (2.38)	0.0714 (0.189)	0.223 (0.165)	3.82 (1.08)	1.12 (0.237)	0.184 (0.246)	1.74 (2.66)
	Median [Min, Max]	0 [0, 0.500]	7.10 [3.10, 10.3]	0 [0, 0.500]	0.225 [0, 0.440]	3.95 [2.40, 4.97]	1.12 [0.690, 1.40]	0.0700 [0, 0.630]	0.480 [0, 10.3]
DDT	Mean (SD)	24.0 (4.65)	13.1 (2.65)	4.57 (1.36)	8.66 (4.66)	5.93 (3.40)	3.98 (0.555)	15.6 (5.20)	10.9 (7.33)
	Median [Min, Max]	25.1 [17.0, 29.9]	12.8 [8.72, 16.7]	4.44 [2.91, 6.96]	7.78 [2.75, 15.3]	4.71 [3.33, 11.8]	4.21 [3.05, 4.64]	14.4 [9.59, 25.6]	9.59 [2.75, 29.9]
heptachlor	Mean (SD)	0.523 (0.710)	0.421 (0.385)	1.21 (1.13)	0.389 (0.368)	1.53 (0.782)	0.196 (0.298)	0.260 (0.291)	0.596 (0.728)
	Median [Min, Max]	0.335 [0, 1.86]	0.400 [0, 1.07]	0.670 [0, 3.24]	0.320 [0, 0.910]	2.04 [0.630, 2.17]	0 [0, 0.670]	0.205 [0, 0.660]	0.460 [0, 3.24]
mirex	Mean (SD)	0.203 (0.0372)	0.295 (0.0773)	0.199 (0.0919)	0.170 (0.116)	0.0840 (0.0789)	0.254 (0.0493)	0.155 (0.0984)	0.199 (0.100)
	Median [Min, Max]	0.210 [0.140, 0.250]	0.265 [0.210, 0.460]	0.220 [0, 0.270]	0.200 [0, 0.310]	0.120 [0, 0.170]	0.260 [0.170, 0.330]	0.200 [0, 0.230]	0.220 [0, 0.460]
toxaphene	Mean (SD)	0 (0)	0.379 (0.545)	0.370 (0.544)	0.156 (0.158)	0.180 (0.00707)	0.0257 (0.0680)	0.0675 (0.125)	0.173 (0.329)
	Median [Min, Max]	0 [0, 0]	0.225 [0, 1.59]	0 [0, 1.20]	0.170 [0, 0.460]	0.180 [0.170, 0.190]	0 [0, 0.180]	0 [0, 0.280]	0 [0, 1.59]
HCHs	Mean (SD)	0.678 (0.304)	10.4 (8.08)	0.797 (0.301)	12.7 (5.82)	0.896 (0.342)	0.639 (0.317)	2.55 (1.05)	4.56 (6.29)
	Median [Min, Max]	0.700 [0.330, 1.05]	7.45 [2.25, 26.1]	0.730 [0.470, 1.27]	11.5 [4.50, 23.7]	1.03 [0.290, 1.11]	0.570 [0.300, 1.20]	2.50 [1.10, 3.84]	1.20 [0.290, 26.1]
endosulfan	Mean (SD)	3.90 (3.06)	2.20 (2.17)	2.59 (1.35)	0.636 (1.00)	1.06 (0.695)	2.88 (2.56)	8.85 (3.13)	3.27 (3.39)
	Median [Min, Max]	3.35 [0, 7.80]	2.20 [0, 5.10]	2.70 [1.00, 4.40]	0.205 [0, 2.90]	1.20 [0, 1.90]	1.50 [0.640, 7.50]	9.10 [1.90, 12.0]	1.90 [0, 12.0]
PCB6	Mean (SD)	6.16 (1.53)	5.52 (1.04)	1.20 (0.293)	15.0 (10.6)	6.07 (1.29)	0.747 (0.279)	3.54 (0.357)	5.57 (6.22)
	Median [Min, Max]	6.13 [3.46, 7.66]	5.37 [4.50, 7.63]	1.10 [0.950, 1.80]	13.7 [3.58, 29.5]	6.09 [4.62, 7.82]	0.710 [0.520, 1.33]	3.56 [2.91, 3.94]	4.50 [0.520, 29.5]
HCB	Mean (SD)	3.42 (0.823)	3.23 (0.774)	3.53 (1.61)	19.5 (5.50)	2.32 (0.638)	3.17 (1.67)	7.91 (5.57)	6.61 (6.78)
	Median [Min, Max]	3.35 [2.30, 4.60]	3.30 [1.80, 4.40]	2.80 [1.90, 6.30]	19.5 [13.0, 27.0]	1.90 [1.80, 3.20]	3.10 [1.60, 6.10]	5.90 [3.10, 19.0]	3.60 [1.60, 27.0]
PeCBz	Mean (SD)	0.995 (0.413)	1.35 (0.295)	1.02 (0.490)	8.66 (6.82)	0.672 (0.101)	0.846 (0.454)	2.60 (2.26)	2.51 (3.94)
	Median [Min, Max]	0.990 [0.580, 1.70]	1.35 [0.870, 1.80]	0.910 [0.510, 1.80]	6.15 [2.60, 20.0]	0.690 [0.520, 0.760]	0.800 [0.310, 1.30]	1.60 [0.870, 7.00]	1.20 [0.310, 20.0]
HCBD	Mean (SD)	3.18 (0.854)	1.04 (0.398)	4.91 (3.53)	75.7 (117)	1.13 (0.731)	3.05 (2.70)	7.44 (9.55)	15.4 (52.4)
	Median [Min, Max]	3.25 [1.90, 4.10]	0.905 [0.820, 2.00]	3.70 [0.480, 11.0]	8.90 [3.00, 334]	1.20 [0, 1.90]	2.50 [0.940, 8.50]	3.05 [1.50, 30.0]	3.00 [0, 334]

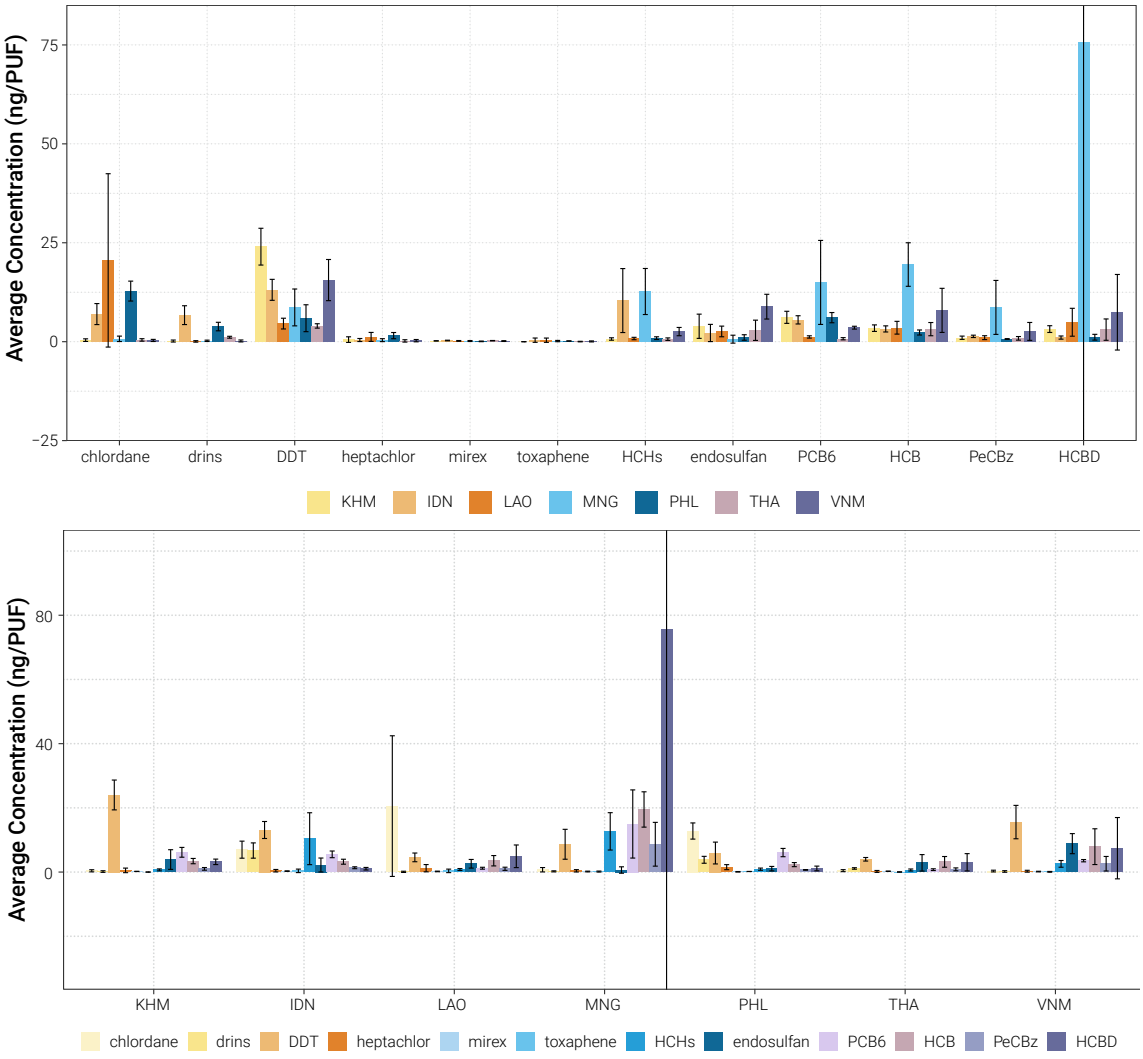


Figure 6: PAS/PUF: Mean values and SD for chlorinated POPs in PAS/PUF (n=49)

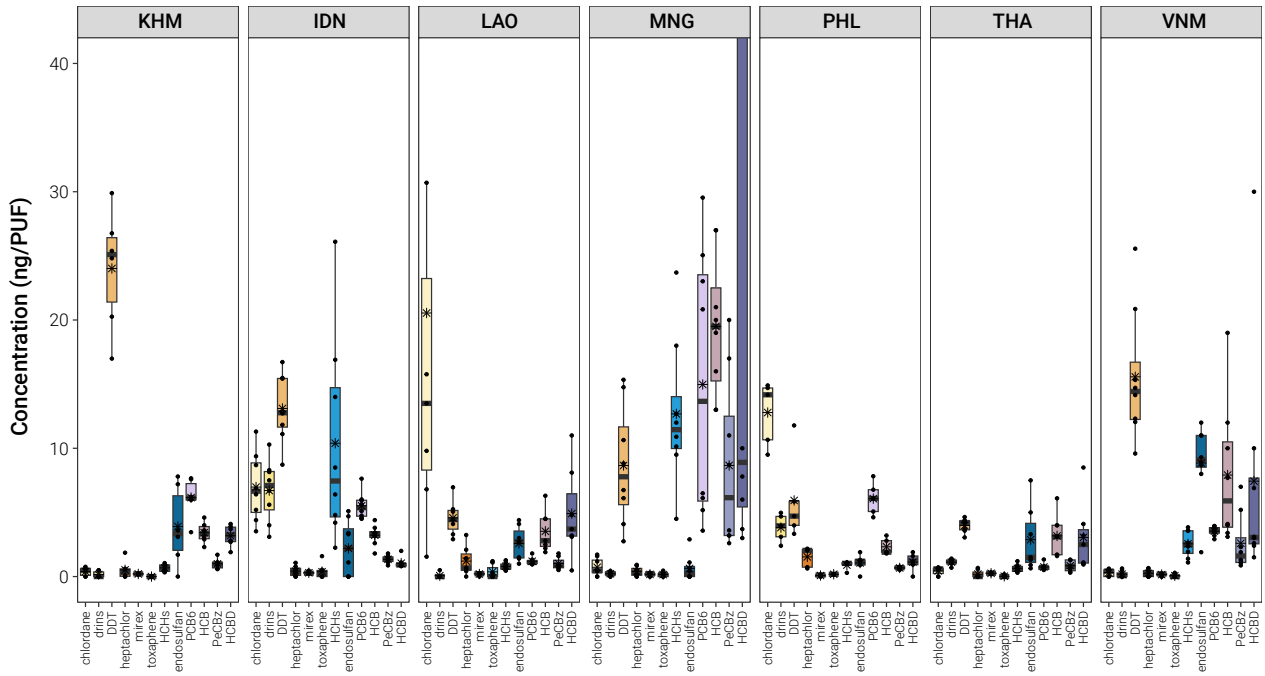


Figure 7: PAS/PUF: Unscaled boxplots for chlorinated POPs in air per country (n=49). Concentrations in ng/PUF. Note: y-axis zoomed to 40 ng/PUF

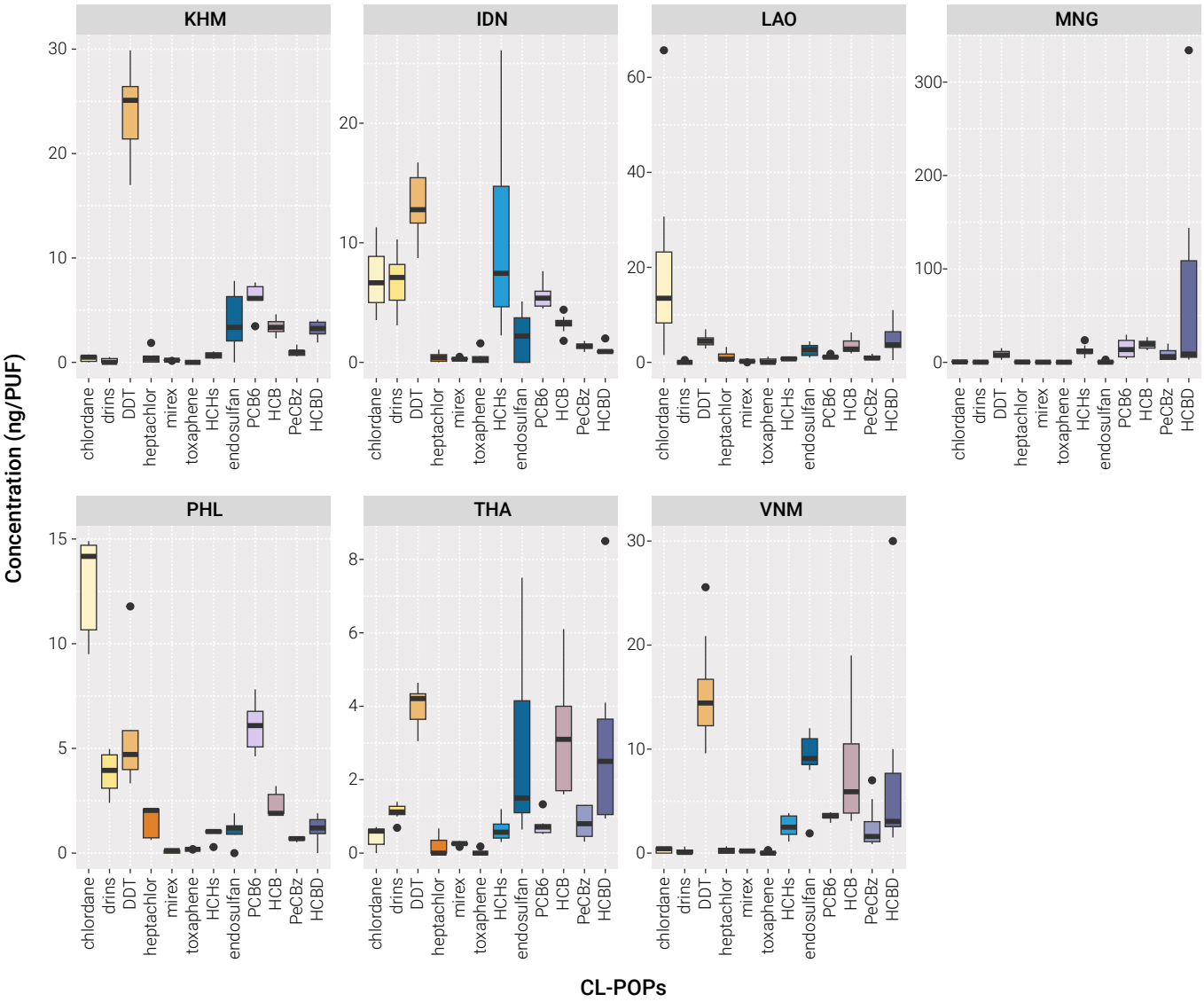


Figure 8: PAS/PUF: Scaled boxplots for sums of chlorinated POPs by country (n=49)

Applying a significance of p=0.05, the data for the Cl-POPs showed that there are significant differences between the countries as to the scale of the POPs in the PAS/PUFs (p=0.0028). Assessment of pairwise values gave significant differences only between Thailand and Indonesia (p=0.0003) and Thailand and Philippines (p=0.048).

4.2.2. Dioxin-like POPs

For Mongolia in 2017 and Viet Nam in 2017, three quarterly samples were analyzed by combining the two PUFs deployed in parallel from PAS-5 and PAS-7. In addition, all quarterly samples from one year were combined for an "annual sample" to allow comparison with the other countries. In 2018, there were four parallel samples from Viet Nam, which was amended by an annual sample to give five samples in 2018. For the other countries, the quarterly samples were combined to an annual sample. In total, 30 results are available from Asian countries for assessment.

Table 9: Number of PUFs per country and year, analyzed for dl-POPs

	2017 (N=9)	2018 (N=13)	2019 (N=8)	Overall (N=30)
KHM		1	1	2
IDN		1	1	2
LAO	1	1	1	3
MNG	4	1	1	6
PHL		1	1	2
THA		3	2	5
VNM	4	5	1	10

The results of the PUF extracts are detailed in Table S 5.

Table 10 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 TEQ_DF and TEQ_PCB

The mean values and standard deviations for each country are shown in Figure 9. It can be seen that the TEQ_DF is always higher than the TEQ_PCB.

Table 10: Partial TEQs in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (pg TEQ/PUF and 3 month)

TEQs	Central tendencies	KHM (N=2)	IDN (N=2)	LAO (N=3)	MNG (N=6)	PHL (N=2)	THA (N=5)	VNM (N=10)	Overall (N=30)
TEQ_DF	Mean (SD)	20.2 (10.1)	35.8 (6.32)	4.15 (2.34)	3.88 (2.25)	9.80 (1.03)	0.83 (0.94)	23.8 (8.35)	13.6 (12.6)
	Median [Min, Max]	20.2 [13.0, 27.3]	35.8 [31.4, 40.3]	4.29 [1.73, 6.41]	3.59 [1.25, 6.64]	9.80 [9.07, 10.5]	0.452 [0.162, 2.47]	23.4 [13.6, 35.8]	9.80 [0.162, 40.3]
TEQ_PCB	Mean (SD)	4.61 (2.32)	6.39 (0.482)	1.04 (0.627)	3.49 (2.78)	2.40 (0.568)	0.02 (0.01)	4.80 (1.74)	3.30 (2.55)
	Median [Min, Max]	4.61 [2.98, 6.25]	6.39 [6.05, 6.74]	1.32 [0.321, 1.47]	3.13 [0.913, 8.57]	2.40 [1.99, 2.80]	0.025 [0.003, 0.03]	4.35 [3.08, 7.73]	3.10 [0.003, 8.57]

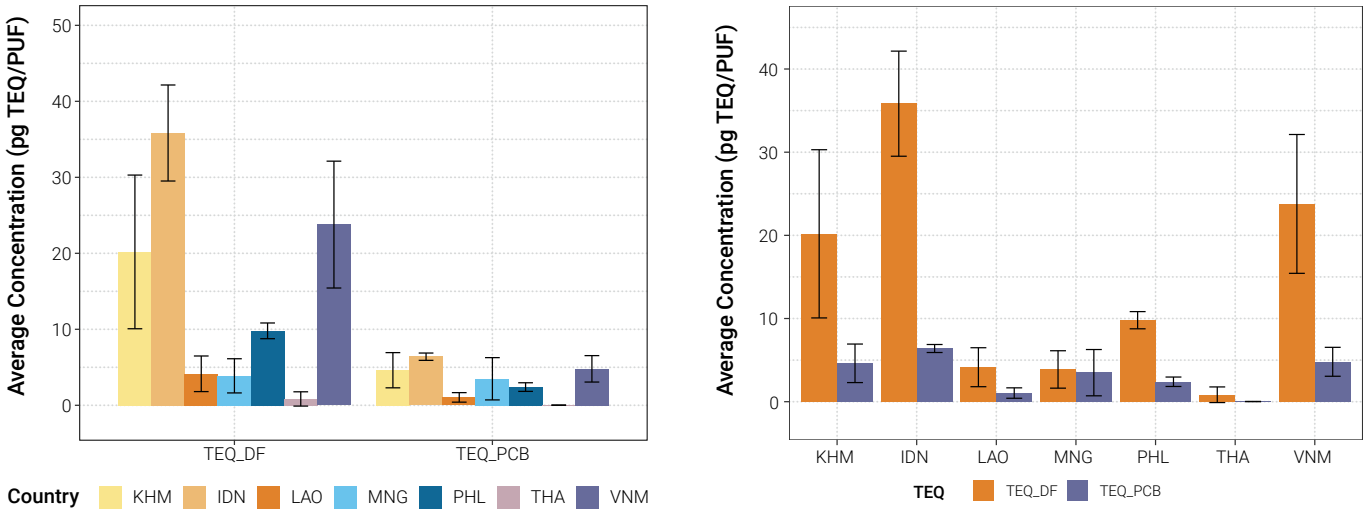


Figure 9: PAS/PUF: Mean values and SD for dl-POPs for countries (n=30)

Graphical sketches provide the summary and comparison of results for PCDD/PCDF and dl-PCB, as TEQ. The highest values were found in the Indonesian samples (Figure 10). Stacked bar graphs show the contribution of the partial TEQs by sample (Figure 11). For each country, the results are displayed in Figure 12, Figure 13, and Figure 14. Overall, the highest values, as median values, were found in Indonesia. Further, the pattern, on TEQ basis, were quite consistent throughout the two years within a country; however, not necessary between years.

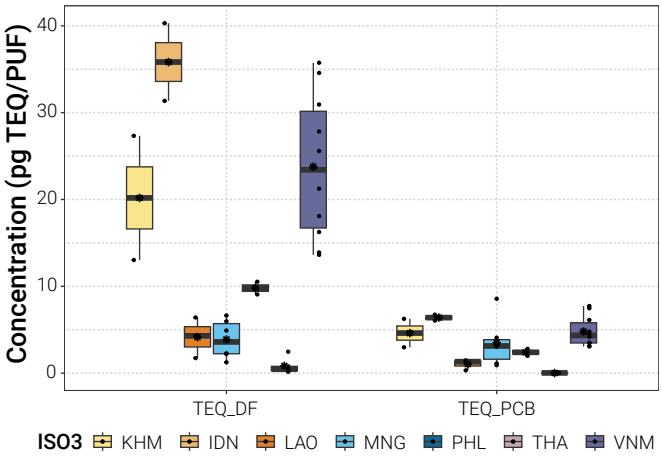


Figure 10: PAS/PUF: Box whisker plots for dl-POPs by country displayed for 2 TEQ

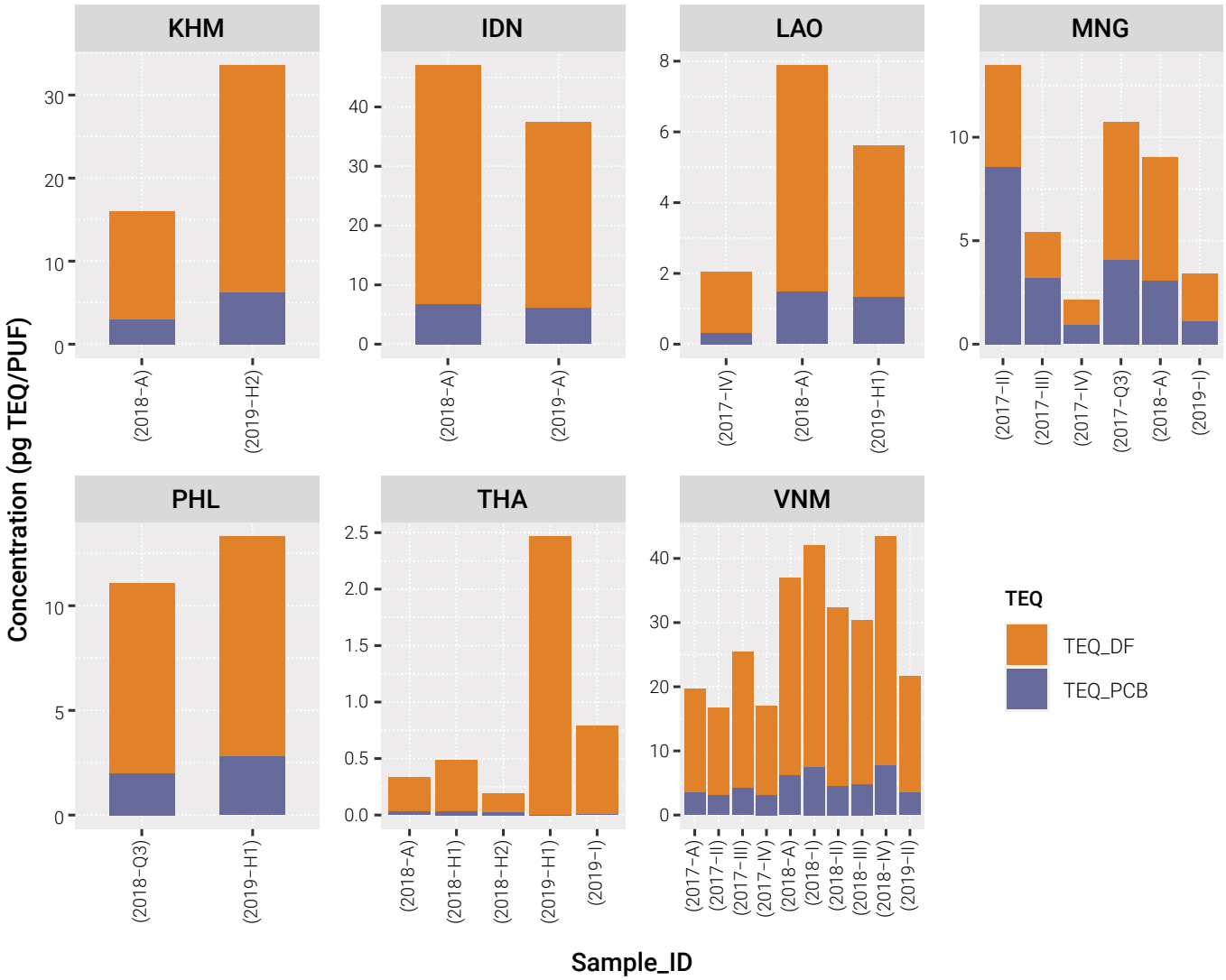


Figure 11: PAS/PUF: Stacked bar graphs for dl-POPs as 2 TEQ by country and sample (n=30)

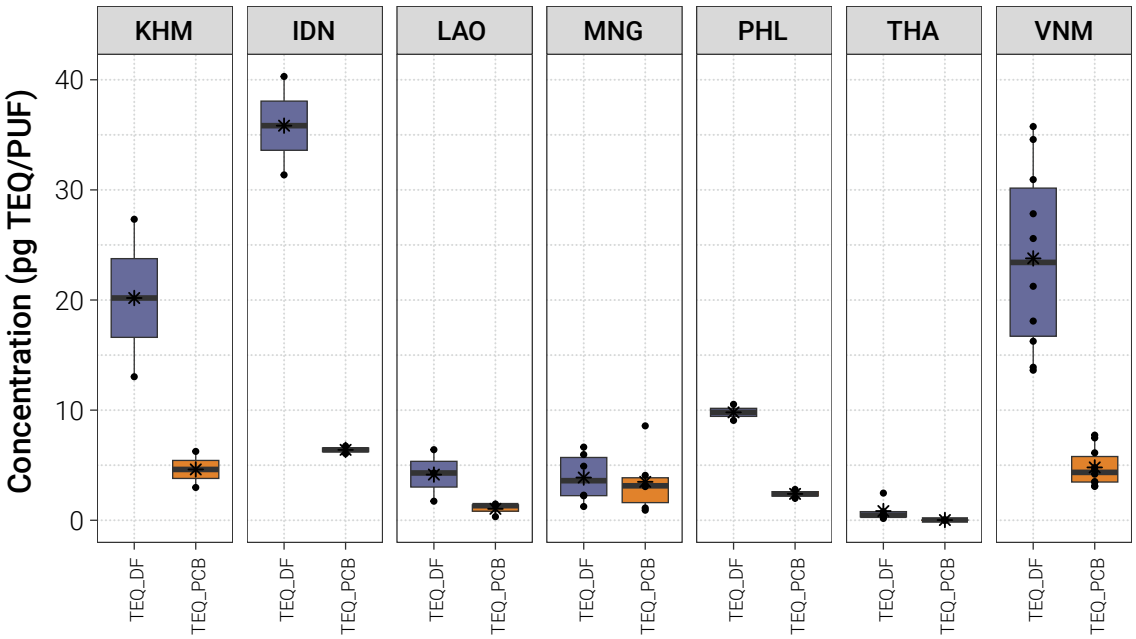


Figure 12: PAS/PUF: Box whisker plots unscaled for dl-POPs (for 2 TEQ) per country (n=30)

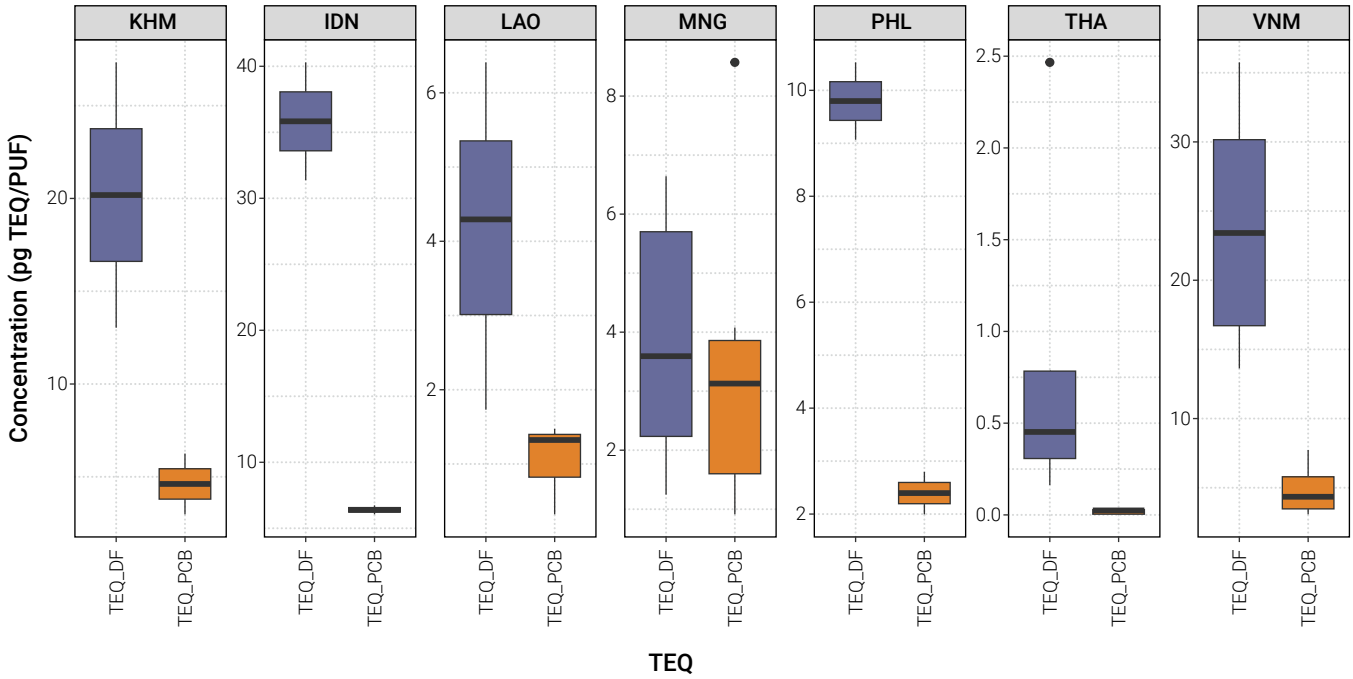


Figure 13: PAS/PUF: Scaled boxplots for concentrations of 2 TEQs by country (n=30)

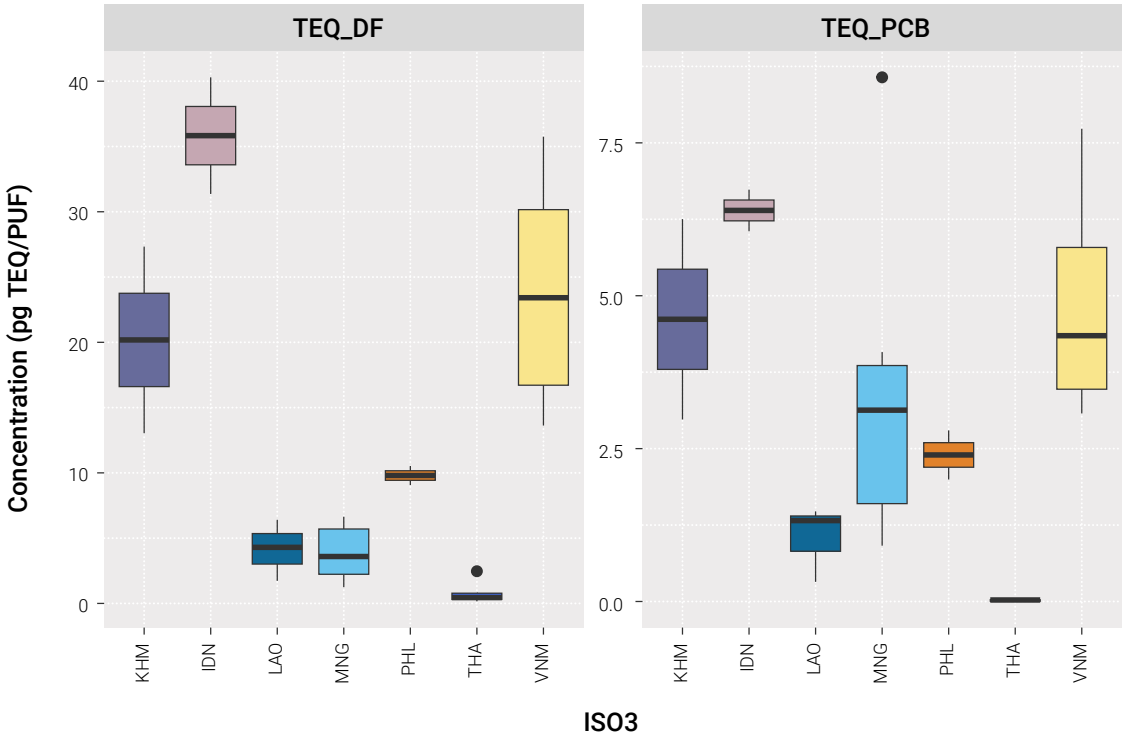


Figure 14: PAS/PUF: Scaled boxplots for concentrations by 2 TEQs for country

Applying a significance of p=0.05, the data for the two TEQs showed that there were significant differences between the countries as to the scale of the POPs in the PAS/PUFs ($p=2.0\times10^{-6}$). Assessment of pairwise values gave significant differences for Thailand with all other countries and in addition between Viet Nam with Lao or Mongolia and Lao with Indonesia.

4.2.3. Brominated POPs

Brominated POPs (Br-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. A total of 49 PUFs have been analyzed (Table 11).

$PBDE_8$ was very low across all countries. HBCD was elevated in MNG with the highest mean value (30.6 ng/PUF) and the highest maximum value (75.6 ng/PUF). PBB153 was not quantified above LOD in any sample (Table 12). The overview in Figure 16 shows that concentrations of Br-POPs were low except for values found in Mongolia for PBDE 209 and HBCD. Throughout all measurements, the Mongolian samples had the highest values (Figure 17 to Figure 20). Mongolia is also the only country that had high portions of HBCD whereas the other countries had more PBDE. PBB153 was hardly quantified and was found only in few samples.

Table 11: Number of PUFs per country and year, analyzed for Br-POPs

	2017 (N=8)	2018 (N=27)	2019 (N=14)	Overall (N=49)
KHM		4	2	6
IDN		4	4	8
LAO	1	4	2	7
MNG	3	4	1	8
PHL		3	2	5
THA	1	4	2	7
VNM	3	4	1	8

Table 12: Brominated POPs in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (ng/PUF)

POPs	Central tendencies	KHM (N=6)	IDN (N=8)	LAO (N=7)	MNG (N=8)	PHL (N=5)	THA (N=7)	VNM (N=8)	Overall (N=49)
PBDE8	Mean (SD)	1.67 (1.01)	1.68 (0.869)	0.139 (0.295)	0.454 (0.555)	0.622 (0.205)	0.391 (0.415)	0.469 (0.681)	0.769 (0.847)
	Median [Min, Max]	1.80 [0.390, 2.97]	1.28 [0.980, 3.16]	0 [0, 0.790]	0.195 [0, 1.38]	0.530 [0.45, 0.89]	0.210 [0, 1.19]	0.0950 [0, 1.72]	0.520 [0, 3.16]
PBDE209	Mean (SD)	0.883 (1.02)	1.76 (1.32)	0.529 (0.957)	14.7 (11.9)	0 (0)	0 (0)	0.938 (1.92)	3.09 (7.07)
	Median [Min, Max]	0.600 [0, 2.10]	1.75 [0, 3.60]	0 [0, 2.40]	10.5 [3.40, 39.0]	0 [0, 0]	0 [0, 0]	0 [0, 5.30]	0 [0, 39.0]
PBB153	Mean (SD)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Median [Min, Max]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]	0 [0, 0]
HBCD	Mean (SD)	0.322 (0.336)	0.161 (0.0822)	0.191 (0.327)	30.6 (22.4)	0.0580 (0.0427)	0.240 (0.622)	0.0413 (0.0577)	5.14 (14.2)
	Median [Min, Max]	0.175 [0, 0.760]	0.155 [0.05, 0.26]	0 [0, 0.670]	22.3 [8.19, 75.6]	0.0500 [0, 0.100]	0 [0, 1.65]	0 [0, 0.130]	0.100 [0, 75.6]

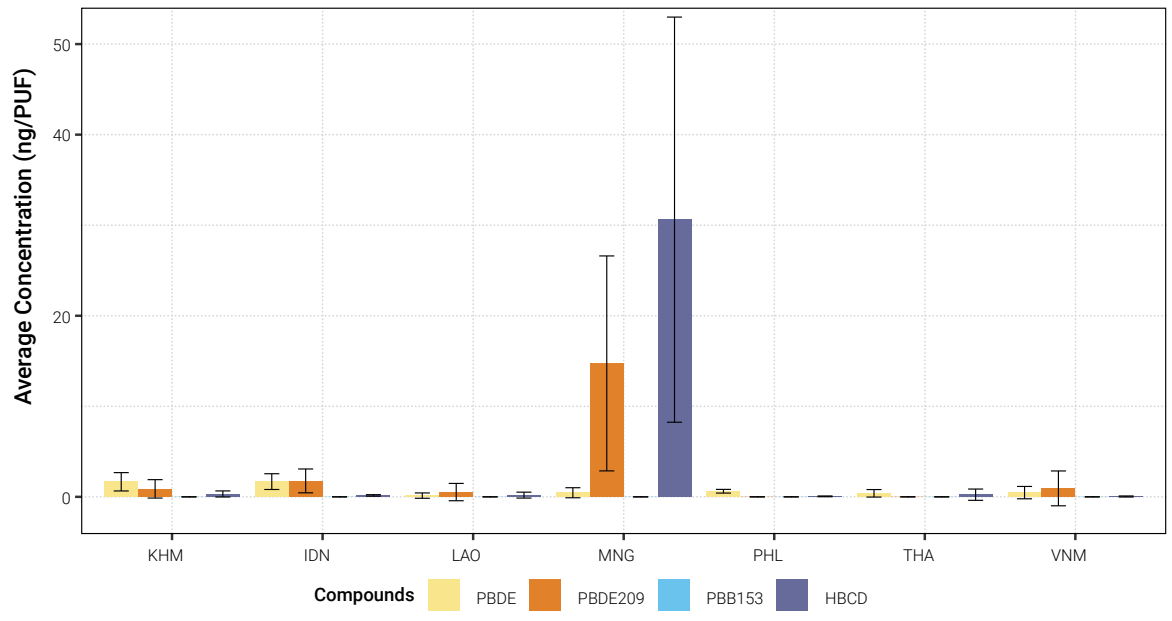


Figure 15: PAS/PUF: Mean values and SD for brominated POPs (n=49)

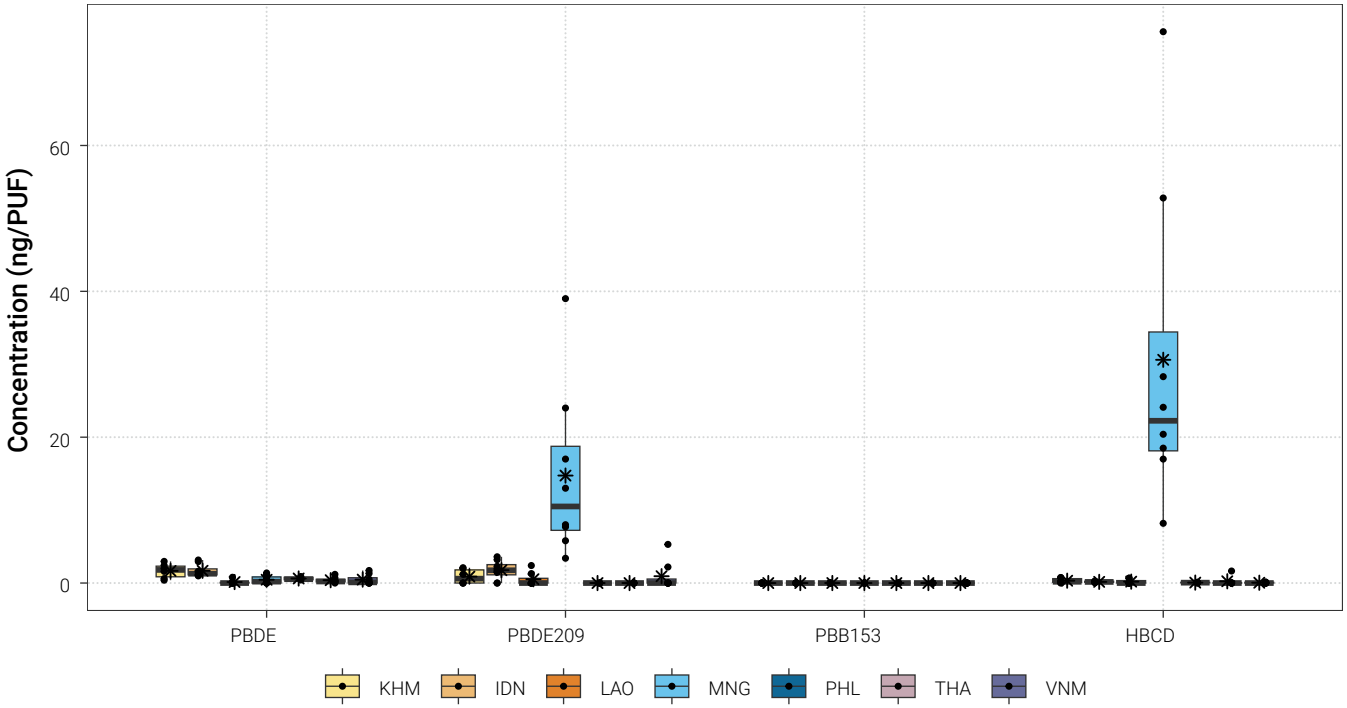


Figure 16: PAS/PUF: Box plots for brominated POPs: summary across all samples (n=49)

Photo: ©Cambodia / Ministry of Environment (Cambodia)

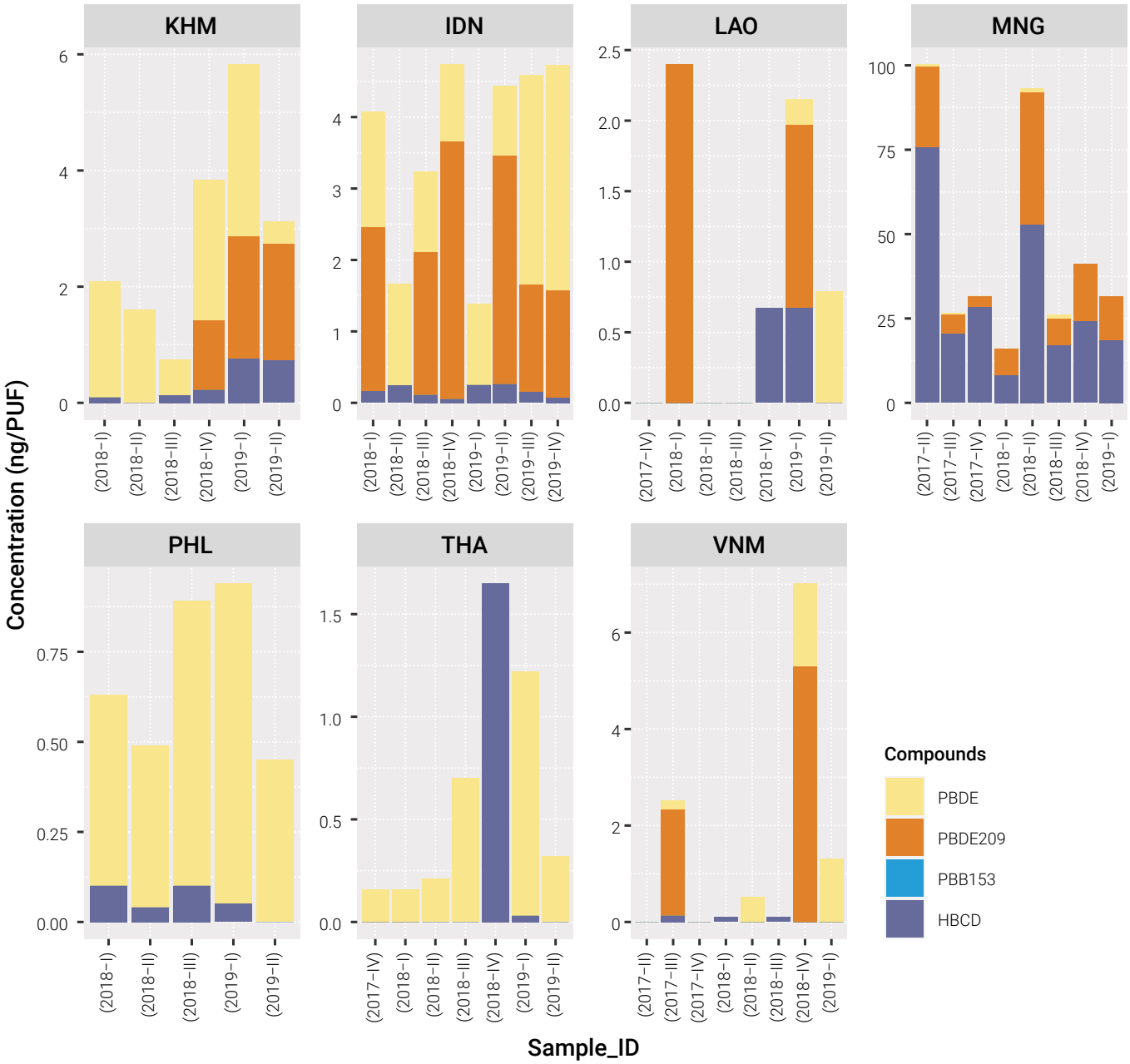


Figure 17: PAS/PUF: Stacked bar graphs for brominated POPs by country and sample (n=49)

Statistically, the Br-POPs data were significantly different in the Asia project; however, pairwise significant differences were found mainly for Mongolia with all other countries (p=0.0014 to p=0.048) but not with Indonesia (p=0.80).

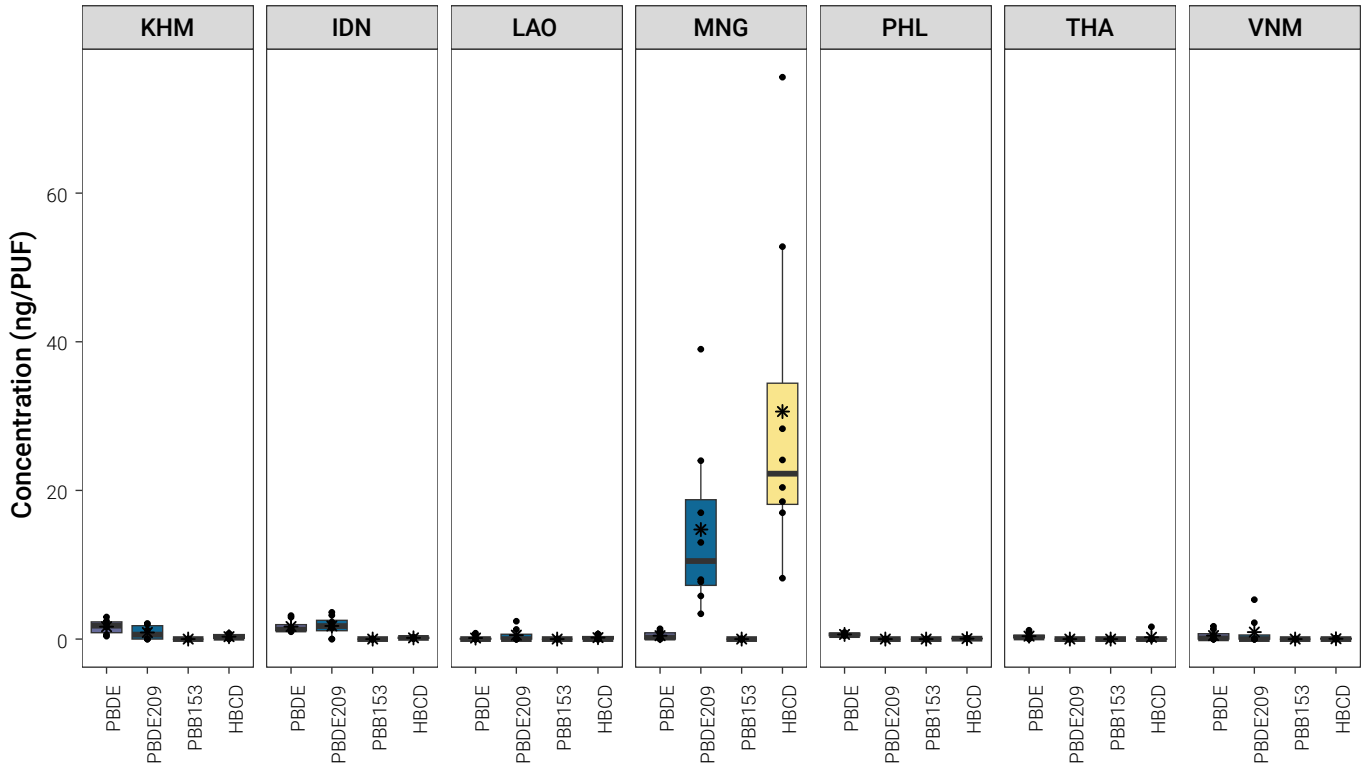


Figure 18: PAS/PUF: Unscaled boxplots for brominated POPs per country. Concentrations in ng/PUF (n=49)

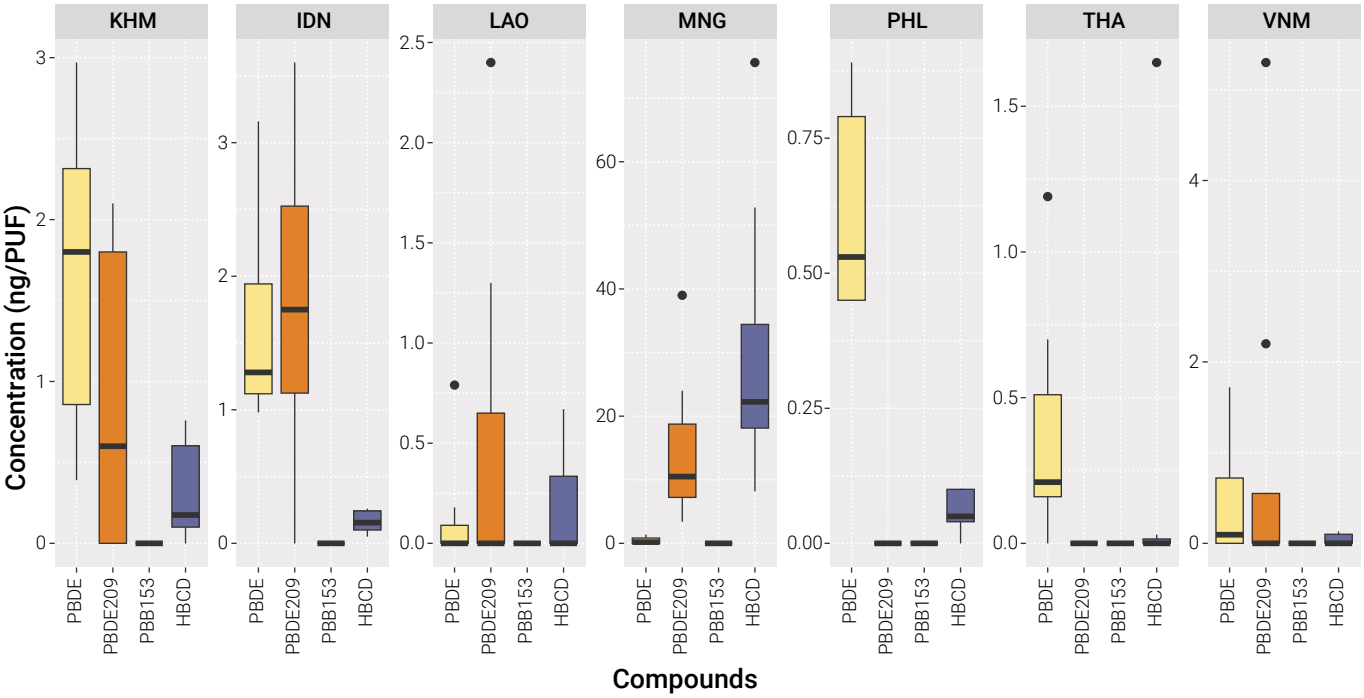


Figure 19: PAS/PUF: Scaled boxplots for sums of brominated POPs by country (n=49)

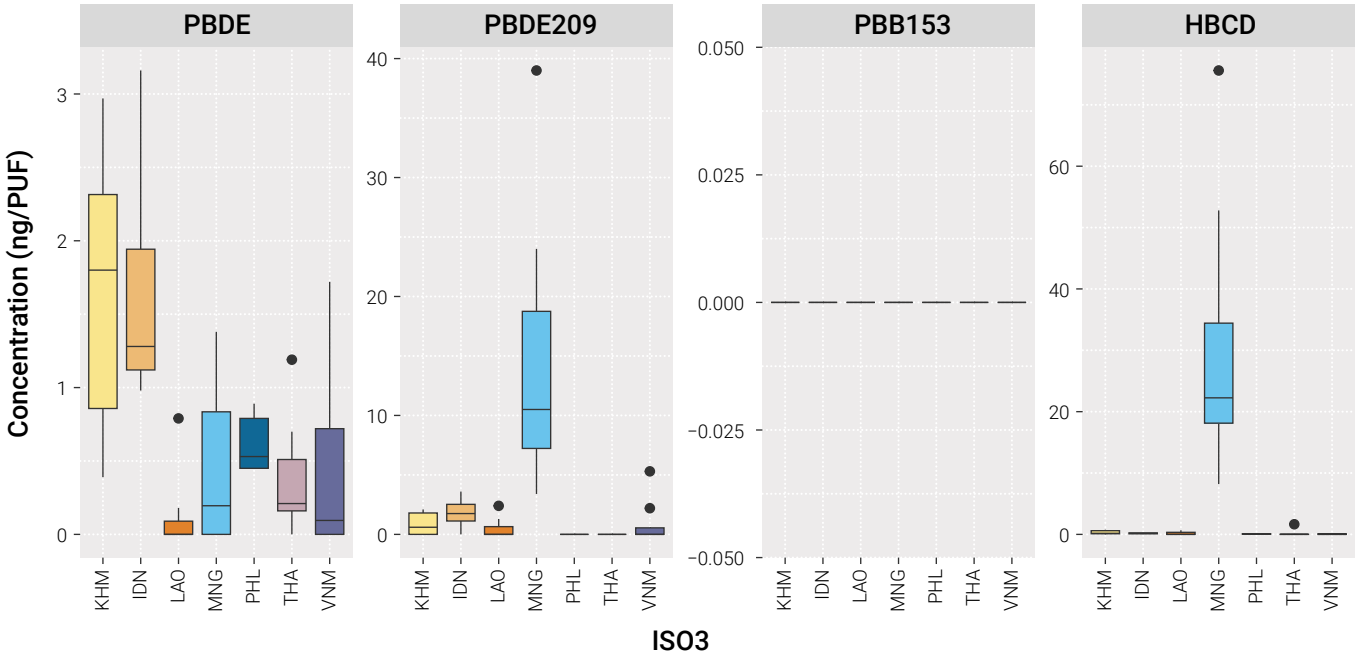


Figure 20: PAS/PUF: Scaled boxplots for country by brominated POPs (n=49)

4.2.4. Fluorinated POPs

46 samples were received and analyzed (Table 13).

Table 13: PAS/PUFs: Overview of samples with results analyzed for PFAS by year of sampling

	2017 (N=9)	2018 (N=29)	2019 (N=8)	Overall (N=46)
KHM		5	1	6
IDN		5	3	8
LAO	1	5	2	8
MNG	2	5	1	9
PHL			1	1
THA	1	5	3 NR	6
VNM	4	4		8

The results of the PUF extracts for PFAS are detailed in Table S 7 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 14 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. From the PFOS precursors, only FOSA could be quantified in the samples; FOSEs and FOSAs did not play a role. For details, see Camoiras González *et al.* (2021). Overall, the mean and median values of PFOA were higher than for PFOS. The samples from Viet Nam had the highest values. Samples from PHL were so deteriorated so that only in one sample, PFOS could be quantified. 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 Asian 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.

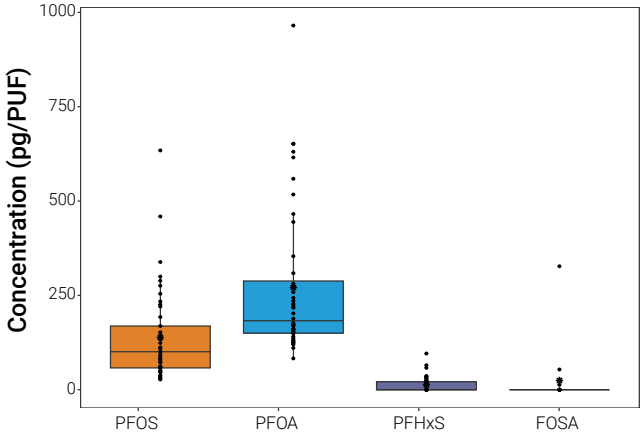


Figure 21: PAS/PUF: Summary of PFAS in PAS/PUFs Box whisker

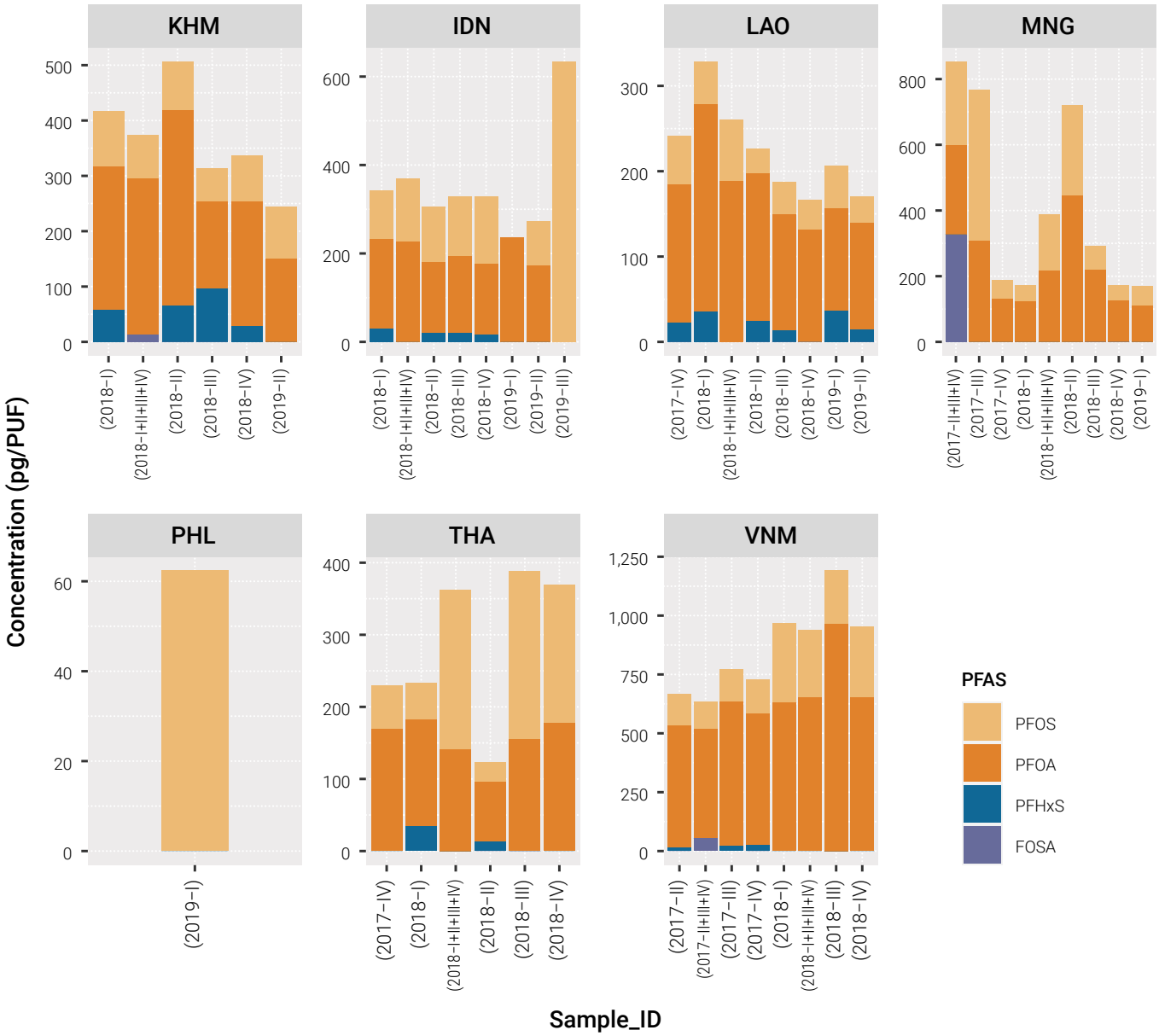


Figure 22: PAS/PUF: Stacked bar graphs for PFAS POPs by country and sample (n=46)

Table 14: Four PFAS in PAS/PUF: Mean (with standard deviation, SD), median, minimum and maximum values (pg/PUF) 30 samples could not be analyzed for FOSA

PFAS	Central tendencies	KHM (N=6)	IDN (N=8)	LAO (N=8)	MNG (N=9)	PHL (N=1)	THA (N=6)	VNM (N=8)	Overall (N=46)
PFOS	Mean (SD)	83.8 (14.1)	199 (192)	45.6 (14.5)	160 (144)	62.4	131 (94.5)	210 (89.4)	139 (122)
	Median [Min, Max]	85.1 [59.9, 101]	135 [101, 634]	44.1 [29.9, 71.9]	73.3 [46.3, 459]	62.4	126 [27.3, 234]	185 [113, 339]	101 [27.3, 634]
PFOA	Mean (SD)	238 (77.3)	190 (31.6)	160 (41.7)	217 (111)	NA	146 (33.4)	632 (150)	271 (194)
	Median [Min, Max]	241 [151, 354]	173 [160, 235]	149 [120, 243]	217 [111, 445]	NA	152 [83.1, 177]	623 [466, 965]	183 [83.1, 965]
PFHxS	Mean (SD)	41.4 (38.5)	12.5 (12.4)	20.8 (12.9)	0 (0)	0	7.79 (13.8)	7.48 (10.7)	13.4 (20.7)
	Median [Min, Max]	43.7 [0, 96.1]	16.2 [0, 30.1]	22.1 [0, 36.5]	0 [0, 0]	0	0 [0, 34.0]	0 [0, 24.9]	0 [0, 96.1]
FOSA	Mean (SD)	4.37 (7.56)	NA	0 (0)	109 (189)	NA	0 (0)	17.9 (31.0)	24.6 (81.8)
	Median [Min, Max]	0 [0, 13.1]	NA	0 [0, 0]	0 [0, 327]	NA	0 [0, 0]	0 [0, 53.7]	0 [0, 327]

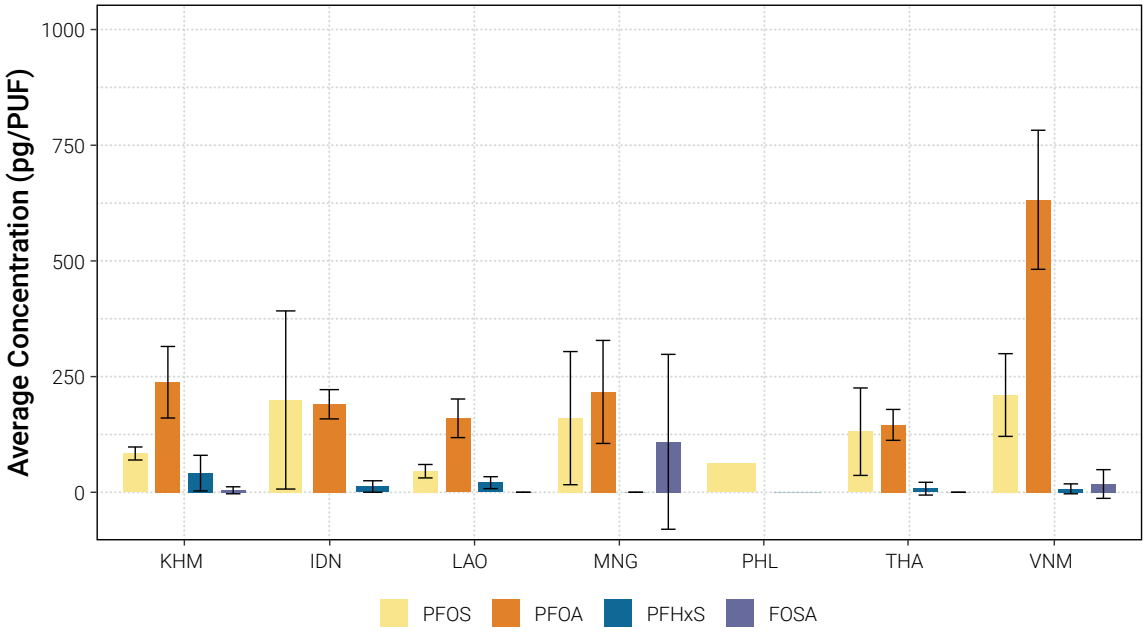


Figure 23: PAS/PUF: Mean values and SD for 4 PFAS (n=46)

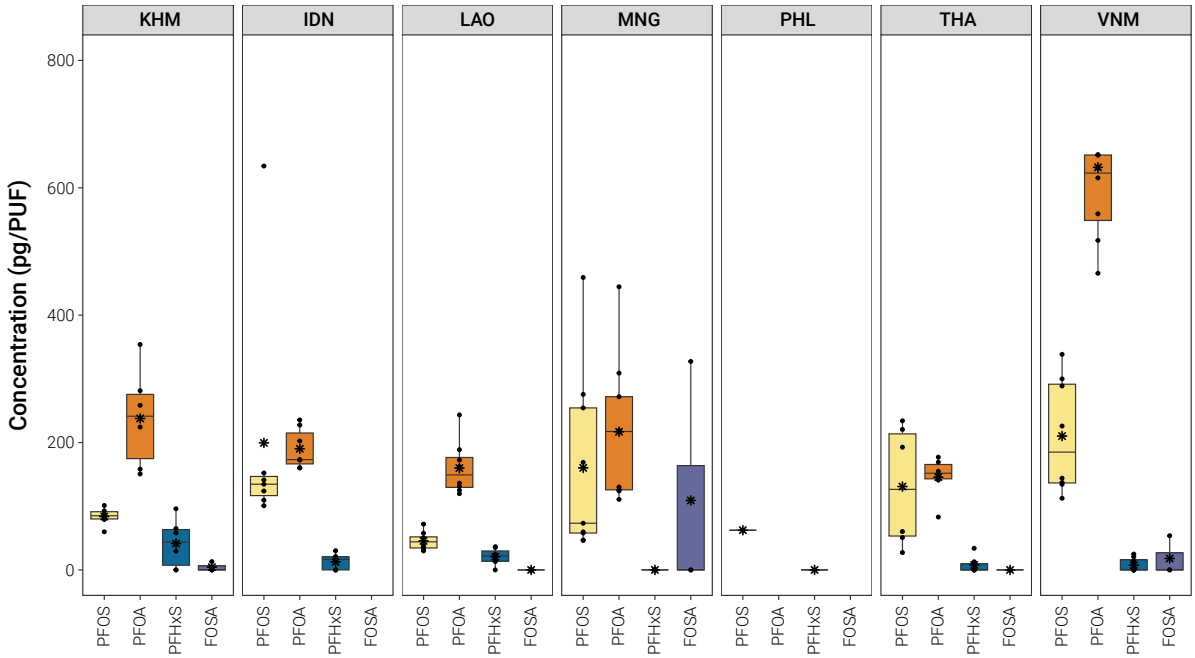


Figure 24: PAS/PUF: Unscaled for concentrations of 4 PFAS in PUFs by country. Y-axis zoomed to 800 pg/PUF (n=46)

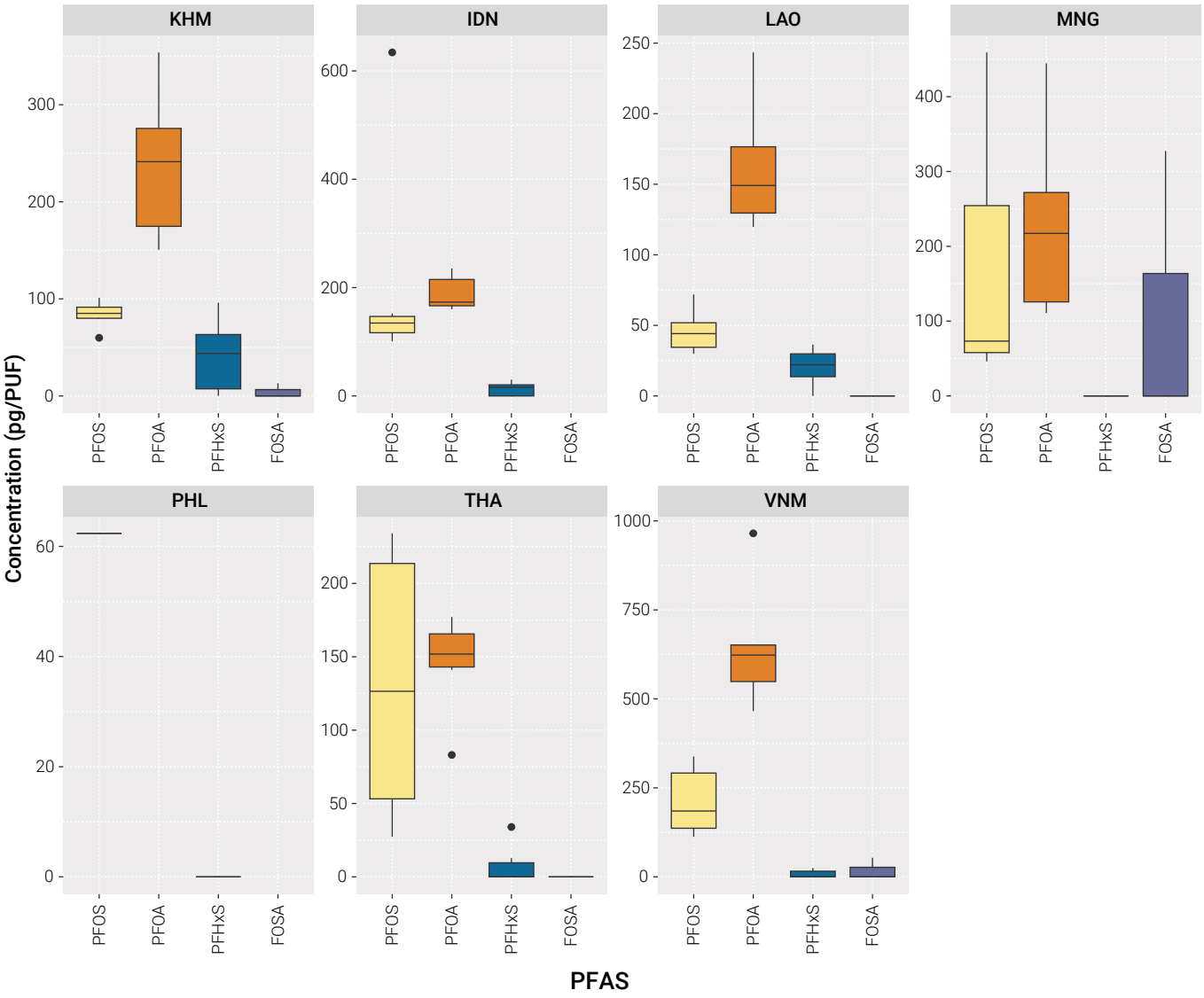


Figure 25: PAS/PUF: Scaled boxplots for concentrations of 4 PFAS by country (pg/PUF) (n=46)

Photo: ©Unsplash / Lewis J Goetz

Between countries, Kruskal-Wallis chi-squared = 7.7456, df = 6, p-value = 0.2573; thus, no significant differences between countries. Pairwise values were between p=0.59 and 0.71. There was no statistically significant difference with respect to years.

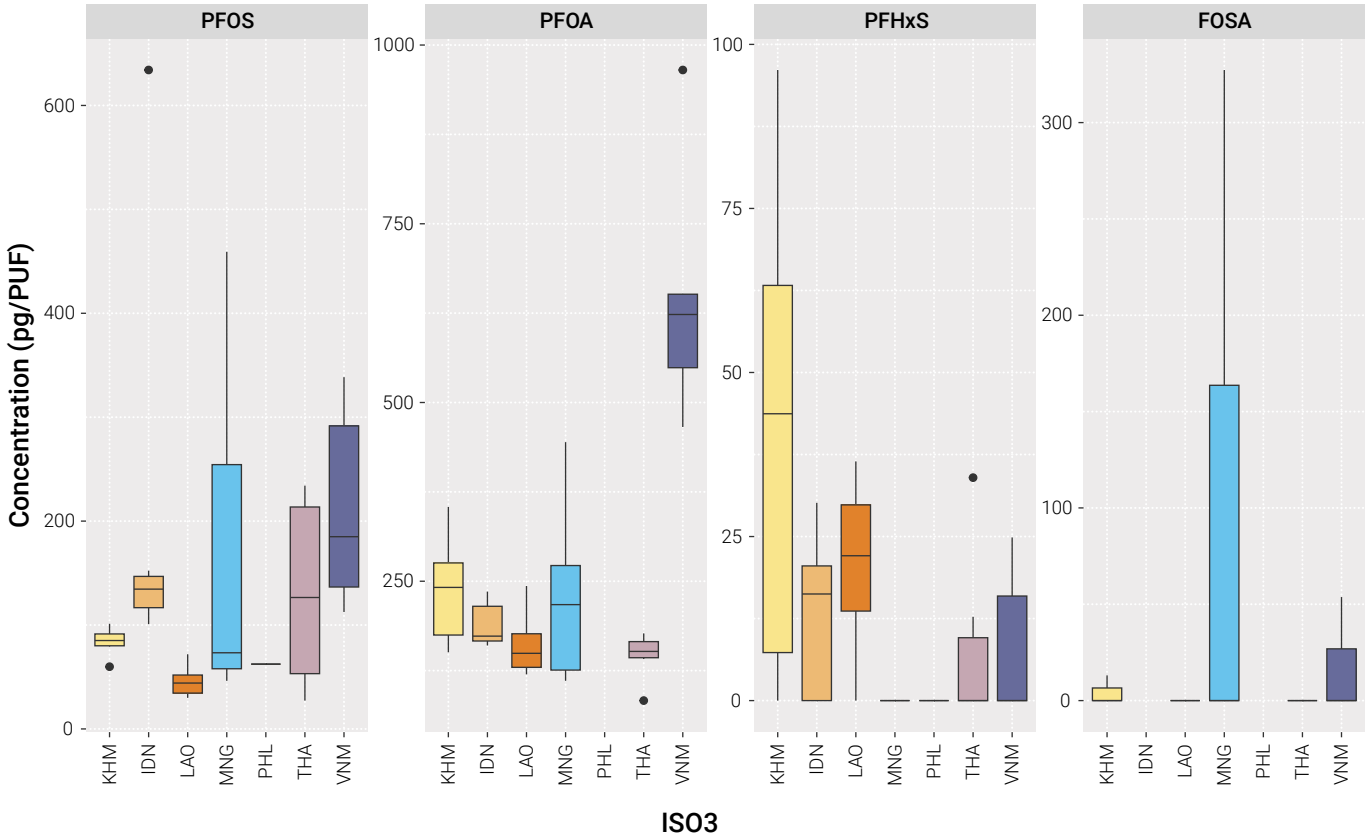


Figure 26: PAS/PUF: Scaled boxplots for concentrations according PFOS, PFOA, PFHxS by country (pg/PUF) (n=46)

4.2.5. Ambient air with active sampler

Active air sampling (AAS) was performed in Mongolia and Viet Nam. The sample_ID defines the year and the month, when the air was sampled. It shall be noted that in Mongolia, PFAS could not be determined since the sample was lost in the laboratory. In Viet Nam, only toluene pre-conditioned PUFs were exposed. For PFAS analysis, the solvent was changed to methanol; for this sample, no glass fiber filter was available so that only PUF and XAD were analyzed. A summary of the results is presented in Table 15. In Mongolia, the highest values were found for HCHs and PeCBz, followed by HCB and PCB_6. It is striking that the December sample MNG (2019-09) had much lower values than the September sample MNG (2019-12). Such large difference was not seen for the dl-POPs. The dl-POPs results from Viet Nam had one sample with about 3-times higher TEQ_DF whereas the TEQ_PCB differed less. The lower values from Viet Nam were comparable in scale with the values from Mongolia.

Table 15: Active air sampling: Results for Cl-POPs, Br-POPs (pg/m³), dl-POPs (fg TEQ/m³) and PFAS (pg/m³) (endosulfan=a-endosulfan)

Sample_ID	drins	chlordane	DDT	heptachlor	mirex	HCHs	endosulfan
MNG (2019-09)	<LOD	0.834	16.9	<LOD	0.36	206	<LOD
MNG (2019-12)	<LOD	<LOD	0.329	<LOD	<LOD	<LOD	<LOD

Sample_ID	PCB6	HCB	PeCBz	PBDE7	PBDE209	HBCD
MNG (2019-09)	91.9	130	199	3.34	23.2	30.8
MNG (2019-12)	3.85	<LOD	<LOD	1.48	15.8	10.5

Sample_ID	PFOS	PFOA	PFHxS	FOSA	TEQ_DF	TEQ_PCB
MNG (2019-09)					83.3	11.6
MNG (2019-12)					122	7.16
VNM (2019-BV01)					141	10.4
VNM (2019-BV03)					50.8	6.57
VNM (2019-BV04)	0.06	<LOQ	<LOQ	<LOQ	56.6	8.38

The following graphics display the occurrence and pattern found in the AAS samples from Asia. The large difference in scale of the Mongolian samples can be seen in Figure 27. The September sample had mainly HCHs, HCB, and PeCBz present; also some PCB_6 and a small amount of DDT. Chlordane, and mirex were close to LOD and heptachlor and endosufan below LOD. The December sample had a very small amount of DDT and PCB_6 . Unfortunately, HCBD, which was dominating in the PAS/PUFs could not be quantified due to interferences in the laboratory.).

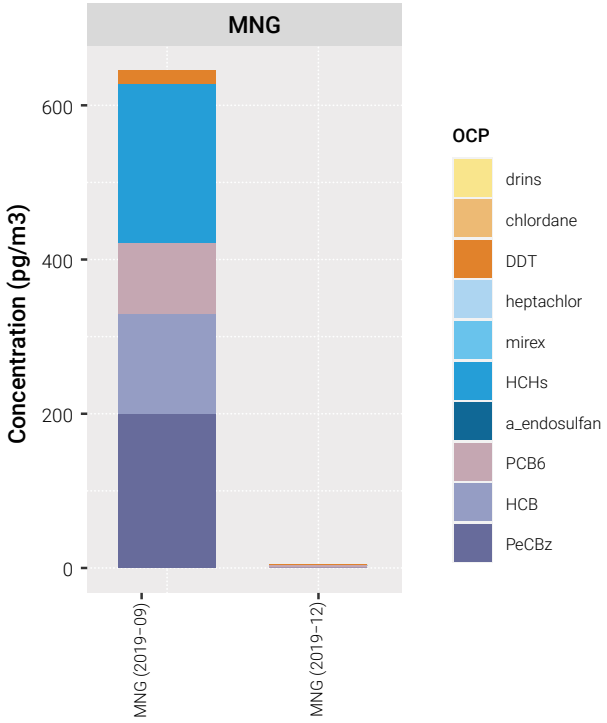


Figure 27: AAS Asia: Stacked bars for OCPs+industrial POPs

Dioxin-like POPs were available from Mongolia and Viet Nam (Figure 28). The concentrations were comparable as to the scale of the values but also the pattern. In the four samples from two countries, the TEQ_DF dominated over the TEQ_PCB.

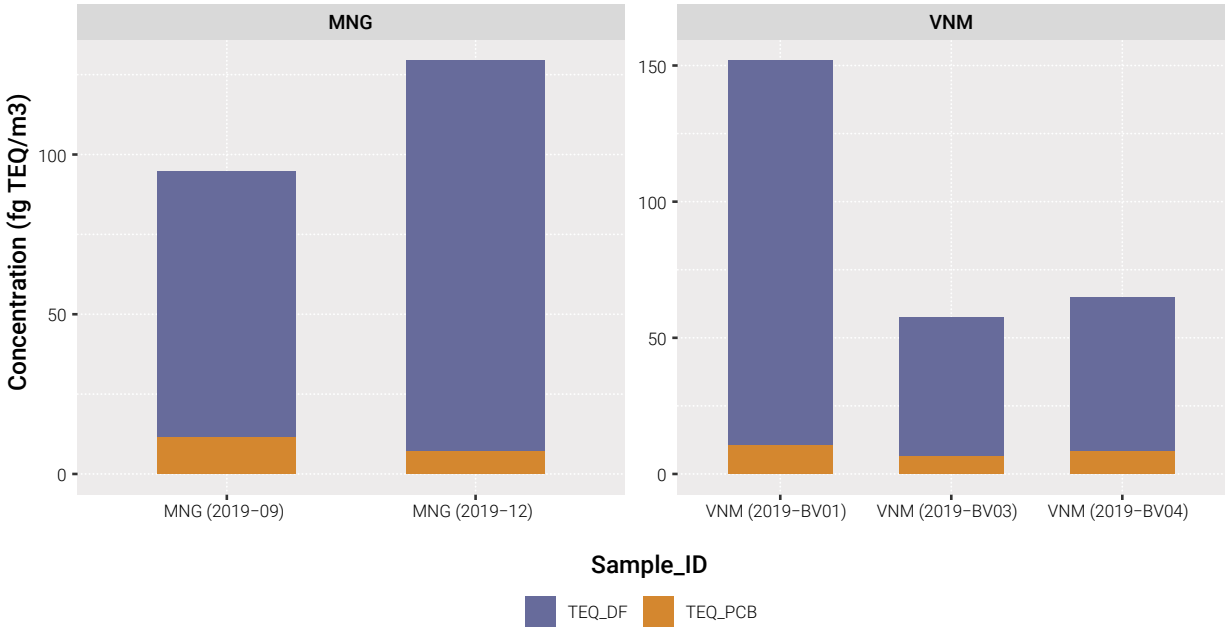


Figure 28: AAS Asia: Stacked bars for dl-POPs

Br-POPs in Mongolia exhibited the same pattern with a high abundance of PBDE 209 and HBCD and small amounts for the remaining PBDE (Figure 29). The scale differed by 50%. In the extract of the Viet Nam sample, only PFOS could be quantified (Figure 30).

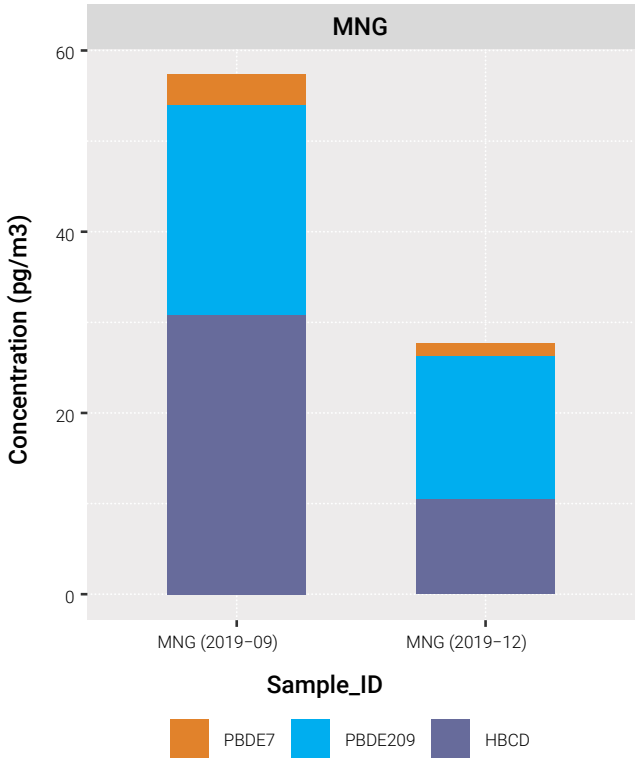


Figure 29: AAS Asia: Stacked bars for Br-POPs

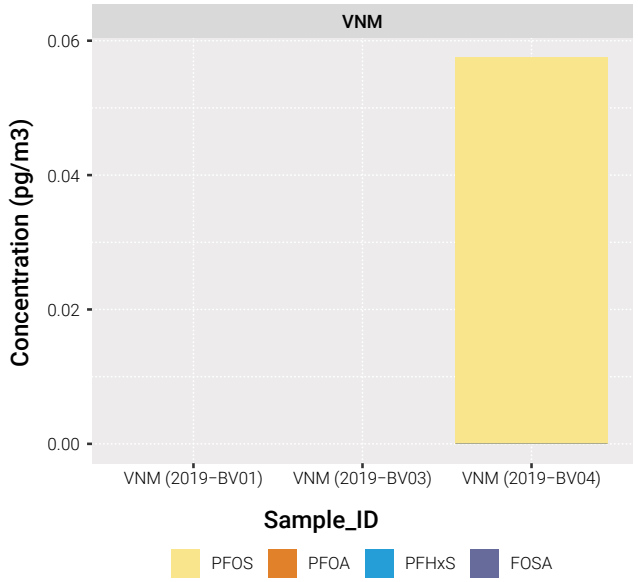
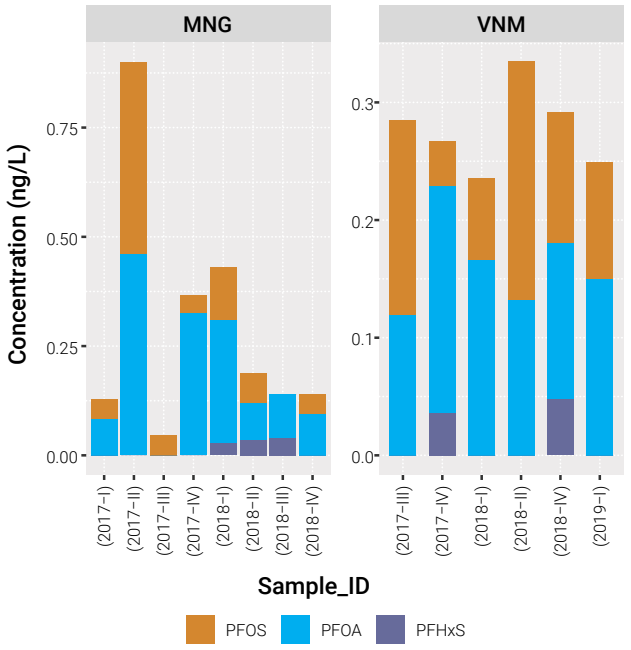


Figure 30: AAS Asia: Stacked bars for PFAS

4.3. Water

The results of the water samples for the sum of the three targeted PFAS and including the L-PFOS and br-PFOS isomers are detailed in Table S 8. Table 16 provides the mean, median, minimum and maximum values for each country. In total, eight samples were received from Mongolia and six from Viet Nam:



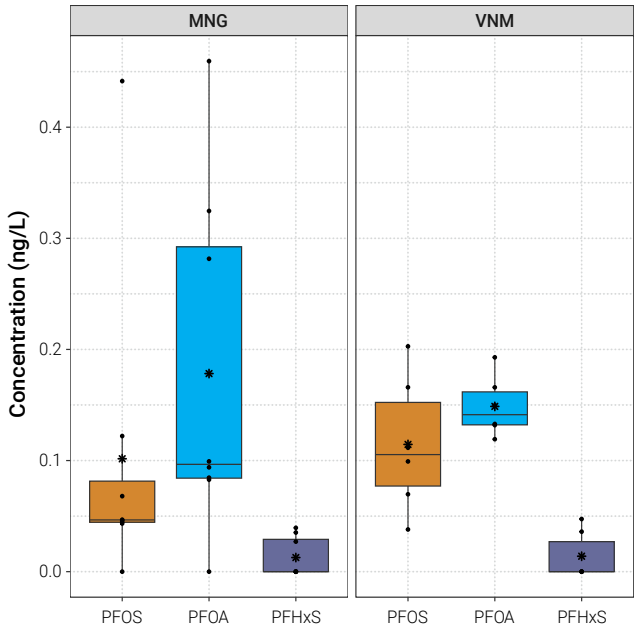


Figure 31: Water: Overview on PFAS concentrations by sample and country (stacked boxplots) and box whisker plots for overview. Concentrations in ng/L

Overall, the concentrations in the MNG and VNM water samples were very low with respect to PFOS and PFOA; and extremely low for PFHxS (Figure 33).

Graphical sketches provide an overview on all samples analyzed from Asia in Figure 31 as well as the comparison of results of chemical analyses for PFAS as boxplots. The mean values with SD are shown in Figure 32. Br-PFOS was detected in almost all samples.

Table 16: PFAS in water: Mean (with standard deviation, SD), median, minimum and maximum values (ng/L)

PFAS	Central tendencies	MNG (N=8)	VNM (N=6)	Overall (N=14)
PFOS	Mean (SD)	0.102 (0.141)	0.115 (0.0609)	0.107 (0.111)
	Median [Min, Max]	0.0466 [0, 0.441]	0.105 [0.0380, 0.203]	0.0688 [0, 0.441]
PFOA	Mean (SD)	0.178 (0.158)	0.149 (0.0270)	0.166 (0.118)
	Median [Min, Max]	0.0966 [0, 0.459]	0.141 [0.119, 0.193]	0.132 [0, 0.459]
PFHxS	Mean (SD)	0.0127 (0.0179)	0.0139 (0.0218)	0.0132 (0.0189)
	Median [Min, Max]	0 [0, 0.0395]	0 [0, 0.0474]	0 [0, 0.0474]

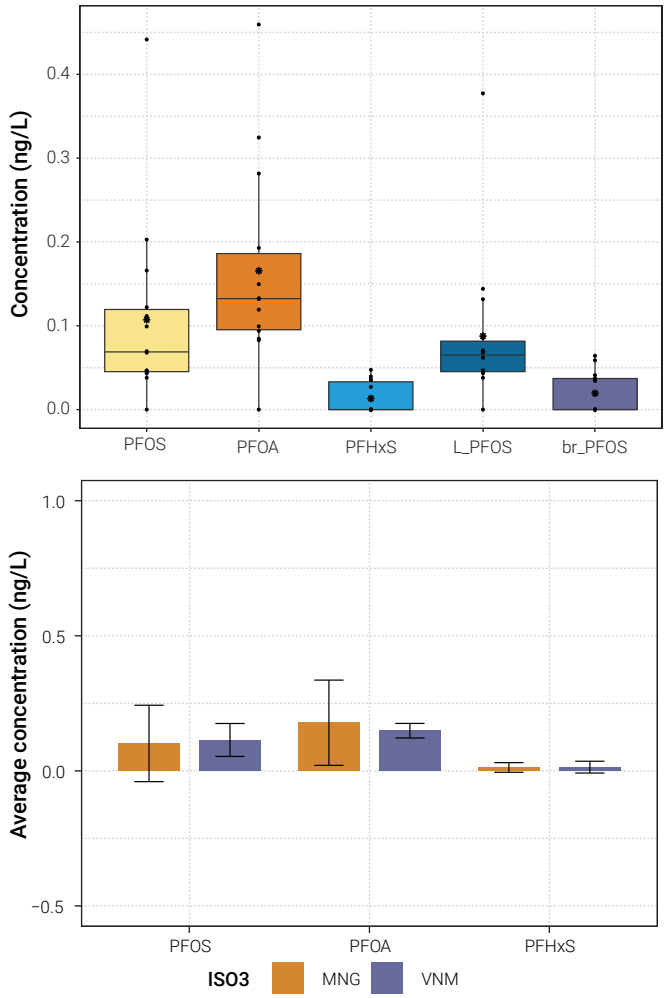


Figure 32: Water: Box whisker plot for 5 PFAS and mean values and SD for 3 PFAS in water (n=14)

The amounts of PFAS found in Asia according to countries is shown in Figure 33.

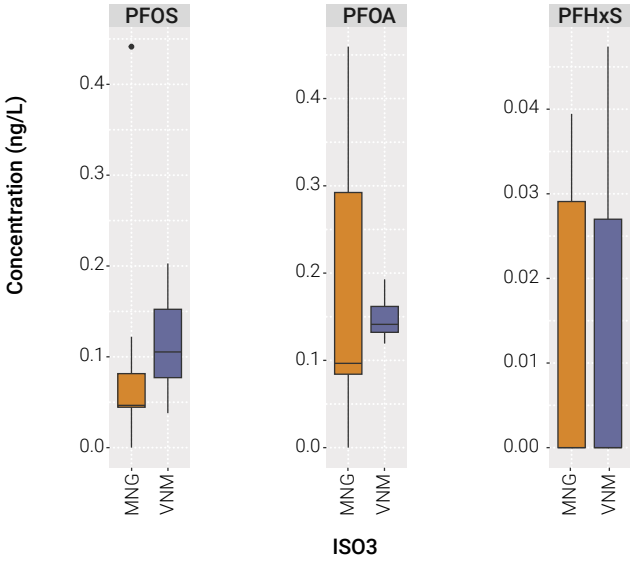


Figure 33: Water: Amounts according PFOS, PFOA, PFHxS by country (ng/L)

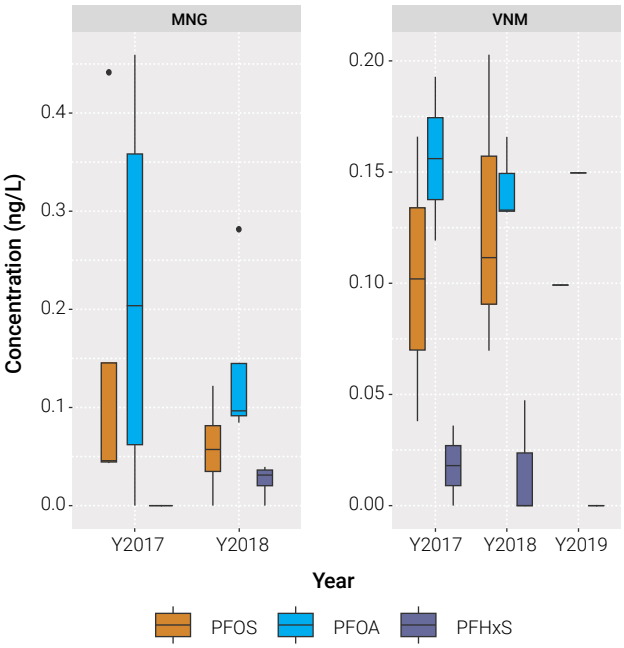


Figure 34: Water: Comparison of values for each country for PFOS, PFOA, PFHxS concentrations (ng L^{-1}) according to Year

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. The results from Asian samples are summarized in Table 17 for OCP, PCB_6 and BFRs and in Table 18 for dl-POPs and PFAS. 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.

Table 17: Concentration of chlorinated and brominated POPs in human milk (ng/g lipid) for Asian national pools

	KHM (N=1)	MNG (N=1)	THA (N=1)	VNM (N=1)	Overall (mean)	Overall median
Chlordane	<LOD	2.45	4.45	0.581	1.87	1.52
Dieldrin	<LOD	0.500	0.644	<LOD	0.286	0.250
DDT	83.5	41.0	425	151	175	117
HCHs	0.569	41.6	0.765	3.32	11.6	2.04
cis_Hepo	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
Mirex	<LOD	<LOD	0.862	<LOD	0.215	<LOD
HCB	2.48	34.0	2.79	4.80	11.0	3.79
SCCP	29.0	164	18.3	89.0	75.0	59.0
PCB6	3.68	15.6	3.25	14.8	9.33	9.22
PBDE6	0.658	0.429	0.411	1.00	0.625	0.544
PBDE_209	0.142	0.223	0.163	0.138	0.166	0.153
HBCD_a	<LOD	0.500	<LOD	0.300	0.200	0.150
Toxaphenes	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD

The chlorinated POPs by country are shown in Figure 36. Among the chlorinated POPs, DDT and SCCPs had the highest concentrations. DDT were dominant in three countries – Cambodia, Thailand, and Viet Nam, but not in Mongolia. The highest DDT were found in Thailand. Among the Asian countries, Mongolia had the highest concentrations for chlordane, β-HCH, PCB_6, HCB, SCCP, PBDE 209, and α-HBCD. Thailand had the maxima for dieldrin, DDT, mirex, PFOA, and PFHxS. Viet Nam the maxima for toxaphene, lindane, $PBDE_6$, TEQ_PCB, and PFOS. Cambodia had the maximum value for TEQ_DF in Asia. Heptachlor, endosulfan, α-HCH were not quantified in any of the Asian samples but in other regions (Figure 35).

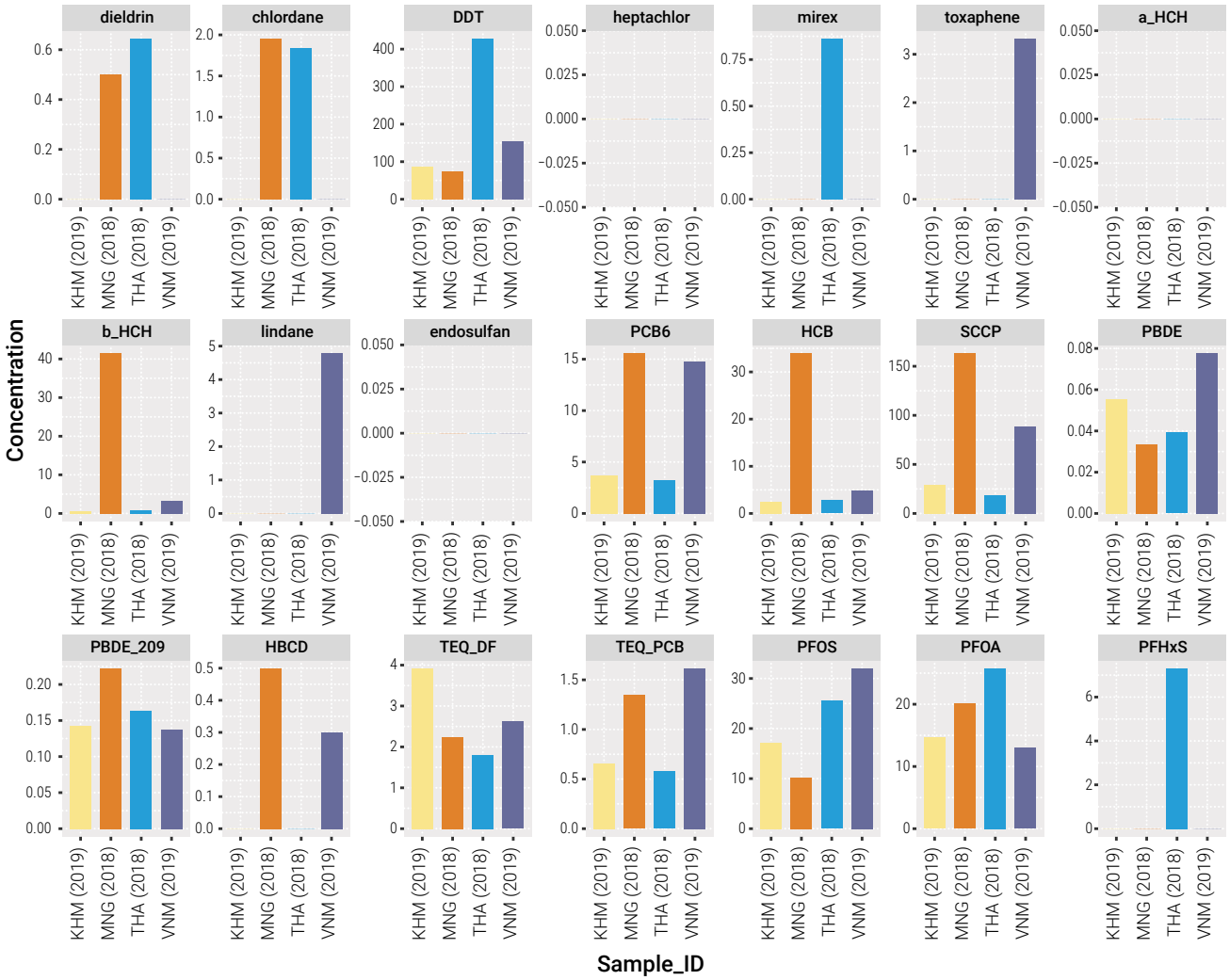


Figure 35: Human milk: Scaled barplots by POPs with concentrations by country (pg TEQ/g lipid for the dl-POPs, pg/g f.w. for PFOS and PFOA; all other in ng/g lipid)

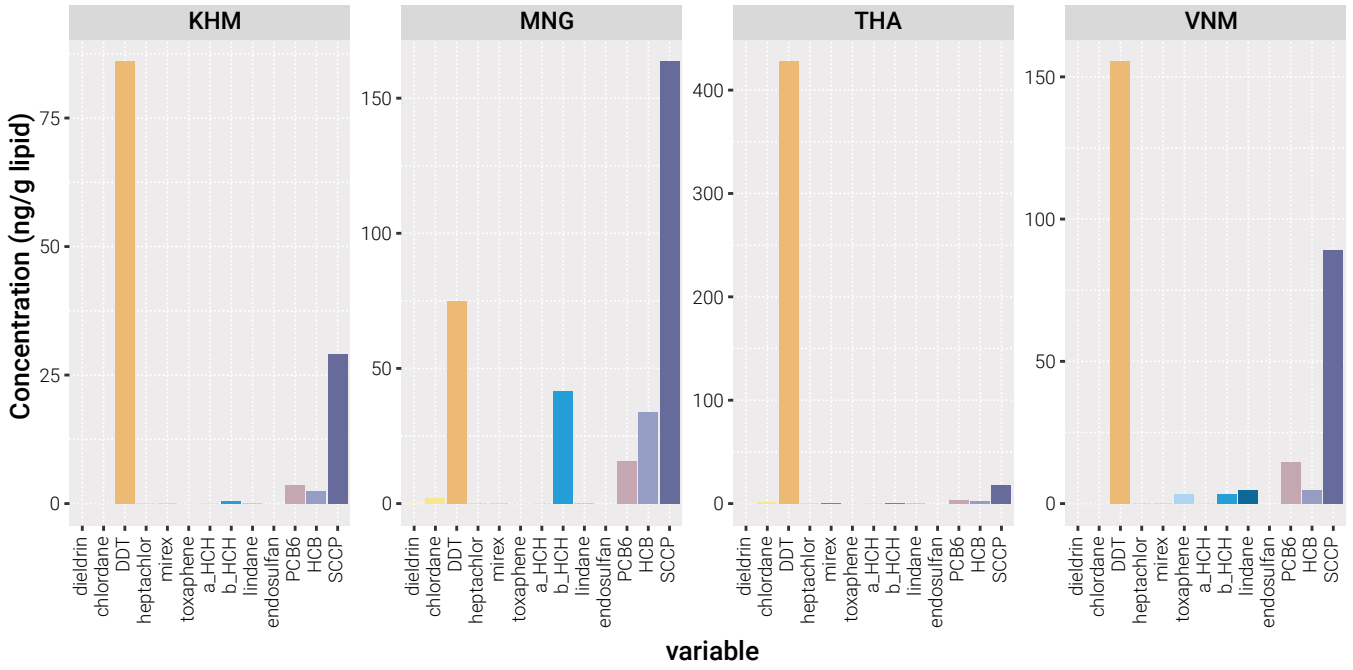


Figure 36: Human milk: Scaled barplots for chlorinated POPs by country (ng/g lipid)

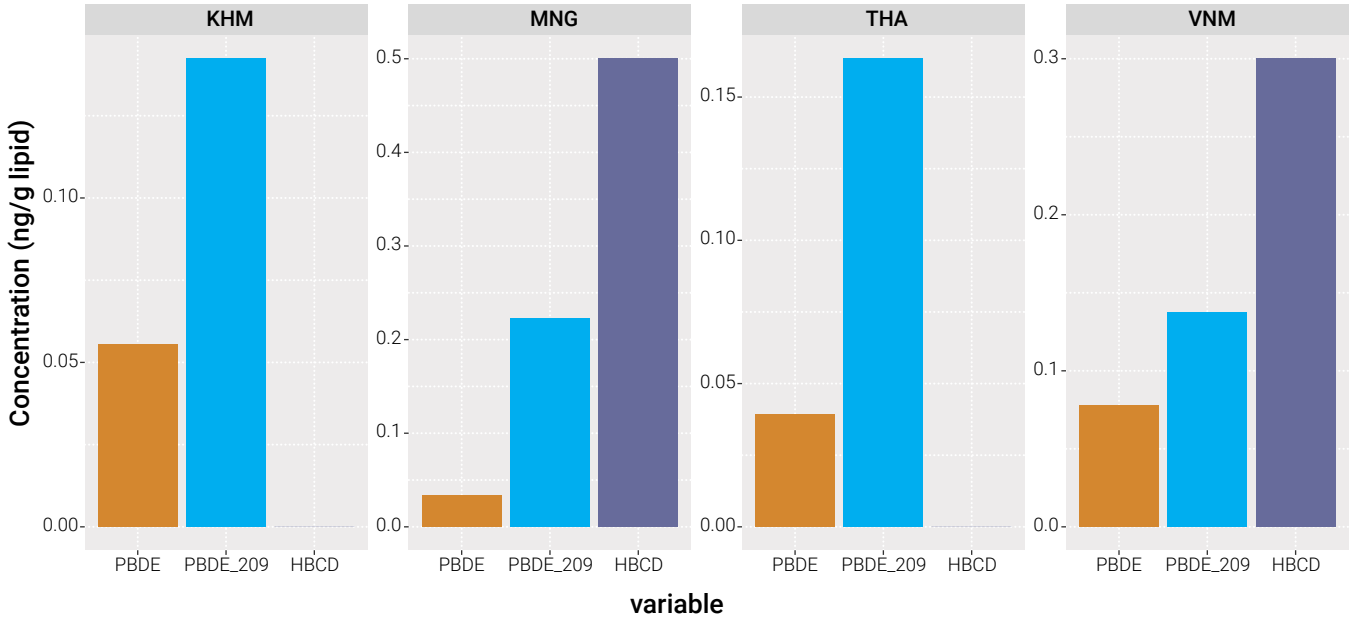


Figure 37: Human milk: Scaled barplots for brominated POPs by country (ng/g lipid)

The brominated POPs are summarized by country in Figure 37. Concentrations were all below 1 ng/g lipid. Whereas PBDE 209 dominated in Cambodia and Thailand, a-HBCD dominated in Mongolia and Viet Nam.

With respect to dl-POPs, Table 18 and Figure 38, the TEQs from PCDD/PCDF (TEQ_DF) were always higher than the TEQ from dl-PCB (TEQ_PCB). The highest value for TEQ_DF was found in Cambodia; the highest TEQ_PCB was found in Viet Nam. This result is amazing since Viet Nam is associated with 2,3,7,8-TCDD, thus TEQ_DF and not with PCB.

PFOS and PFOA were found in all countries; PFHXs was not detected in any of the Asian samples (Figure 39). Overall, the ranges for dl-POPs and PFAS were quite narrow (Table 18).

Table 18: Concentration of dl-POPs in human milk (pg TEQ/g lipid) and PFAS (pg/g f.w.) for Asian national pools collected under the UNEP project from 2016 to 2019

	KHM	MNG	THA	VNM	Overall mean	Overall median
pg TEQ/g lipid						
TEQ_DF	3.92	2.24	1.80	2.62	2.65	2.43
TEQ_PCB	0.657	1.35	0.577	1.62	1.05	1.00
pg/g f.w.						
PFOS	17.17	10.17	25.54	32.05	21.2	21.4
PFOA	14.63	20.09	25.79	12.96	18.4	17.4

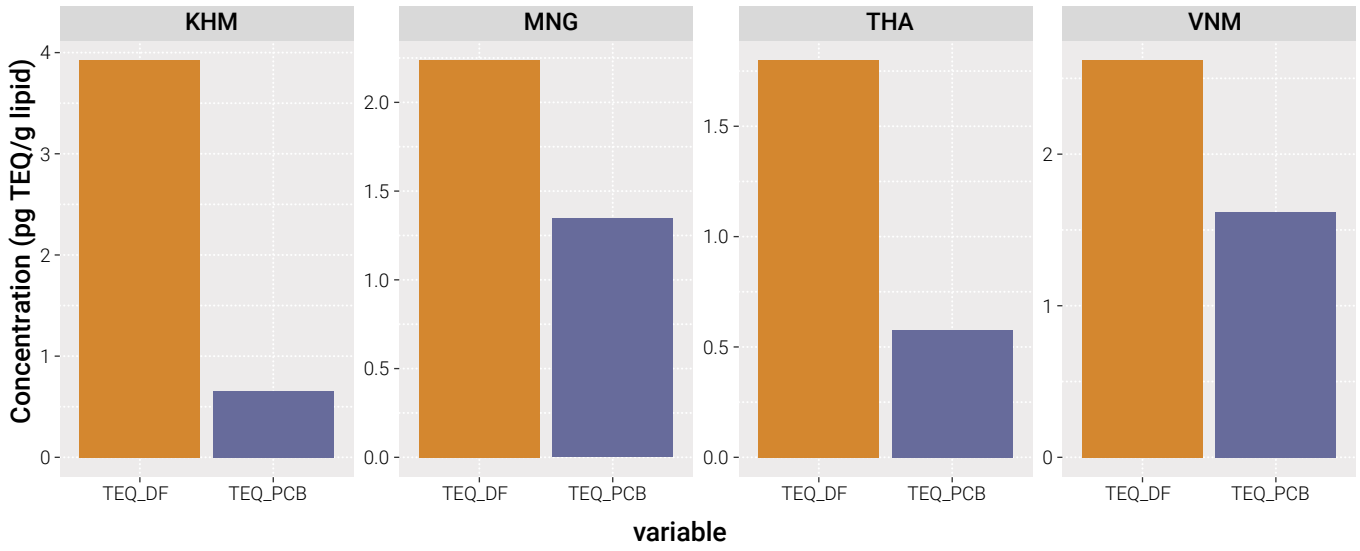


Figure 38: Human milk: Scaled barplots for dl-POPs as TEQ by country (pg TEQ/g lipid)

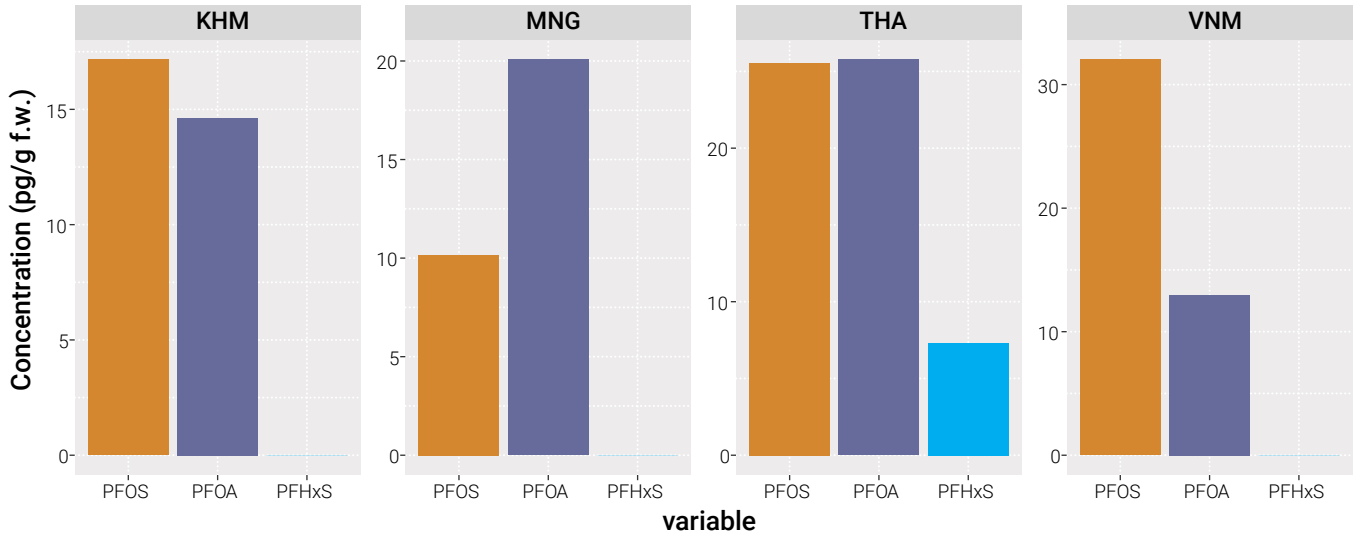


Figure 39: Human milk: Scaled barplots for PFAS by country (pg/g f.w.)

SECTION 5

Capacity building activities and regional workshops

Photo: ©Unsplash / Radoslav Bali

5. CAPACITY BUILDING ACTIVITIES AND REGIONAL WORKSHOPS

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

As much as possible, countries are encouraged to promote gender-responsive capacity building in line with the SDGs, the GEF gender policy, the Paris Agreement as well as various other international agreements.

5.1. Regional inception workshop

The inception workshop for UNEP/GEF project ´Implementation of the POPs Monitoring Plan in the Asian Region under the Stockholm Convention´ and the final results workshop on the UNEP/GEF project ´Tools and methods to include the nine new POPs into the global monitoring plan (GMP) for POPs´ were held on 25-27 January 2016, Hanoi, Viet Nam. The workshops mainly delivered the following outputs:

- Good understanding of the context of the project, including the effectiveness evaluation of the Stockholm Convention
- 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 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 on the 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 Asia Region was held on 8-10 August 2018 in Ulaanbaatar, Mongolia.

The midterm workshop aims to strengthen communication among core partners on the progress of the 2nd phase of the POPs global monitoring plan (GMP2) in the Asian Region, and to discuss about future needs, opportunities, and challenges beyond GMP2, as well as the sustainable monitoring of POPs on nation, regional and global level.

Documents, presentations and the report of the workshop are available on the 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 Asia Region was held on 5 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 Asia and Pacific Regions was held on 25 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 is provided to national laboratories in six countries. Due to COVID-19, some planned trainings could not be conducted, and a few others were delivered virtually. As of February 2022, two scheduled trainings have been completed with eight countries participating (Table 19).

Table 19: Trainings in project countries planed and progress made.

Region	No. of trainings planned	No. of trainings conducted	No. of countries participated	No. of female participants	No. of male participants
Asia	6	5	8*	36	22

* LAO PDR, Malaysia and Myanmar joined the training in Indonesia

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 6.3.2). 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 chapter 4.2 and expert laboratory data in chapter 5. The performance of all laboratories was checked through two rounds of inter-laboratory 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 2021a) and publications in the peer-reviewed literature (Fiedler, van der Veen and de Boer 2020b; de Boer, vaan 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 are shown in orange color and results from national laboratories in blue color; 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 uppercase letters and those analyzed by national laboratories have all lower case letters.

For chlorinated POPs, results from national laboratories are available from the Philippines and from Viet Nam. Both national laboratories were able to quantify only a few OCPs or PCB and the comparison of their data with those from the expert laboratory is shown in Figure 40.

Photo: ©BCRC Indonesia water sampling

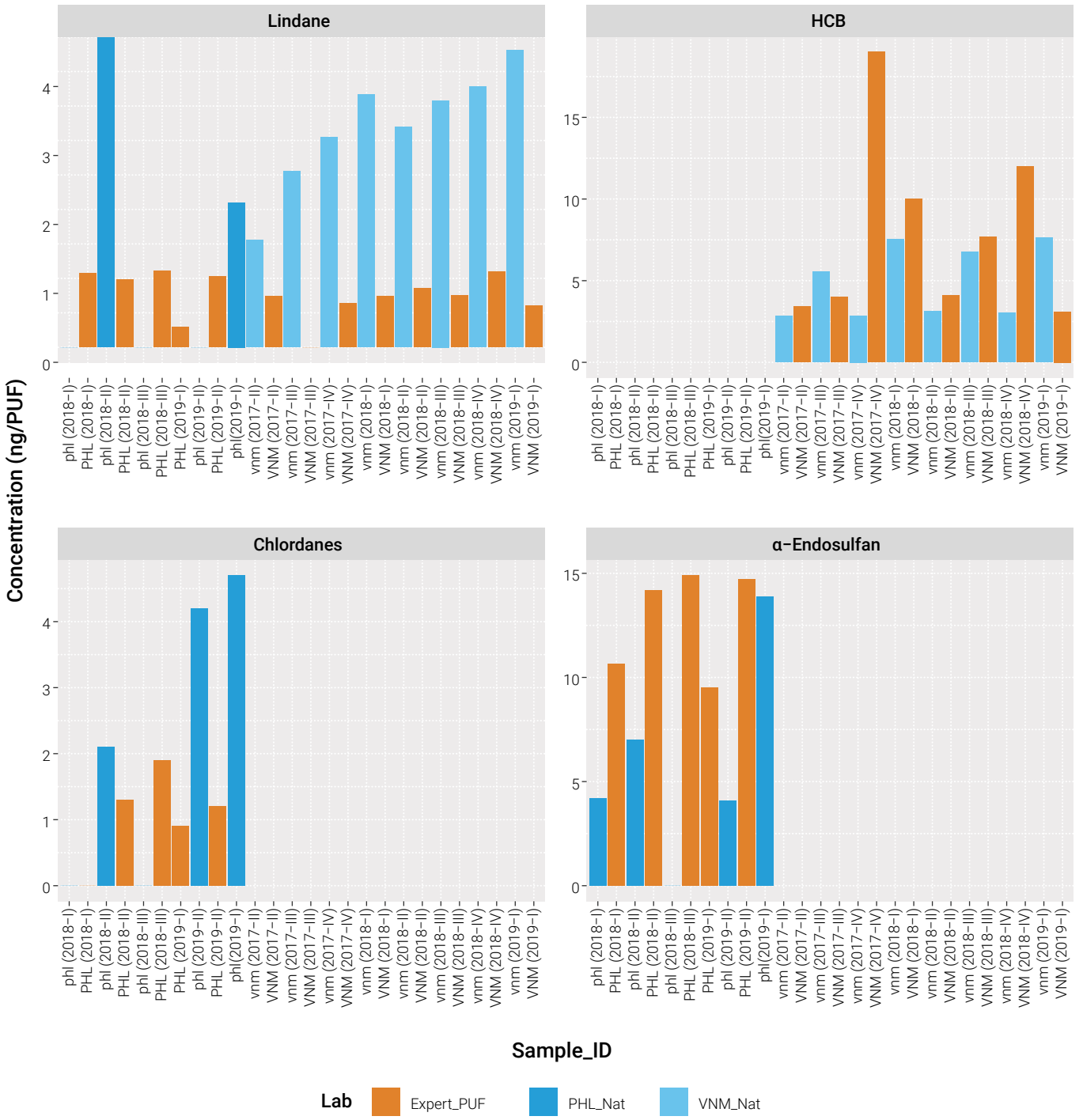


Figure 40: Philippines and Viet Nam, selected Cl-POPs in PAS/PUFs: Comparison of results from national laboratory and expert laboratory by sample_ID

Thailand had undertaken national lab analysis for dioxin-like POPs and PFOS in PUF samples. For dl-POPs, the national laboratory could quantify only dl-PCB). The results for PFOS analysis by the national laboratory and the expert laboratory are shown in Figure 41. There were only a few samples that had been analyzed by both labs and therefore, it is difficult to draw conclusions. Whereas for L-PFOS, there is some consistency observed, the values for br_PFOS and subsequently Sum PFOS differ largely. The PCA shows that both laboratories had very distinct but well-defined narrow ellipses.

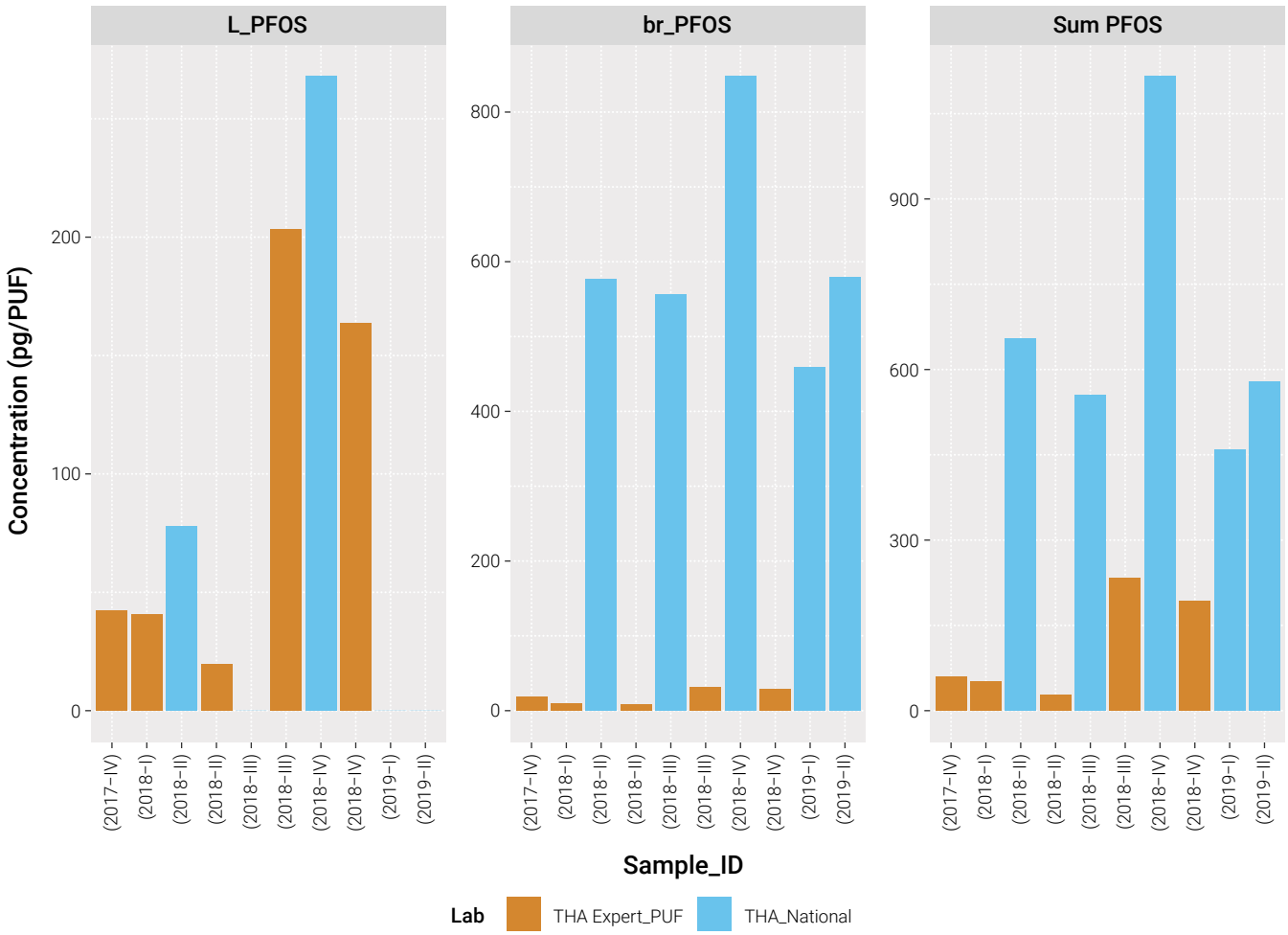


Figure 41: Thailand, PFOS in PAS/PUFs: Comparison of results from national laboratory and expert laboratory by sample_ID and PCA for the two laboratories

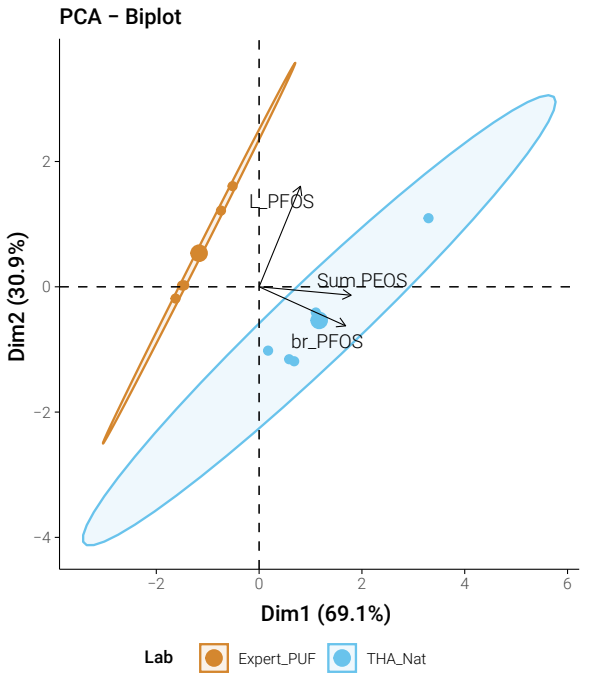


Figure 42: Thailand, PFOS in PAS/PUFs: Comparison of results from national laboratory and expert laboratory by sample_ID and PCA for the two laboratories

Viet Nam: the national laboratory analyzed PFOS and PFOA in PAS/PUFs. The comparison is shown in Figure 42. The Viet Nam laboratory had higher PFOS and PFOA values than in the expert laboratory but also much more amounts below the LOD.

For the water samples, the comparison is shown in Figure 44. It can be clearly seen that the expert laboratory quantified PFOS much more frequently than the Viet Nam laboratory.

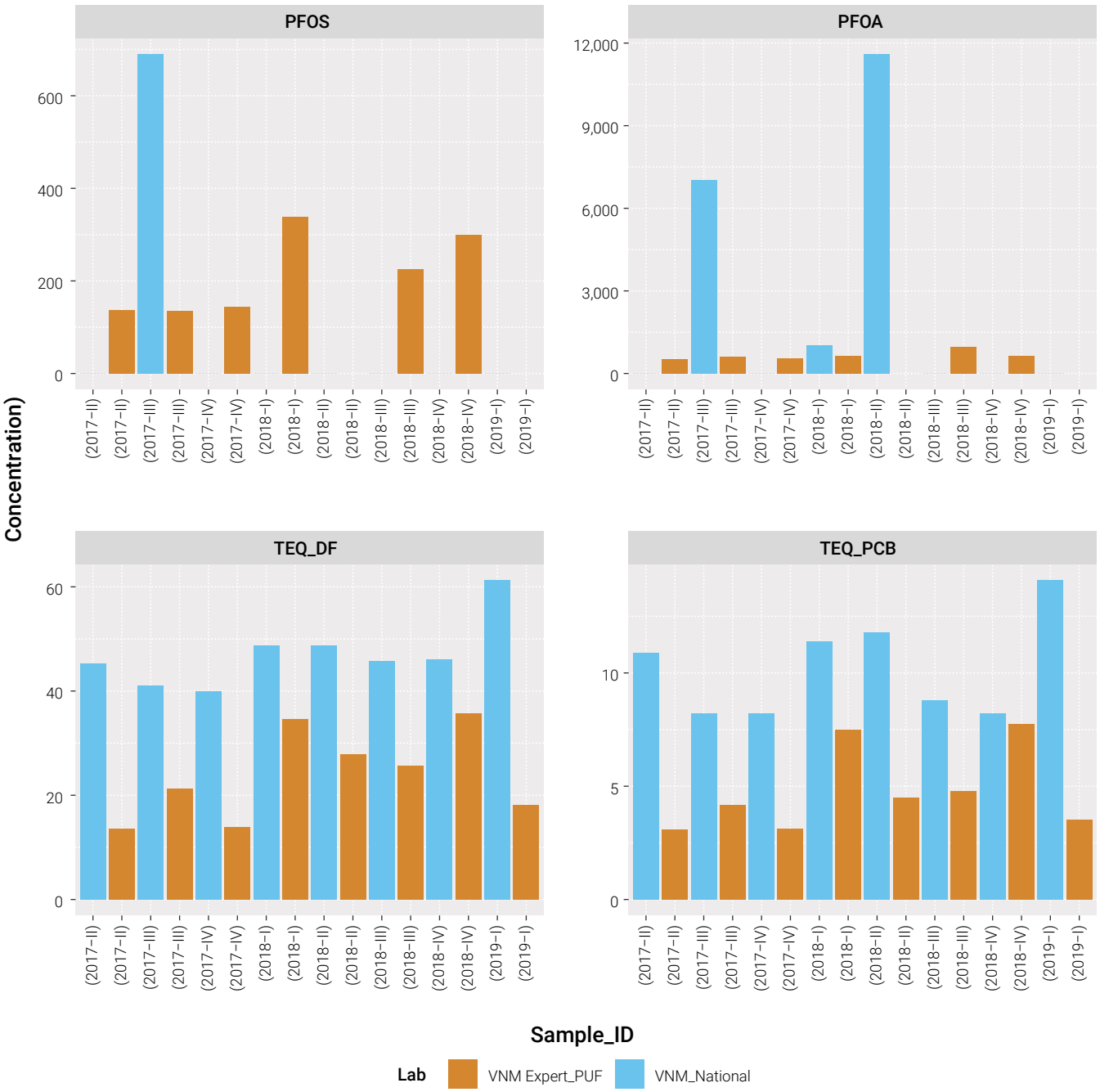


Figure 43: Viet Nam, dl-POPs and PFAS in PAS/PUFs: Comparison of results from national laboratory and expert laboratory by sample_ID and PCA for the two laboratories

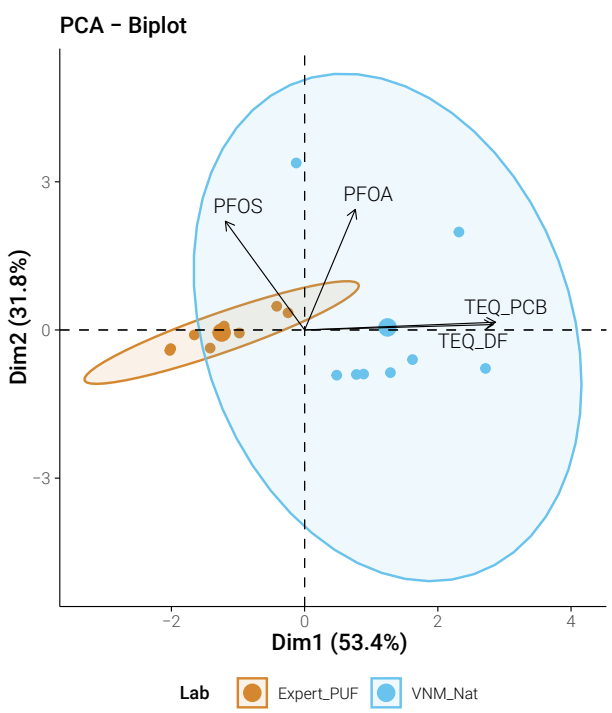


Figure 44: Viet Nam: PCA for PFAS and dl-POPs analysis in PUFs colored by laboratory

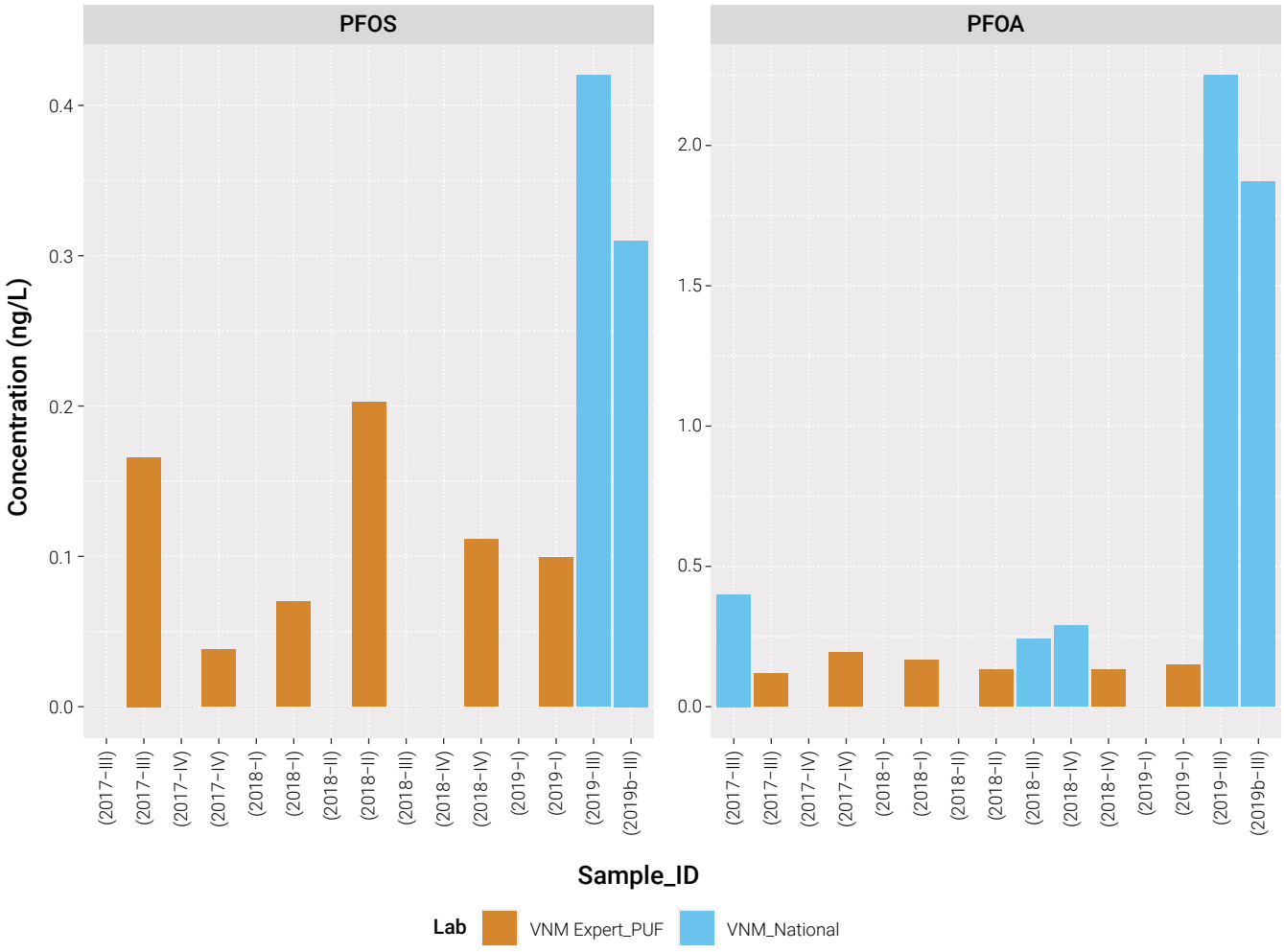


Figure 45: Viet Nam, water: Comparison of PFOS and PFOA results from national laboratory and expert laboratory by sample_ID and PCA for the two laboratories

SECTION 6

Sustainability plans

Photo: ©Unsplash / Nikohoshi

6. SUSTAINABILITY PLANS

6.1. National plans

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

6.1.1. Cambodia

The Ministry of Environment is an institution under the Royal Government of Cambodia responsible for promoting environmental protection and conservation of natural resources throughout the Kingdom, thus contributing to improve environmental quality, public welfare, national culture and the economy. The Ministry facilitates the development and implementation of policies, plans and legal instruments to promote and ensure the rational use of and management of the country's natural resources. Simultaneously, the Ministry has the role of motivating and supporting public participation in decision-making to resolve environmental and natural resource use issues. In carrying out its mission, the Ministry collaborates with other Ministries of the Royal Government, other institutions, national and international organizations, non-government, the private sector and the people of Cambodia.

There are two main departments under the Ministry of Environment of Cambodia mandated to monitor and analyses POPs. To be specific, the department of Hazardous Substance Management and the Laboratory. The Hazardous Substance Management department acts as the focal for Stockholm Convention. The department plays main role in facilitating and coordinating with stakeholders to develop POPs Monitoring and Action Plan. The department is also in charge of international cooperation regarding POPs monitoring. Another agency involving with POPs monitoring and analyses is the Laboratory. The agency is assigned as a national laboratory for POPs monitoring and analyses. In detail, the Laboratory conducts POPs monitoring and POPs analyses. In addition, the laboratory plays active role in join research regarding POPs survey with international agencies.

Currently, regarding POPs monitoring and Analyses, Cambodia is still in an early stage. In Cambodia the Laboratory had joined POPs air monitoring 2 times (once in 2005 with Japan expert and in 2017-2019 supported by UNEP). For POPs survey in human mike, Cambodia participated in 2017-2019. The laboratory is facing the lack of technical skill for POPs analyses and supported analytical equipment. However, the laboratory has constructed connection with other local laboratory such as laboratory of ministry of commerce and laboratory of institute of technology of Cambodia to run some basis POPs analyses.

After the project implementation, the laboratory plans to propose POPs capacity building training, POPs analysis and monitoring action plans to the government in order to receive some fund to implement the assignment, although the support (technical and financial resources) from international organization is still very essential for ensure the sustainability on POPs analysis and monitoring.

The need for sustain continued sampling and monitoring of POPs are listed

- Sustain budget for regular monitoring and sampling (every 3 months)
- Analytical equipment for POPs
- Joint research and survey with national and internal agencies
- Attending workshops or training on POPs monitoring and analyses

6.1.2. Mongolia

Key points to be included for the sustainable plan

We need to identify contaminated sites polluted with POPs throughout the country and create a database with detailed information on every single soums and province. To create the database for POPs contamination, we need to conduct inventory for each group of POPs and should be able to analyze the POPs in our national laboratory.

The analysis of POPs chemicals including sample preparation, instrumental measurements, and data processing are all very complicated processes. It needs the experience of years. The most important issue for the sustainable plan on POPs is to be able to monitor/analyze the POPs in various matrices. A permanent service for the maintenance of analytical instruments is needed and for that we need funding. For successful implementation of creating laboratory capacity, we need to train the people who are working in the laboratory for sample preparation as well as for instrumental measurements, and importantly, those trained researchers should permanently be working with

the POPs analysis only. Although this is our internal issue, right now we don't have permanent staff at the POPs laboratory and the researchers in the laboratory are working on their research in different fields, so the POPs chemical analysis is like side work when they have time or when they are obliged to research special projects such as GMP2.

Status of capacity and future expectations on capacity

As mentioned in chapter 4, the National laboratories which deal with POPs related analysis are still of very basic quality. In general, we need to improve the laboratory capacity, apparatus, and instruments as well as the skills of staff working for the POPs analysis. The improvements which do not cost could be made on our own. The analytical instruments maintenance is to be done regularly. The most important is, that regular analyses of POPs are carried out so that the staff can build up a routine. Laboratory staff needs to participate in training, workshops, or seminars to learn more about POPs analysis. Staff training e.g. by a traineeship in a reference lab, may be useful.

All laboratories listed in Chapter 4 has equipped with GC-MS, GC (with ECD) and GC-MS/MS (Triple Quadrupole), and other portable instruments. However, the instruments are not fully used due to the lack of experience of the lab staff. Using the protocol provided by UNEP and other expert laboratories, we manage to do the POPs inventory and sample collection on our own. However, for sample preparation and instrumental analysis, there is no concrete routine built up so far.

Current POPs regulations and plans on POPs monitoring

One of the key objectives of updated NIP is "To become PCB-Free Country" through phasing out Polychlorinated Biphenyls (PCBs) in electrical equipment by 2020. With the PCB treatment facility which was established under the National Electricity Transmission Grid State-Owned Stock Company, we already completed the decontamination of the equipment containing PCBs above 50 ppm and now cleaning the equipment with up to 20 ppm of PCBs.

It was an excellent opportunity to prepare the samples and send them to the expert laboratory to analyze the POPs contamination under the GMP2 project. The continuous support from the UNEP and the experts is very much encouraging for us to improve the capacity for POPs monitoring in Mongolia. The long-term purpose of the national POPs laboratory is to analyze and monitor as many as different matrices for all types of POPs. The near future aim is to start monitoring and analysis with sediment, air, water, human breast milk, and some food samples such as milk and meat. We plan to monitor basic POPs, PCBs, Hexachlorocyclohexane, and dioxin/furan, based on the previous history on the usage of pesticides and the monitoring results of the GMP2 project during 2017-2019.

The data generated by the GEF projects on POPs monitoring, such as the level of POPs in abiotic and biotic matrices and capacities developed through various project activities, will be used to review and update national policies and legislation related to the sound management of POPs. Enhancement of understanding of POPs chemicals and their negative impact on human health and environment through the provision of knowledge to decision-makers on a relevant scientific publication is necessary. With this aim, one publication at Chemosphere is submitted and the second one is under preparation.

Regular participation in Interlaboratory assessments is crucial for under developing laboratories like us for quality control.

National POPs monitoring activities carried out by our country should be continued to provide background POPs levels for future evaluation. Regional POPs monitoring programmes, such as the East Asian POPs Monitoring Programme (POPsEA) and UNEP/GEF programmes should be also continued for capacity building/enhancement as well as for regional comparison and temporal trend analysis.

As said in the previous section, the laboratory capacity needs a substantial improvement to be able to continue the monitoring activity of POPs. Funding for laboratory staff training is needed. Instead of sending a restricted number of people abroad for training, the in-situ training might be useful for us. In this way, more people can attend the training and learn about different aspects of POPs analysis. Need to take part in the monitoring of new POPs and receive adequate training and capacity-building activities.

The GMP2 final report with all the analysis results will be sent to the Ministry of Environment and Tourism. Those analytical results with POPs levels in many different matrices have been achieved for the first time in our country which will be used to create better legal conditions, institutional capacity, and infrastructure for collecting, storage, treatment, and disposal of hazardous wastes, particularly POPs chemicals.

6.1.3. Philippines

Although chemical management in the Philippines is not a priority program, the foundation of chemical management is already in place. The Philippines already has a chemical inventory through the Philippine Inventory of Chemicals and Chemical Substances (PICCS), there is already an existing law, Republic Act 6969, governing chemical management and being a Party to Multilateral Environmental Agreements (MEAs), particularly the Stockholm Convention on POPs. As a Party to the Stockholm Convention, the Philippines has already developed its National Implementation Plan, thereby institutionalizing the action plans on the phase out and monitoring of POPs in the country. To a certain extent, there are limitations on the budget allocated for POPs management on the timely implementation of these action plans. In most cases, these action plans are being implemented through Foreign-Assisted projects like the GMP2. In order to sustain the works and outputs which the projects has done, the following needs to be ensured:

- Strengthening the implementation of policies, laws and regulations related to POPs.
- Development of new policies in relation to emerging global issues on POPs.
- Strengthen involvement of private sector and local government units in monitoring and management of products containing POPs.
- Involvement of the academic sector in the conduct of baseline studies on POPs.
- Integrating POPs monitoring in regular chemical monitoring programme of the Bureau.
- Sustained capacity building of staff on POPs analysis.

Replication of the monitoring activities in this project is highly feasible. Lessons were learned on the limitations and delays that were encountered which can help improve future implementation of future endeavours.

6.1.4. Thailand

Thailand had participated in the project entitled "Enabling Activities to Review and Update the National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants" in order to provide updated information on the 12 initial POPs and new information on the 15 new POPs listed in Annexes A, B and C of the Stockholm Convention during 2009-2017 (excluding SCCP) and form a basis for the update of the National Implementation Plan (NIP), obligated under Article 7 of the Stockholm Convention to be in line and meet with its objective and goal. It definitely includes the establishment of the national POPs monitoring plan in Thailand.

Under the implementation of this POPs monitoring project, the capacities of some national and academic laboratories has been expanded through the monitoring of POPs in various types of samples including atmospheric air samples in clean areas, human breast milk and some national samples (such as river sediments, chicken eggs, duck eggs, fish and beef) as well as the inter-laboratory assessment activity. There are ongoing efforts to strengthen the capabilities of relevant laboratories as a network of POPs analysis laboratories in Thailand to be able to efficiently support the country's POPs monitoring activities in the long term. Some of these relevant laboratories have been encouraged to participate as core laboratories in POPsEA Project in order to receive the technical assistant from Japanese government to expand their capabilities to sustain the POPs routine monitoring in the region.

According to the result of the project, it has been noticed that there is a potential need of the national long term POPs surveillance and monitoring programme along the food chain in order to assess the risk and exposure opportunity from POPs in the Thai population. Consequently, there is also a need for the capability development of national laboratories either in analyzing of new and variety POPs or in increasing the analytical sensitivity.

6.1.5. Viet Nam

Experience from POPs monitoring under the Stockholm Convention

The provisions of the Stockholm Convention on the monitoring of POPs are specified in Article 11 - "Research, Development and Monitoring". Viet Nam needs the support and knowledge or experience sharing from advanced countries to enhance the capacity to monitor POPs, PTS and mercury. Point f, Clause 2, Article 11 requires "Encourage and/or undertake cooperation with regard to storage and maintenance of information generated from research, development and monitoring."

Clause 2 of Article 16 on performance assessment stated that "In order to facilitate such evaluation, the Conference of the Parties shall, at its first meeting initiate the establishment of arrangements to provide itself with comparable monitoring data on the presence of the chemicals listed in Annexes A, B and C, as well as their regional and global environmental transport". Experience from the global monitoring plan for POPs.

The global monitoring plan (GPM) is established by UNEP has been implemented in many developing countries and thus evaluation of its implementing progress will be useful for building POPs monitoring capacity for Viet Nam in the future.

The GMP also encountered two major issues: the fragmentation of regional management and the large gap in technical levels between regions. Viet Nam has been facing these issues at certain extent and in smaller scale. Therefore, analyzing the issues of the GMP may provide useful experiences.

The experience gained during the implementation of the two phases of GMP by 2015 demonstrates several challenges that need to be addressed to improve the POPs monitoring in the future.

Inter-laboratory assessments

NCEM lab has participated in all of these ILPs. In the beginning, NCEM lab only registered to participate in the analysis of PCDD/PCDF few sample matrixes. From the second round, more POPs compounds such as PCDD/PCDF, dl-PCBs, PCBs, etc. in most of sample matrix include standard solution, sediment, fish, air extract, and human milk were registered for analysis. Reports from these ILPs provide independent feedback on the quality of the lab's analytical results. Based on these assessments, our lab can monitor and improve performance over time.

There are several challenges and point important for sustainability such as:

- Challenges with communication and information exchange
- Sample specimen banking needs
- Financial difficulties for POPs monitoring
- Manage, achieve, and retrieve data
- Dealing with low detection limits in future monitoring

Suggestions for sustainable plan for POPs monitoring in Viet Nam

This is a brief overview of some initial issues relating POPs in the environmental monitoring including POPs residue. The consultants have also overviewed global POPs monitoring activities coordinated by UNEP. By overview for international experience in POPs monitoring, we recognize that with management and technical characteristics of Viet Nam, the experiences gained from the GMP might be valuable for POPs monitoring activities in Viet Nam and gradual improvement of POPs monitoring competence in the future. We would like to address some significant issues, which may need to be tackled, for the sustainable monitoring of POPs in Viet Nam as follows:

1. Dispersion of regional management. The UNEP laboratories are located in a variety of areas, with the distinction of qualifications and development conditions. In order to create an effective network of labs, the UNEP Global monitoring programme has established regional POPs centers such as those in Japan and China. Regional POPs centers large laboratories, with higher levels of expertise, a good staff of professionals, and a strong commitment, appropriate vision and effective operation in promoting POPs monitoring in relevant regions. The regional center is the hub that connects regional laboratories in joint monitoring programs. UNEP master Laboratories in Europe is capable for providing regional centers with training and consultancy supports, which create the spillover effects of the operation in the network. In the worst case, regional centers are still able to provide basic monitoring data of a certain area to maintain the continuity of the larger POPs monitoring programmes. For Viet Nam, there might be at least, one regional center acting as a hub in the north, central and the south. Consequently, POPs monitoring data can at least be maintained on a broad enough scale to assess the impact of national POPs control policies.

2. There is a large technical distinction between the laboratories in the monitoring system. There are laboratories in developed countries capable of analyzing most types of POPs in different matrices with high accuracy. There are, however, only laboratories capable of analysis for basic POPs such as organochlorine pesticides. To address this issue, the Global POPs Monitoring Programme allows the labs to participate in POPs monitoring programmes in accordance with their capabilities. Laboratories in Viet Nam also have very different qualifications. Therefore, consideration should be given to developing POPs monitoring programmes in which laboratories with different capacities can participate in the selection of appropriate POPs groups for monitoring. Therefore, a national POPs monitoring programme should be developed flexibly enough so that laboratories at different levels can participate and select appropriate POPs groups for monitoring.

3. Viet Nam has a system of legal documents on environmental monitoring and environmental protection activities for POPs. The Law on Environmental Protection

2020 was promulgated and supplemented with some new regulations, including the issue of POPs. Article 69 of the law stipulates requirements for environmental protection in the management of POPs and raw materials, fuels, materials, products, goods and facilities containing POPs. This works as a new regulation that was not included in the existing Law on Environmental Protection 2014. The system of sub-law documents such as decrees and circulars guiding the implementation of LEP 2020 have been compiled and promulgated. A system of legal document to provide guidance in POPs monitoring operation for local organizations has been enacted. However, a comprehensive guidance for POPs monitoring is still lacking, and need to be further improved. Examples of compliance monitoring for new POPs (PBDEs, PFOS/PFOA, etc), unintended POPs (Dioxin, PCB, HCB).

4. The system of standard methods prescribed by Viet Nam is not sufficient for all POPs, environmental matrices and analytical equipment. Therefore, there are an urgent requirement for Viet Nam to research, update and amend the system of new monitoring methods through disseminating national technical regulations for different POPs monitoring. In the case of the issuance facing difficulties or time-consuming, qualified local labs may invite prominent experts to compile guidance documentation from reliable international sources.

5. Laboratory assessment can be conducted through a variety of methods, in which proficiency tests can provide the most accurate results. So far, there is not any lab in Viet Nam that are certified to provide POPs certified reference materials as well as service for proficiency test. Learning from the Global POPs monitoring programme demonstrates that participating in proficiency testing programs helps labs better understand their own capacities and thereby selects appropriate POPs substances as well as planning for the gradual improvement building capacity in the future. The Northern Center Environmental Monitoring (formerly Center Environmental Monitoring) of the Viet Nam Environment Administration is currently the focal point in the national monitoring network for proficiency testing activities. Therefore, POPs proficiency test activities can be a component of national monitoring system.

6. In Viet Nam, the implementation of retrospective research to assess the pollution change of new POPs in the past is not feasible. However, it has been proved that POPs retrospective research is essential as the quantity of new POPs have been gradually increasing. Thus, planning for the establishment of an environmental sample bank is also important mission to periodically sample which will be used in the future when the labs have sufficient technical and capacity to conduct a retrospective research of new POPs such as short-chain chlorinated paraffin and some PFCs. More experience can be learned from operation of environmental specimen banks in The United States, Sweden, Germany, Japan.

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. Mongolia

Mongolia is part of the system on Environmental Monitoring of Persistent Organic Pollutants in East Asian Countries (POPsEA) since 2003. The environmental POPsEA project was initiated in 2003 aiming to contribute to monitoring activities under the global monitoring plan and the effectiveness evaluation of the Stockholm Convention, Article 16. The activities of the POPsEA project have been achieving excellent outcomes for the monitoring activities in the East and South-east Asia sub-region and have been keeping and improving monitoring capacity by sharing technical information among the member countries. Mongolia participated regularly in the Workshop on Environmental Monitoring of Persistent Organic Pollutants in East Asian Countries which has been organized biannually since 2005.

Furthermore, Mongolia had experienced ambient air sampling cooperative monitoring within the framework of the POPsEA project. The monitoring was done in the background area of the Terelj which is about 60 kilometers away from Ulaanbaatar, in 2006, 2007, and 2013. During the POPsEA project monitoring, there were no noticeable POPs contaminations found in the background air samples. However, both active and passive air sampling site of the current GMP project is located in an urban area in Ulaanbaatar.

Due to the Kovid-19 pandemic, the background air monitoring planned in 2019 under the POPsEA project has been postponed. We hope the background air sampling will be conducted in 2022.

Although our National laboratory can implement the limited scope of POPs monitoring now, we are planning to join the Core Laboratory Capacity Building Programme and we sent our request to the National Committee on POPsEA and Ministry of Environment, Government of Japan.

6.2.2. Philippines

The Environmental Management Bureau through the Environmental Quality Management Division (EQMD) and the Environmental Research and Laboratory Services Division (ERLSD) is currently involved with the Persistent Organic Pollutants Monitoring Network in East Asia (POPsEA) Project in partnership with the Ministry of Environment – Japan through the Jaan Environmental Sanitation Center. The project aims to enhance monitoring capability for POPs of east Asian countries, with Japan and South Korea providing the technical guidance and training. Moreover, the project also assists the member countries in contributing to the effectiveness evaluation requirement of the Stockholm Convention through conduct of ambient air monitoring in identified background sites in each country and analyzing these for a variety of POPs.

In February 2020, the Philippines completed its scheduled technical training and ambient air sampling in Mt. Sto. Tomas in Benguet under this Project. Experts from Japan led by Dr. Takuya Shiozaki and Dr. Tomonori Takeuchi, visited the country to provide participants from EMB a seminar on POPs monitoring and analysis, quality assurance/quality control and instrumentation and data analysis. In addition, technical personnel of the Bureau were also trained on conduct of active and passive ambient air sampling, field QA/QC requirements, sampler calibration, among others. All in all, the personnel involved in this activity managed to collect a total of nine (9) 24-hr ambient air samples collected over a span of three consecutive days as well as two passive air samples exposed for approximately one (1) month in the same sampling site. The samples were analyzed by JESC and results will be provided to EMB once the QA/QC checks have been completed by the experts.

The Project is also looking at the EMB Central Office Laboratory of the Philippines to be designated as a candidate to become a POPs Core Laboratory in the East Asian Region. It is envisioned that Core Laboratories under the project will provide additional support the expert laboratories in Japan and in South Korea in terms of sample analysis and generation of data for submission to the Stockholm Convention, ultimately leading to an increase in frequency of POPs monitoring activities in the region.

6.2.3. Thailand

As set out by the first national implementation Plan, Thailand has monitored POPs in environment through national and international cooperation projects. This includes the POPsEA Project (Environmental monitoring of persistent organic pollutants (POPs) in East-Asian Countries) with the technical and financial supports from the Japanese Government which aims to monitor 9 types of OCPs in the atmosphere of East Asian Countries. The participating countries include Cambodia, Indonesia, Japan, Korea, Lao PDR, Malaysia, Mongolia, Philippines, Singapore, Thailand and Viet Nam since 2002. Under the project, Japanese government has a bilateral cooperative monitoring on POPs with selected countries as follows:

1. Cambodia in 2006, 2008 and 2015;
2. Indonesia in 2005, 2006 and 2012;
3. Lao PDR in 2006, 2011 and 2017;
4. Malaysia in 2007, 2009 and 2016;
5. Mongolia in 2006, 2007 and 2013;
6. Philippines in 2006 and 2010;
7. Thailand in 2006, 2007 AND 2014; and
8. Viet Nam in 2005-2006, 2009-2010 and 2012-2013.

The objectives of POPsEA are as follows:

1. To know the background levels of POPs in the environment in the East Asia sub-region;
2. To provide comparable and scientifically sound data on the media considered as essential; and
3. To contribute to the effectiveness evaluation under the Stockholm Convention, Article 16.

So far, they organized 13 POPsEA workshops in order to review the POPs monitoring results obtained in this project; to exchange the views on policy and technical aspects of the POPs monitoring; and to discuss the update of the on-going monitoring plans and future directions of the activities in this project. The 13th POPsEA Workshop was just organized in Bangkok, Thailand, during 29-31 January 2020. The results of the recent workshop agreed to establish more core laboratories in the regions in order to expand the capacity of the selected potential laboratories among Indonesia, Philippines, Thailand or Viet Nam to sustain the POPs routine monitoring in the region.

6.2.4. Viet Nam

Currently, in Viet Nam there are two systems for accreditation of laboratorial abilities in the field of chemical and biological testing: the VILAS system managed by Bureau of Accreditation of Viet Nam (BOA, managed by the Ministry for Science and Technology) and the Viet Nam certificate system for the environmental monitoring and testing (VIMCERTS, managed by Ministry of Natural Resources and environment). It is worthy to note that BOA is a full member of international organization for accreditation bodies such as ILAC and MRA.

In the management system of BOA, a total of approximately 1500 laboratories have been given VILAS ISO Accreditation. These laboratories operate in 7 areas of testing: Mechanical, Pharmaceutical, Electrical & Electronic, Measurement & Calibration, Non-Destructive, Chemistry and Biology. Of this, there are about 600 laboratories operating in the field of chemical analysis (including chemical residues in the environment, foods, quality components of products, etc). The number of laboratories registered for the analysis of pollutants POPs is 76 laboratories, accounting for about 13% and mainly focusing on pesticide chemicals and PCBs. There are very few organizations registering for Dioxin related compounds and none for new POPs such as PBDEs, PFOS, etc.

At the end of 2018, there were 250 laboratories being given the certificate for environmental monitoring and analysis which is named as VIMCERTS. Of this, there are 40 laboratories registering for POPs analysis accounted for 18.6% (mostly for organochlorine pesticides), including 5 private laboratories and 35 state laboratories (see Appendix 7 for more details).

In 2018, re-organization processes in the Viet Nam Environment Administration (VEA) took place and the authorization of VIMCERTS was transferred to the Agency for Environmental Quality Management which belongs to VEA. The publication of VIMCERTS statistics has been halted from then. In this review, we focus the assessment on data collected before 2019. However, it is believed that there has been only an insignificant change of laboratories in POPs monitoring.

For the environmental monitoring purpose, VIMCERTS is essential for POPs laboratories to be recognized as authorized organizations. Therefore, when the national network of POPs Laboritories in Viet Nam is reinforced in the future, such VIMCERTS laboratories should be given more attention (previously, academic institutions normally receive more attention for capacity building).

6.3. Regional monitoring under the Stockholm Convention arrangements for GMP

The PAS/PUF data generated by the expert laboratories in the UNEP/GEF GMP2 projects (UNEP 2024b) 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.).

SECTION 7

Conclusion

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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 Asia 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, Africa, 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 Asian 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.

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8. APPENDIX

8.1. Responsible people in the Asian region

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

Country	Responsibility	Person (name)	Affiliation	E-mail
Cambodia	Coordinator	Laska Sophal	Hazardous Substance office Department of Hazardous Substance Management Ministry of Environment	sophallaska.moe@gmail.com
	Air	Siv Kung	Environmental Quality Research & Laboratory Laboratory Department Ministry of Environment	sivkung@yahoo.com
	Water	NA		
	Human milk	Thlork Serey Pagna	Laboratory Department Ministry of Environment	serey_pagna@yahoo.com
Indonesia	Coordinator	Anton Purnomo	Basel & Stockholm Conventions Regional Centre for Southeast Asia	antonpurnomo@gmail.com
	Air	Luckmi Purwandari	Head of Sub Directorate of Inventory and Air Quality Management	luckmip@gmail.com
	Water	NA		
	Human milk	No sample		
Lao PDR	Coordinator	Virasack Chundara	Natural Resources and Environment Institute (NREI)	sack_4369@yahoo.com
	Air	Vanhna Phanphongsa	Ministry of Natural Resources and Environment (MoNRE)	vanhnatt@gmail.com
	Water	NA		
	Human milk	No sample		
Mongolia	Coordinator	Enkhtuul Surenjav	Laboratory of inorganic chemistry Institute of chemistry and chemical technology Mongolian Academy of Sciences	enkhtuulls@yahoo.com
	Air	Khureldavaa Otgonbayar	Laboratory of Ecological Chemistry Institute of Chemistry and Chemical Technology,	khureldavaa@gmail.com
	Water			
	Human milk			
Philippines	Coordinator	Joel Maleon	Environmental Quality Management Division	jjdm0439@yahoo.com
	Air	Renato T. Cruz	Environmental Management Bureau – Department of Environment and Natural Resources Air Quality Management	cruz.renato.t@gmail.com
	Water	NA		
	Human milk	No sample		
Thailand	Coordinator	Pensri WATCHALAYANN	Faculty of Public Health Thammasat University	pensri.watchalayann@gmail.com
	Air			
	Water	NA		
	Human milk	Teeraporn WIRIWUTIKORN	Hazardous Substance Division Waste and Hazardous Substance Management Bureau Pollution Control Department	teeraporn.w@pcd.go.th
Viet Nam	Coordinator	Nguyen Nhan Hue	Department of Environment Quality Management, Viet Nam Environment Administration	nguyenhue85@yahoo.com
	Air			
	Water			
	Human milk			

8.2. Locations of air and water sampling sites

Table S2: Locations of air sampling sites (PAS/PUF)

Country	Physical Address	Alt (m)	Latitude	Longitude
Cambodia	Sinhanuk province	116	10.636	103.519
Indonesia	Indonesian Agency for Meteorology, Climatology and Geophysics (IAMCG), Kemayoran, Jakarta	4	-6.1558	106.842
Lao PDR	Nalongkoun village	178	18.493	102.4489
Mongolia	Peace avenue, Bayanzurkh district of Ulaanbaatar city	1350	47.918	106.9699
Philippines	National Agrometeorological (AGROMET) Station, Los Baños, Laguna, about 70.2 km south of Manila	23	14.165	121.250
Thailand	Wachiralongkorn Dam	142	14.784	98.600
Viet Nam	Ba Vì, Hanoi	150	21.085	105.37

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

Country	Site name	Type	Latitude (decimal)	Longitude (decimal)
Mongolia	Tuul River	Fresh	47.889	106.910
Viet Nam	Do Quan Bridge, Mekong River	Fresh	20.3858	106.1586

8.3. Monitoring results from expert laboratories

8.3.1. Ambient air

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

ISO3	Sample_ID	Drins	Chlordane	DDT	Heptachlor	HCHs	a_Endosulfan	Mirex	Toxaphene	PCB6	HCB	PeCBz	HCBD
IDN	IDN (2018-I)	10	11	17	1.1	17	3.4	0.46	0.45	5.6	4.4	1.5	1.1
IDN	IDN (2018-II)	6.7	6.4	15	0.78	4.8	4.7	0.26	1.59	7.6	3.4	1.8	0.82
IDN	IDN (2018-III)	4.0	4.4	11	0.12	4.2	3.3	0.21	0.46	5.9	2.6	1.4	0.89
IDN	IDN (2018-IV)	8.2	8.7	15	0.34	8.5	5.1	0.26	0.53	6.0	1.8	0.87	0.83
IDN	IDN (2019-I)	7.5	6.9	13	0.60	26	1.1	0.34	<LOQ	4.6	3.4	1.2	0.84
IDN	IDN (2019-II)	5.6	5.2	12	0.00	6.4	<0.3	0.27	<LOQ	5.1	3.2	1.6	2
IDN	IDN (2019-III)	3.1	3.5	8.7	0.00	2.3	<0.39	0.25	<LOQ	4.5	3.2	1.3	0.92
KHM	KHM (2018-I)	0.50	0.61	30	0.00	0.38	7.2	0.2	<LOQ	7.7	4	1.1	2.7
KHM	KHM (2018-II)	0.48	0.38	25	0.00	0.33	3.1	0.22	<LOQ	6.0	2.3	0.58	1.9
KHM	KHM (2018-III)	0.00	0.00	20	1.9	0.53	1.7	0.22	<LOQ	3.5	3.6	0.88	2.8
KHM	KHM (2018-IV)	0.00	0.61	17	0.10	0.87	7.8	0.14	<LOQ	7.6	4.6	1.7	3.9
KHM	KHM (2019-I)	0.00	0.76	25	0.61	0.91	3.6	0.25	<LOQ	6.2	3.1	1.1	3.7
KHM	KHM (2019-II)	0.00	0.00	27	0.57	1.1	<0.3	0.19	<LOQ	6.0	2.9	0.61	4.1
LAO	LAO (2017-IV)	0.00	1.6	3.3	0.59	1.3	4.1	0.22	<LOQ	0.97	6.3	1.8	11
LAO	LAO (2018-I)	0.00	31	4.4	2.1	0.73	4.4	0.27	<LOQ	1.1	2.8	0.91	8.1
LAO	LAO (2018-II)	0.50	66	5.1	3.2	0.47	3	0.21	1.1	0.95	1.9	0.51	0.48
LAO	LAO (2018-III)	0.00	14	4.1	1.4	0.70	2.7	0.19	1.2	1.8	4.5	0.94	3.7
LAO	LAO (2018-IV)	0.00	6.8	2.9	0.42	0.84	1.4	<0.1	<LOQ	1.3	4.5	1.6	4.8
LAO	LAO (2019-I)	0.00	9.8	7.0	0.67	1.1	1.5	0.24	<LOQ	1.1	2.2	0.68	3.1
LAO	LAO (2019-II)	0.00	16	5.3	0.00	0.47	1	0.26	0.29	1.1	2.5	0.7	3.2
MNG	MNG (2017-II)	0.18	0.42	15	0.16	13	0.41	0.26	<LOQ	30	13	3.2	3
MNG	MNG (2017-III)	0.17	1.2	11	0.56	18	2.9	0.23	0.46	23	16	3.6	6
MNG	MNG (2017-IV)	0.37	0.43	4.1	0.48	10	<0.28	<0.11	0.17	6.5	27	17	97
MNG	MNG (2018-I)	0.00	0.00	2.8	0.00	4.5	0.68	0.17	0.17	3.6	20	8.7	10
MNG	MNG (2018-II)	0.44	1.6	15	0.86	12	<0.15	0.31	0.22	25	13	2.6	3.7
MNG	MNG (2018-III)	0.00	1.7	8.8	0.91	24	1.1	0.24	0.23	21	21	3.2	7.8
MNG	MNG (2018-IV)	0.27	0.46	6.1	0.14	9.5	<0.24	<0.1	<LOQ	6.1	27	20	334
MNG	MNG (2019-I)	0.35	0.00	6.7	0.00	11	<0.29	0.15	<LOQ	5.2	19	11	144
PHL	PHL (2018-I)	3.1	11	12	2.1	1.1	<0.15	0.13	0.17	4.6	2.8	0.76	1.2
PHL	PHL (2018-II)	4.0	14	4.7	2.0	0.98	1.3	0.12	0.18	6.1	1.9	0.52	1.6
PHL	PHL (2018-III)	4.7	15	5.9	2.2	1.1	1.9	0.17	0.19	7.8	3.2	0.69	1.9
PHL	PHL (2019-I)	2.4	9.5	3.3	0.63	0.29	0.9	<0.11	0.18	5.1	1.9	0.63	<0.23
PHL	PHL (2019-II)	5.0	15	4.0	0.73	1.0	1.2	<0.11	0.18	6.8	1.8	0.76	0.93
THA	THA (2017-IV)	1.1	0.71	4.3	0.58	1.2	7.5	0.33	<LOQ	0.52	6.1	1.3	4.1
THA	THA (2018-I)	1.4	0.60	4.4	0.00	0.70	5	0.28	<LOQ	0.81	4	1.3	8.5
THA	THA (2018-II)	1.2	0.48	4.2	0.00	0.39	0.64	0.24	<LOQ	0.71	1.7	0.35	1
THA	THA (2018-III)	0.69	0.00	3.1	0.67	0.57	1.3	0.23	0.18	1.3	3.1	0.8	3.2
THA	THA (2018-IV)	1.0	0.69	3.7	0.12	0.88	3.3	0.26	<LOQ	0.74	4	1.3	2.5
THA	THA (2019-I)	1.1	0.61	3.6	0.00	0.30	1.5	0.27		0.59	1.6	0.56	1.1
THA	THA (2019-II)	1.4	0.00	4.6	0.00	0.43	0.9	0.17	<LOQ	0.53	1.7	0.31	0.94
VNM	VNM (2017-II)	0.00	0.44	12	0.41	1.9	11	<0.11	<LOQ	3.9	3.4	1.1	2.4
VNM	VNM (2017-III)	0.22	0.62	15	0.00	1.1	9.3	0.19	<LOQ	3.9	4	1.1	3.1
VNM	VNM (2017-IV)	0.14	0.00	10	0.41	2.6	8.7	<0.11	<LOQ	3.5	19	7	30
VNM	VNM (2018-I)	0.48	0.53	21	0.60	3.8	11	0.23	<LOQ	3.5	10	2.3	6.9
VNM	VNM (2018-II)	0.63	0.52	26	0.00	3.6	8	0.23	<LOQ	3.8	4.1	1.3	2.6
VNM	VNM (2018-III)	0.00	0.00	14	0.66	2.4	8.9	0.22	<LOQ	3.6	7.7	1.9	3
VNM	VNM (2018-IV)	0.00	0.00	12	0.00	3.6	12	0.21	#N/A	3.2	12	5.2	10
VNM	VNM (2019-I)	0.00	0.40	15	0.00	1.4	1.9	0.16	0.26	2.9	3.1	0.87	1.5

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

ISO-3	Sample ID	Unit	TEQ_DF	TEQ_PCB
KHM	KHM (2018-I+II+III+IV)	pg TEQ/4 PUF	52.1	11.9
KHM	KHM (2019-I+II)	pg TEQ/2 PUF	54.7	12.5
IDN	IDN (2018-I+II+III+IV)	pg TEQ/4 PUF	161.2	26.9
IDN	IDN (2019-I+II+III+IV)	pg TEQ/4 PUF	125.5	24.2
LAO	LAO (2017-IV)	pg TEQ/1 PUF	1.7	0.3
LAO	LAO (2018-I+II+III+IV)	pg TEQ/4 PUF	25.6	5.9
LAO	LAO (2019-I+II)	pg TEQ/2 PUF	8.6	2.6
MNG	MNG (2017-II+III+IV)	pg TEQ/3 PUF	19.9	12.2
MNG	MNG (2018-I+II+III+IV)	pg TEQ/4 PUF	23.9	12.2
MNG	MNG (3 months)	pg TEQ/ PUF	2.3	1.1
PHL	PHL (2018-I+II+III)	pg TEQ/3 PUF	27.2	6.0
PHL	PHL (2019-I+II)	pg TEQ/2 PUF	21.1	5.6
THA	THA (2018-I+II)	pg TEQ/3 PUF	1.4	0.1
THA	THA (2018-III+IV)	pg TEQ/4 PUF	0.6	0.1
THA	THA (2019-I+II)	pg TEQ/4 PUF	9.1	0.0
VNM	VNM (2017-II)	pg TEQ/2 PUF	27.3	6.2
VNM	VNM (2017-III)	pg TEQ/2 PUF	42.5	8.4
VNM	VNM (2017-IV)	pg TEQ/2 PUF	27.8	6.2
VNM	VNM (2018-I)	pg TEQ/2 PUF	69.2	15.0
VNM	VNM (2018-II)	pg TEQ/2 PUF	55.7	9.0
VNM	VNM (2018-III)	pg TEQ/2 PUF	51.2	9.6
VNM	VNM (2018-IV)	pg TEQ/2 PUF	71.5	15.5
VNM	VNM (2019-I)	pg TEQ/2 PUF	36.2	7.0

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

ISO3	Sample_ID	PBDE8	Toxaphene	HBCDs	PBB153
IDN	IDN (2018-I)	1.6	0.45	0.16	<0.08
IDN	IDN (2018-II)	1.4	1.6	0.24	<0.08
IDN	IDN (2018-III)	1.1	0.46	0.11	<0.08
IDN	IDN (2018-IV)	1.1	0.53	0.05	<0.08
IDN	IDN (2019-I)	1.1	<LOQ	0.25	<0.08
IDN	IDN (2019-II)	0.98	<LOQ	0.26	<0.08
IDN	IDN (2019-III)	2.9	<LOQ	0.15	<0.08
IDN	IDN (2019-IV)	3.2	<LOQ	0.07	<0.08
KHM	KHM (2018-I)	2.0	<LOQ	0.09	<0.08
KHM	KHM (2018-II)	1.6	<LOQ	<LOQ	<0.08
KHM	KHM (2018-III)	0.61	<LOQ	0.13	<0.08
KHM	KHM (2018-IV)	2.4	<LOQ	0.22	<0.08
KHM	KHM (2019-I)	3.0	<LOQ	0.76	<0.08
KHM	KHM (2019-II)	0.39	<LOQ	0.73	<0.08
LAO	LAO (2017-IV)	0.00	<LOQ	<LOQ	<0.08
LAO	LAO (2018-I)	0.00	<LOQ	<LOQ	<0.08
LAO	LAO (2018-II)	0.00	1.1	<LOQ	<0.08
LAO	LAO (2018-III)	0.00	1.2	<LOQ	<0.08
LAO	LAO (2018-IV)	0.00	<LOQ	0.67	<0.08
LAO	LAO (2019-I)	0.18	<LOQ	0.67	<0.08
LAO	LAO (2019-II)	0.79	0.29	<LOQ	<0.08
MNG	MNG (2017-II)	0.74	<LOQ	76	<0.08
MNG	MNG (2017-III)	0.29	0.46	20	<0.08

Table S6 (continued)

ISO3	Sample_ID	PBDE8	Toxaphene	HBCDs	PBB153
MNG	MNG (2017-IV)	0.00	0.17	28	<0.08
MNG	MNG (2018-I)	0.00	0.17	8.2	<0.08
MNG	MNG (2018-II)	1.4	0.22	53	<0.08
MNG	MNG (2018-III)	1.1	0.23	17	<0.08
MNG	MNG (2018-IV)	0.10	<LOQ	24	<0.08
MNG	MNG (2019-I)	0.00	<LOQ	19	<0.08
PHL	PHL (2018-I)	0.53	0.17	0.10	<0.08
PHL	PHL (2018-II)	0.45	0.18	0.04	<0.08
PHL	PHL (2018-III)	0.79	0.19	0.10	<0.08
PHL	PHL (2019-I)	0.89	0.18	0.05	<0.08
PHL	PHL (2019-II)	0.45	0.18	<LOQ	<0.08
THA	THA (2017-IV)	0.16	<LOQ	<LOQ	<0.08
THA	THA (2018-I)	0.16	<LOQ	<LOQ	<0.08
THA	THA (2018-II)	0.21	<LOQ	<LOQ	<0.08
THA	THA (2018-III)	0.70	0.18	<LOQ	<0.08
THA	THA (2018-IV)	0.00	<LOQ	1.7	<0.08
THA	THA (2019-II)	0.32	<LOQ	<LOQ	<0.08
THA	THA-1 (2019-I)	1.2	<LOQ	0.03	<0.08
VNM	VNM (2017-II)	0.00	<LOQ	<LOQ	<0.08
VNM	VNM (2017-III)	0.19	<LOQ	0.13	<0.08
VNM	VNM (2017-IV)	0.00	<LOQ	<LOQ	<0.08
VNM	VNM (2018-I)	0.00	<LOQ	0.10	<0.08
VNM	VNM (2018-II)	0.52	<LOQ	<LOQ	<0.08
VNM	VNM (2018-III)	0.00	<LOQ	0.10	<0.08
VNM	VNM (2019-I)	1.3	0.26	<LOQ	<0.08

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

ISO3	Sample ID	Unit	SPFOS	PFOA	L-PFHxS	FOSA
IDN	IDN (2018-I)	pg/1 PUF	109	202	30	NR
IDN	IDN (2018-I+II+III+IV)	pg/4 PUF	565	910	<12	NR
IDN	IDN (2018-II)	pg/1 PUF	124	160	20	NR
IDN	IDN (2018-III)	pg/1 PUF	135	173	21	NR
IDN	IDN (2018-IV)	pg/1 PUF	152	160	16	NR
IDN	IDN (2019-I)	pg/1 PUF	NR	235	<12	NR
IDN	IDN (2019-I+II+III+IV)	pg/4 PUF	NR	NR	NR	NR
IDN	IDN (2019-II)	pg/1 PUF	101	172	<12	NR
IDN	IDN (2019-III)	pg/1 PUF	634	NR	NR	NR
IDN	IDN (2019-IV)	pg/1 PUF	NR	NR	NR	NR
KHM	KHM (2018-I)	pg/1 PUF	101	258	58	NR
KHM	KHM (2018-I+II+III+IV)	pg/4 PUF	317	1,125	<12	52
KHM	KHM (2018-II)	pg/1 PUF	88	354	65	<25
KHM	KHM (2018-III)	pg/1 PUF	60	158	96	<25
KHM	KHM (2018-IV)	pg/1 PUF	82	224	29	NR
KHM	KHM (2019-I)	pg/1 PUF	NR	NR	NR	NR
KHM	KHM (2019-I+II)	pg/2 PUF	NR	NR	NR	NR
KHM	KHM (2019-II)	pg/1 PUF	93	151	<12	NR
LAO	LAO (2017-IV)	pg/1 PUF	58	162	22	<25

Table S7 (continued)

ISO3	Sample ID	Unit	SPFOS	PFOA	L-PFHxS	FOSA
LAO	LAO (2018-I)	pg/1 PUF	50	243	35	NR
LAO	LAO (2018-I+II+III+IV)	pg/4 PUF	288	755	NR	NR
LAO	LAO (2018-II)	pg/1 PUF	30	172	24	<25
LAO	LAO (2018-III)	pg/1 PUF	38	136	13	<25
LAO	LAO (2018-IV)	pg/1 PUF	35	131	<12	<25
LAO	LAO (2019-I)	pg/1 PUF	50	120	36	NR
LAO	LAO (2019-I+II)	pg/1 PUF	NR	NR	NR	NR
LAO	LAO (2019-II)	pg/1 PUF	31	125	14	<25
MNG	MNG (2017-II)	pg/1 PUF	NR	NR	NR	NR
MNG	MNG (2017-II+III+IV)	pg/3 PUF	763	816	<12	327
MNG	MNG (2017-III)	pg/1 PUF	459	309	<12	NR
MNG	MNG (2017-IV)	pg/1 PUF	60	130	<12	NR
MNG	MNG (2018-I)	pg/1 PUF	47	124	<12	NR
MNG	MNG (2018-I+II+III+IV)	pg/4 PUF	676	869	<12	NR
MNG	MNG (2018-II)	pg/1 PUF	276	445	<12	NR
MNG	MNG (2018-III)	pg/1 PUF	73	219	<12	<25
MNG	MNG (2018-IV)	pg/1 PUF	46	126	<12	<25
MNG	MNG (2019-I)	pg/1 PUF	58	111	<12	NR
PHL	PHL (2018-I)	pg/1 PUF	NR	NR	NR	NR
PHL	PHL (2018-I+III)	pg/1 PUF	NR	NR	NR	NR
PHL	PHL (2018-III)	pg/1 PUF	NR	NR	NR	NR
PHL	PHL (2019-I)	pg/1 PUF	62	NR	<12	NR
PHL	PHL (2019-II)	pg/1 PUF	NR	NR	NR	NR
THA	THA (2017-IV)	pg/1 PUF	60	169	<12	NR
THA	THA (2018-I)	pg/1 PUF	51	149	34	NR
THA	THA (2018-I+II+III+IV)	pg/4 PUF	882	564	<12	NR
THA	THA (2018-II)	pg/1 PUF	27	83	13	<25
THA	THA (2018-III)	pg/1 PUF	234	155	<12	<25
THA	THA (2018-IV)	pg/1 PUF	193	177	<12	NR
THA	THA (2019-I)	pg/1 PUF	NR	NR	NR	NR
THA	THA (2019-I+II)	pg/2 PUF	NR	NR	NR	NR
THA	THA (2019-II)	pg/1 PUF	NR	NR	NR	NR
VNM	VNM (2017-II)	pg/1 PUF	137	517	14	<25
VNM	VNM (2017-II+III+IV)	pg/3 PUF	338	1,397	<12	161
VNM	VNM (2017-III)	pg/1 PUF	134	616	21	NR
VNM	VNM (2017-IV)	pg/1 PUF	144	559	25	<25
VNM	VNM (2018-I)	pg/1 PUF	339	631	<12	NR
VNM	VNM (2018-I+II+III+IV)	pg/4 PUF	1,155	2,605	<12	NR
VNM	VNM (2018-II)	pg/1 PUF	NR	NR	NR	NR
VNM	VNM (2018-III)	pg/1 PUF	226	965	<12	NR
VNM	VNM (2018-IV)	pg/1 PUF	300	652	<12	NR
VNM	VNM (2019-I)	pg/1 PUF	NR	NR	NR	NR

8.3.2. Water

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

Sample_ID	Year	Season	PFOS	PFOA	PFHxS	L_PFOS	br_PFOS
MNG (2017-I)	2017	I	0.04	0.08	<LOQ	0.04	<LOQ
MNG (2017-II)	2017	II	0.44	0.46	<LOQ	0.38	0.06
MNG (2017-III)	2017	III	0.05	<LOQ	<LOQ	0.05	<LOQ
MNG (2017-IV)	2017	IV	0.04	0.32	<LOQ	0.04	<LOQ
VNM (2017-III)	2017	III	0.17	0.12	<LOQ	0.13	0.03
VNM (2017-IV)	2017	IV	0.04	0.19	0.04	0.04	<LOQ
MNG (2018-I)	2018	I	0.12	0.28	0.03	0.09	0.04
MNG (2018-II)	2018	II	0.07	0.08	0.04	0.07	<LOQ
MNG (2018-III)	2018	III	<LOQ	0.10	0.04	<LOQ	<LOQ
MNG (2018-IV)	2018	IV	0.05	0.09	<LOQ	0.05	<LOQ
VNM (2018-I)	2018	I	0.07	0.17	<LOQ	0.07	<LOQ
VNM (2018-II)	2018	II	0.20	0.13	<LOQ	0.14	0.06
VNM (2018-IV)	2018	IV	0.11	0.13	0.05	0.07	0.04
VNM (2019-I)	2019	I	0.10	0.15	<LOQ	0.06	0.04

8.3.3. Human milk

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

Country →	Cambodia	Mongolia	Thailand	Viet Nam
Unit	ng/g lipid	ng/g lipid	ng/g lipid	ng/g lipid
Sum drins	<0.5	0.50	0.64	<0.5
Sum chlordane	<0.5	2.45	4.45	0.58
Sum DDT	83.5	41.0	425	151
Sum HCHs	0.57	41.6	0.77	3.32
PCB(6)	3.68	15.6	3.25	14.8
HCB	2.48	34.0	2.79	4.80
PBDE(6)	0.66	0.43	0.41	1.00
PBDE 209	0.14	0.22	0.16	0.14
SCCP	29	164	18	89

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

Country →	Cambodia	Mongolia	Thailand	Viet Nam
Unit	pg/g lipid	pg/g lipid	pg/g lipid	pg/g lipid
TEQ_{DF}	3.92	2.24	1.80	2.62
TEQ_{PCB}	0.66	1.35	0.58	1.62

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

Country →	Cambodia	Mongolia	Thailand	Viet Nam
Unit	pg/g f.w.	pg/g f.w.	pg/g f.w.	pg/g f.w.
PFOS	17.2	10.2	25.5	32.1
PFOA	14.6	20.1	25.8	13.0
PFHxS	<5.5	<5.5	7.32	<5.5

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