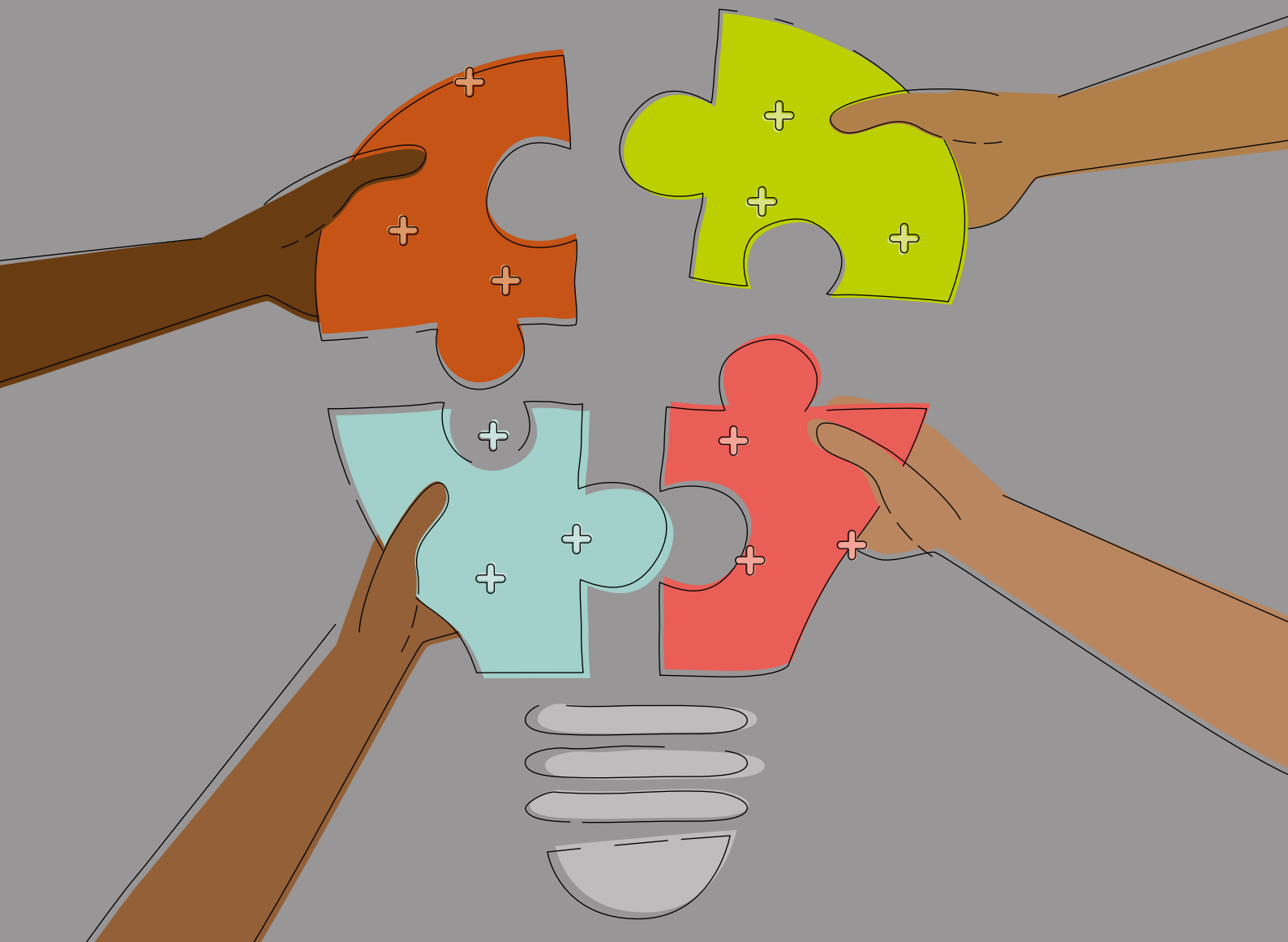
UN environment programme

Training report

Capacity building

on POPs Monitoring in Biota and Abiotic Matrices in the Africa, Asia, Pacific and GRULAC Regions



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Abbreviations

BC	Basel Convention
CRM	certified reference material
CSIC	Spanish National Research Council
FAO	Food and Agriculture Organization
GC	Gas chromatography
GEF	Global Environment Facility
GMP	Global Monitoring Plan
GRULAC	Group of Latin America and the Caribbean
IPCP	International Panel on Chemical Pollution
LC-MS	Liquid chromatography–mass spectrometry
MCCPs	Medium-chain chlorinated paraffins
MS	mass spectrometer
NIES	National Institute for Environmental
NIP	National Implementation Plan
PVC	Polyvinyl chloride
PFAS	perfluorinated alkane substances
POPs	Persistent Organic Pollutants
QA/QC	Quality Control/Quality Assurance
RECETOX	Research Centre for Toxic Compounds in the Environment
SC	Stockholm Convention
SCCPs	short-chain chlorinated paraffins
SOPs	Standard Operating Procedures
UNEP	United Nations Environment Programme
UQ	University of Queensland
VU	Vrije Universiteit
WHO	World Health Organization
XRF	X-ray fluorescence

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Photo: © Thailand - Thammasat University

1. Introduction

Article 16 of the Stockholm Convention requires the Conference of the Parties to evaluate the effectiveness of the Convention, including a Global Monitoring Plan (GMP) to collect comparable and consistent data on the presence of persistent organic pollutants (POPs) in the environment and in humans in order to identify trends and global distribution. Among others, a quantitative objective for temporal trends is stated in the GMP guidance "To detect a 50% decrease within a time period of 10 years with a statistical power of 80% at a significance level of 5%" (United Nations Environment Programme [UNEP] 2021).

Decision 23 of the Sixth Conference of Parties to the Stockholm Convention requests the Secretariat "to support training and capacity building activities to assist countries in implementing the GMP for subsequent effectiveness evaluation". It also invites parties "to support the further development and long-term implementation of the GMP if in a position to do so".

To strengthen the capacity for the implementation of the GMP in developing countries and countries with economies in transition, the United Nations Environment Programme (UNEP), in collaboration with the Secretariat of the Basel, Rotterdam and Stockholm conventions and with financial support from donors including the Global Environment Facility (GEF), implemented the first round of the UNEP/GEF POPs GMP projects in 2009 to 2012 in 31 countries in the Africa, Pacific Islands and the Latin American and the Caribbeans (GRULAC) regions. Building on the success of these projects, a second round of GMP projects (UNEP/GEF POPs GMP2) was implemented from 2016 to 2024 in 42 countries in the Africa, Asia-Pacific and GRULAC regions. Capacity building as one of the major components of the projects provided critical knowledge and technical support to project countries to conduct laboratory analysis according to international standards, and to maintain and further enhance POPs monitoring capacities. During its implementation, the projects developed 16 protocols and Standard Operating Procedures (SOPs) in multiple UN languages to support POPs sampling, analysis, data management, and reporting, including video tutorials. An e-course was also developed to facilitate data management and interpretation. In addition, the project organized 26 training sessions on the analysis of abiotic and biotic core matrices for technical staff from 37 countries. Upon request, trainings were provided to nine Pacific countries and eleven GRULAC countries on data handling and interpretation. Pilot studies were organized on the analysis of POPs in matrices of national interest in nine countries and on strengthening regional coordination for sustainable monitoring of POPs. Furthermore, webinars and workshops were held to share knowledge and results of POPs monitoring in air, water, human milk, and matrices of national interest such as plastics, among others (UNEP n.d. a).

The projects also conducted four rounds of global biennial interlaboratory assessments to facilitate cross validation and quality control/quality assurance (QA/QC). A total of 289 laboratories from all UN regions participated at least in one of the four interlaboratory assessments organized from 2010 to 2019, with 228 laboratories successfully submitting results (UNEP 2023a).

These capacity-building activities have provided invaluable hands-on experience to hundreds of technical staff and laboratory analysts, equipping them with the skills needed for the sampling and monitoring of POPs. Notably, a significant number of female participants actively engaged in these trainings and laboratory analysis, contributing to a balanced representation of gender across all levels of expertise, including the presence of expert laboratories.

This report aims to provide a comprehensive overview of capacity-building activities carried out under the UNEP/GEF POPs GMP2 projects. It seeks to offer insights into sustaining and further enhancing POPs monitoring capabilities in developing countries and countries with economies in transition. The report is structured into seven sections for clarity and coherence.

Section 2 offers an overview of the technical guidance provided and trainings conducted in national laboratories, focusing on sampling and analysis of abiotic and biotic matrices.

Section 3 provides a briefing on the interlaboratory assessments that were carried out.

Section 4 summarizes capacity-building activities related to data management and interpretation in facilitating informed decision-making at the national level, including pilot studies on strengthening regional coordination for sustainable monitoring of POPs.

Section 5 introduces pilot studies and capacity strengthening activities proposed by project countries and stakeholders, including POPs monitoring in matrices of national interest such as plastics, as well as data interpretation for national decision making.

Section 6 and 7 delve into the experiences gained, lessons learned from the capacity-building activities undertaken in the project, and considerations for future endeavours.

SECTION:

2

TRAININGS IN NATIONAL LABORATORIES ON SAMPLING AND ANALYSIS OF ABIOTIC AND BIOTIC MATRICES

Photo: © Mongolia, Mongolian Academy of Sciences

2. Trainings in National Laboratories on Sampling and Analysis of Abiotic and Biotic Matrices

2. 1. Development of Protocols and Standard Operating Procedures

In order to generate high quality data and comparable results, the protocols and methods that are used by the various laboratories when sampling and analysing POPs need to be harmonized ensuring that, over time and between regions, the same basic approaches and quality criteria for acceptance of data and assessment of results are applied. When new POPs are added to the Stockholm Convention, new tools and methods must be developed.

Through the projects, protocols for the passive and active sampling of air, water, human milk and matrices of national interest, and SOPs for the analysis of POPs in various abiotic and biotic matrices were developed. This also includes video tutorials in multiple UN languages. Table 1 is a summary of the protocols and SOPs that have been developed under the projects. Covering the methods for sample preparation, extraction, purification and analysis, these protocols and SOPs serve as a basis for routinary analysis in laboratories towards generation of credible and globally comparable data on POPs (UNEP n.d. b).

2. 2. Capacity Screening

The precision and reliability required in analytical chemistry, particularly when dealing with complex mixtures, are essential due to their potential environmental, health, and safety impacts. Analysts must be proficient in operating sophisticated analytical instruments, from the preparation of the samples, chemical extraction to the use of analytical instrument like gas and liquid chromatography and mass spectrometry, which is facilitated through proper training. Training ensures that analysts understand complex methodologies, including sample preparation, separation techniques, and detection methods, enabling them to follow established procedures accurately. Rigorous quality control/quality assurance (QA/QC), data interpretation skills, and a focus on safety and compliance can also be instilled through training. Analysts learn to follow protocols, calibrate instruments, verify results' accuracy, interpret data, and adhere to safety protocols while handling hazardous substances. Training also aids in error recognition and minimization, encompassing common pitfalls, contamination risks, and troubleshooting strategies. Additionally, continuous training ensures that analysts stay current with evolving methodologies, enabling them to adapt to changing requirements and technologies.

Training is an important part of capacity building under the UNEP/GEF GMP2 projects. Project countries were requested to nominate one laboratory per country with at least basic instruments and existing capacities in order to receive a training. A capacity screening was conducted at the beginning of the projects in 2016 to support designing customized training programme for each nominated laboratory.

Table 1: Protocols and SOPs developed under the UNEP/GEF GMP2 projects

Subject	Available Languages
Passive Sampling of Ambient Air: Methodology and Procedure	English, French, Spanish
Procedure for Air Monitoring using Active Air Samplers (HVS)	English, French, Spanish
Guidelines for Organization, Sampling and Analysis of Human Milk on Persistent Organic Pollutants	English, French, Spanish
Video tutorial for the sampling of human milk	English, French, Spanish
Video tutorial for passive air sampling	English, French, Spanish, Russian
Video tutorial for active air sampling	English, Spanish
Protocol for the Sampling of Water as a Core Matrix in the UNEP/GEF GMP2 Projects for the Analysis of PFOS	English
Protocol for the Sampling and Pre-treatment of National Samples	English, French, Spanish
Analysis of Perfluorooctane Sulfonic Acid (PFOS) in Water and Perfluorooctane Sulfonamide (FOSA) in Mothers' Milk, Human Serum and Air, and the Analysis of Some Perfluorooctane Sulfonamides (FOSAS) and Perfluorooctane Sulfonamido Ethanols (FOSES) in Air	English, French, Spanish
Analysis of Polychlorinated Biphenyls (PCB) and Organochlorine Pesticides (OCPs) in Human Milk, Air and Human Serum	English, French, Spanish
Analysis of Polybrominated Diphenyl Ethers (PBDE) in Human Milk, Air and Human Serum	English, French, Spanish
Analysis of Per- and polyfluoroalkyl substances (PFAS) in Water for the Global Monitoring Plan of the Stockholm Convention	English, French, Spanish
Analyse des polychlorodibenzo-paradioxines, des polychlorodibenzofurannes (PCDD/PCDF) et des polychlorobiphényles (PCB) de type dioxine (dl-PCB) dans l'air ambiant et les tissus humains	French, Spanish
Video 1: Procedimiento para el Análisis de: Dioxinas, furanos y Bifenilos Policlorados similares a dioxinas (dl-PCBs)	Spanish with English subtitltes
Video 2: Procedimiento para el Análisis de: Bifenilos Policlorados no similares a dioxinas (ndl-PCBs)	Spanish with English subtitltes
Video 3: Procedimiento para el Análisis de: Contaminantes Orgánicos Persistentes Básicos (Basic POPs)	Spanish with English subtitltes
Video 4: Procedimiento para el Análisis de: Polibromo Difeniléteres (PBDEs)	Spanish with English subtitltes

This capacity screening, supplemented by bilateral consultations with national coordinators during the regional inception workshops, resulted in a training plan covering 29 courses in national laboratories that UNEP organized in each of the four project regions through its collaboration with expert laboratories (Table 2). In addition, depending on the local circumstances, developing country laboratories were provided with consumables and small materials such as Gas Chromatography (GC) columns, analytical standards, solvents, or sorption materials.

Table 2: Trainings in project countries planed.

Region	No. of trainings planned	Countries
Africa	11	Egypt, Ghana, Kenya, Mauritius, Morocco, Nigeria, Senegal, United Republic of Tanzania, Tunisia, Uganda, Zambia
Asia	6	Cambodia, Indonesia, Mongolia, Thailand, Viet Nam, Philippines
Pacific Islands	1	Fiji
GRULAC	11	Antigua and Barbuda, Argentina, Barbados, Brazil, Chile, Colombia, Ecuador, Jamaica, Maxico, Peru, Uruguay
Total	**29**	

2. 3. Trainings Conducted in National Laboratories

Following the nomination of national laboratories by the national coordinators of the UNEP/GEF POPs GMP2 projects, expert and national laboratories coordinated the detailed training programme from 2017 to 2021. Unprecedent reasons occurred during the implementation of the training plan such as the COVID-19 pandemic caused some delays and deviations in some countries. In other occasions, a number of countries decided to join the same training. Adjustments to the training plan were made by the steering committee of the projects to accommodate the changes and new requests.

By the end of the project, 26 trainings on the analysis of POPs in abiotic and biotic matrices were provided to 37 project countries (Table 3). Due to COVID-19, some planned trainings could not be conducted, and a few others were delivered virtually. Table 4 provided detail information about the trainings by country, expert laboratories that gave the training, date of the trainings, and participation disaggregated by gender.

The trainings covered both the theoretical knowledge (lectures with theory ca. 30%) and laboratory practices ('hands-on' work ca. 70%), including general preparational and operational routines for the sampling and analysis in all matrices as well as specific techniques for the analysis of certain matrices and compounds. The core matrices selected as per the GMP guidance under the Stockholm Convention were human milk, water and air, and additionally provided an interest, the participants may also get an introduction to POPs analysis in other matrices of national relevance such as fish, and sediment.

Attention was paid to sampling, sample handling, sample storage, extraction, clean-up of samples, gas chromatography and mass spectrometry (if applicable), safety issues, reporting and various aspects of QA/QC such as method validation, blanks, calibration, internal standards, reference materials, limit of detection, limit of quantification, interpretation of chromatograms, calculations and reporting of concentration, and so on.

Table 3: Trainings in project countries planed and completed during UNEP/GEF GMP2

Region	UNEP/GEF GMP1 2016-2023		
	No. of trainings planned	No. of trainings conducted	No. of countries participated
Africa	11	9	10*
Asia	6	5	6**
Pacific Islands	1	2***	9
GRULAC	11	10	10
Total	29	26	37

Note: * Senegal and Mali jointed the same training.

** Myanmar joined the training in Indonesia.

*** Upon request, the planned laboratory training in the Pacific Islands region was converted into a hands-on course in air and water sampling for all nine participating countries complemented by theoretical lectures.

In Africa, three expert laboratories- Institute for Environmental Studies (IVM), Vrije Universiteit (VU) Amsterdam, the MTM Research Centre, Örebro University, Sweden and the Research Centre for Toxic Compounds in the Environment (RECETOX), Masaryk University, Czech Republic- provided trainings to national laboratories in Ghana, Kenya, Mali, Mauritius, Morocco, Senegal, Nigeria, United Republic of Tanzania, Tunisia, Uganda, and Zambia. Staff from Mali also joined the training session in Senegal delivered by IVM VU Amsterdam. The other project countries in the regions did not have POPs laboratories according to the capacity screening. Due to travel restrictions caused by the COVID-19 pandemic, training could not be organized in Egypt as planned.

In Asia, trainings were conducted in Cambodia, Indonesia, Mongolia, Philippines, and Thailand by IVM VU Amsterdam and MTM Örebro University. LAO PDR reported to UNEP the establishment of a basic national laboratory in 2018 and requested a training session. However, the laboratory was not yet adequately equipped to analyse POPs thus training was not organized. Through the coordination and invitation via Basel Convention Coordinating Centre (BCCC) in Indonesia. One additional country, Myanmar, participated in the training in Indonesia. Due to COVID-19 Pandemic, the training in Viet Nam could not be conducted.

Table 4: Summary of trainings conducted in national laboratories.

Country	Expert lab	Date and Location	No. of Participants	Gender disaggregated percentage
Africa				
Egypt	MTM Research Centre, Örebro University, Sweden	Cancelled due to COVID-19 Pandemic		
Tunisia	MTM Research Centre, Örebro University, Sweden	5-9 November 2018	n.a	n.a
Uganda	MTM Research Centre, Örebro University, Sweden	10-14 December 2018	n.a	n.a
Mauritius	Vrije Universiteit, Amsterdam	14-22 September 2017	8	Female (5) 62.5% Male (3) 37.5%
Ghana	Vrije Universiteit	19-27 April 2018	16	Female (4) 25% Male (12) 75%
Senegal & Mali	Vrije Universiteit	29 September - 6 October 2017	10	Female (8) 80% Male (2) 20%
United Republic of Tanzania	Vrije Universiteit	12-20 July 2018	8	Male (8) 100%
Zambia	Vrije Universiteit	23-30 April 2018	11	Female (1) 9% Male (10) 91%
Kenya	Research Centre for Toxic Compounds in the Environment (RECETOX)	22-26 May 2017	14	Female (4) 29% Male (10) 71%
Morocco	RECETOX	20-24 Novmber-2017	18	n.a
Asia				
Viet Nam	MTM Research Centre, Örebro University, Sweden	Cancelled due to COVID-19 Pandemic		
Thailand	MTM Research Centre, Örebro University, Sweden	December 2018	12	Female (9) 75% Male (3) 25%
Cambodia	Vrije Universiteit	28 March – 5 April 2019	9	Female (4) 44% Male (5) 56%
Mongolia	Vrije Universiteit	6-14 February 2017	11	Female (7) 64% Male (4) 36%
Philippines	Vrije Universiteit	4-12 December 2017 13-17 Aug. 2018	11	Female (5) 45% Male (6) 55%
Indonesia and Myanmar	Vrije Universiteit	28 March -5 April 2019	15	Female (11) 73% Male (4) 27%
Pacific Islands				
Group training on sampling, storage, shipment and reporting for the Pacific countries	MTM Research Centre, Örebro University, Sweden	6-8 Dec 2017, Apia, Samoa	12	Female (6) 50% Male (6) 50%
Fiji – Australia (UQ)	University of Queensland	February 2020	1	Male
GRULAC				
Antigua and Barbuda	Spanish National Research Council (CSIC)	25-29 March 2019	8	Female (2) 25% Male (6) 75%
Argentina	CSIC, MTM Research Centre, Örebro University, Sweden	30 Sep. 4 Oct. 2019	15	Female (10) 67% Male (5) 33%
Barbados	CSIC	28 May – 1 June 2018	7	Female (4) 57% Male (3) 43%
Brazil	CSIC, MTM Research Centre, Örebro University, Sweden	19-23 February 2018	12	Female (7) 58% Male (5) 42%
Chile	CSIC	4 -15 Jan. 2021(online)	9	Female (8) 89% Male (1) 11%
Colombia	CSIC	28 Nov-2 Dec 2017	9	Female (3) 33% Male (6) 67%
Ecuador	CSIC	18-29 Jan. 2021 (online)	6	Female (2) 33% Male (4) 66%
Jamaica	CSIC	22-26 January 2018	4	Female (2) 50% Male (2) 50%
Mexico	CSIC	Cancelled due to COVID-19 Pandemic		
Peru	CSIC	9-20 Nov. 2020 (online)	10	Female (5) 50% Male (5) 50%
Uruguay	CSIC	16-20 April 2018	9	Female (5) 56% Male (4) 44%

In the Pacific Islands, a training session was planned for the University of South Pacific (USP) in Fiji but could not be delivered as the national laboratory was out of operation until 2018. Meanwhile, despite of the instructions and SOPs provided, the 9 project countries in the Pacific still faced difficulties in correctly collecting, storing, labelling and transporting the samples. To ensure that sample collection satisfy the requirements of the project, a training was scheduled in 2017 in Samoa for national coordinators from all 9 project countries on the sampling, storage, transportation and reporting of biotic and abiotic matrices. The objective of the training was to ensure the sampling of air, water, human milk and matrices of national interest were timely conducted following the globally agreed standards.

With the national laboratory in Fiji reopened in 2018, a regular capacity building mechanism was established between the University of Queensland (UQ) and USP. A Liquid chromatography–mass spectrometry (LC-MS) instrument was donated by UQ to USP in 2019, following which several online and on-side trainings were organized by UQ for technical staff of USP on the analysis of POPs in biotic and abiotic matrices.

In the GRULAC region, trainings were provided by MTM and the Spanish National Research Council (CSIC) to national laboratories in 10 project countries, namely Antigua and Barbuda, Argentina, Barbados, Brazil, Chile, Colombia, Ecuador, Jamaica, Peru and Uruguay. Due to COVID-19 pandemic, the training for Mexico could not be organized and the trainings for Chile, Ecuador, and Peru were conducted virtually.

The individual reports of each training conducted by the responsible expert laboratories are attached in Appendix 1.

2. 4. Gender integration

The participation to the trainings, disaggregated by gender, showed that globally a total of 239 participants joined the sessions, with 115 female (48%) and 124 male (52%) participants, achieving almost gender parity. However, gender integration varied by region. In Africa (excluding Egypt and Morocco), there were 80 participants, with 25 female (31%) and 55 male (69%). In Asia, there were 58 participants, with 36 female (62%) and 22 male (38%). In the Pacific, there were 12 participants, equally split with 6 females (50%) and 6 males (50%). Finally, in GRULAC, there were 89 participants, with 48 female (54%) and 41 male (46%). The participation of both genders in capacity building activities reflected the awareness of gender integration in regions and project countries. Future activities could aim to address the existing imbalances.

2. 5. Discussion

Most laboratories in developing countries and countries with economies in transition still require significant capacity building to generate quality data consistently. Regular analysis is necessary to maintain the acquired knowledge and skills. Recurrent feedback from the trainings organized highlights several areas for improvement across all regions:

- Regular POP analysis programs in laboratories are essential for ensuring good quality results.
- The use and maintenance of instruments and equipment such as GC/MS are important for handling the growing list of POPs. Analysis of biotic samples remain a major challenge in most laboratories.
- There is a shortage of adequate analytical instrumentation for POP analysis, or existing instruments are not in use due to needed repairs or a lack of trained technicians.
- Challenges in ordering standards and servicing instrumentation, including consumables for routine analysis post-training.
- Frequent personnel change: staff sometimes lack adequate qualifications and experience in POP analysis.
- Training attendees are not always involved in POP analysis.
- Long-term business plans are frequently absent.
- SOPs and guidelines are not always correctly followed.
- Safety issues are prevalent.
- Background contamination issues (e.g., dust, cluttered workspaces).
- Environmental laboratories may not always get a priority treatment from their governments.
- Daily power outages in some countries cause delays in extraction steps and validation of chromatographic methods, as analytical equipment must be restarted multiple times, negatively impacting stability.

Despite these challenges, some laboratories that consistently participated in interlaboratory assessments have shown improved performance. Several labs from developing countries submitted good results in the 4th interlaboratory assessment, indicating their potential to contribute to sustainable POP monitoring.

To support the sustainable analysis of POPs in developing country laboratories, mechanisms are encouraged to enhance national demands for scientifically sound data and information. Regular analysis with a QA/QC system in place, as well as regular participation in interlaboratory assessments remain essential. Additionally, it is crucial to continue strengthening analytical capacities including the capacities to use and interpretation results on POPs.

SECTION: 3

INTERLABORATORY ASSESSMENTS

Photo: © UNEP / Victor Estellano

3. Interlaboratory Assessments

3. 1. Overview

The Stockholm Convention GMP requires background data on POPs in the environment to follow the trends of these contaminants and to evaluate the effectiveness of measures and actions undertaken by the Parties to the Convention. POP concentrations are therefore monitored on a regular basis, by various laboratories, in core matrices being air, human milk or human blood, and water (only for PFAS). Analysis of POPs is never simple. It requires a high sensitivity and selectivity and, therefore, sophisticated, and rather expensive instrumentation, and several relatively complicated steps, such as extraction, cleanup, and instrumental analysis, that all contribute to the overall uncertainty of the final result. This uncertainty should, however, not be too high, as trends in POP concentrations need to be determined within a maximum uncertainty of ca. 50%, but preferably lower (Fiedler, van der Veen, and de Boer 2020). When various laboratories provide data for the GMP, an additional uncertainty is added to the data, because differences in performance of laboratories always exist. Those differences should of course be as small as possible. Consequently, the challenge is to ensure high quality accurate POP concentrations per laboratory, and to minimize the variation in data among the laboratories that provide data to the Convention.

Global interlaboratory assessment on POPs is a key element of quality control/quality assurance for chemical analytical laboratory and has an important role under the UNEP/GEF GMP projects. During the two rounds of the UNEP/GEF GMP projects, four interlaboratory assessments were organized covering a wide spectrum of test matrices (Table 5). Two out of the four assessments were conducted under the UNEP/GEF GMP2 projects, from 2016 to 2017 with 176 laboratories registered and 133 reported results in the third round, and the fourth round from 2018 to 2019 with 148 laboratories registered and 116 reported results. A total of 532 laboratories from all UN regions, including governmental labs, civil society and commercial labs, had registered in at least one round of the inter-laboratory assessments and 420 of them submitted results (UNEP 2023a).

Table 5: Numbers of laboratories participated in the four global biennial interlaboratory assessments

Region	1st Interlab 2010-2021		2nd Interlab 2012-2013		3rd Interlab 2016-2017		4th Interlab 2018-2019	
	No. of labs registered	No. of labs reported results	No. of labs registered	No. of labs reported results	No. of labs registered	No. of labs reported results	No. of labs registered	No. of labs reported results
Africa	17	10	12	5	19	14	24	13
Asia-Pacific	38	33	45	42	68	53	48	44
CEE	3	3	4	4	23	16	6	5
GRULAC	32	23	14	11	39	25	37	25
WEOG	13	13	30	27	27	25	33	29
Total	103	82	105	89	176	133	148	116

Participation in the assessment was free of charge for developing countries. In the last interlaboratory assessment from 2018-2019, 16 matrices were offered for analysis including nine test solutions to cover all POPs, two air extracts (one in toluene for the chlorinated and brominated POPs and one in methanol for the fluorinated POPs), sediment, fish, human milk, human plasma and water (the latter two for PFAS only).

In addition, circa 32 laboratories received UNEP-sponsored trainings by experts in POPs analyses from 2008 to 2014, and 37 from 2017 to 2021 through the two rounds of UNEP/GEF GMP projects. Standard operating protocols have been prepared for all laboratories, and guidelines with technical advice were provided to all participants of the interlaboratory studies. In this way a so-called learning exercise was offered to all participants, during which the laboratories could learn from the guidelines and from their results, to improve their methods in the next round. Two workshops were organized to share the results and outcomes of the interlaboratory assessments, and to discuss the analytical aspects and performance with laboratories participated in the assessment (Table 6).

Table 6: Final workshops for the interlaboratory assessments from 2016-2017 (3rd round) and from 2017-2018 (4th round)

Final Result Workshop for the 3rd Round global biennial Interlaboratory Assessment	Final Result Workshop for the 4th Round global biennial Interlaboratory Assessment
6-7 April 2017, Beijing, China	21 -22 July, online workshop
Objectives: -Overview the results and outcomes of the biennial interlaboratory assessment on POPs. -Discuss the analytical aspects and performance with laboratories participated in the assessment. -Participating laboratories have increased the capacity on maintaining quality control and quality assurance in chemical analysis of POPs conforming to the international requirements.	

In addition, a laboratory databank was developed which contains a list of laboratories analyzing POPs, mercury, and lead from all UN regions, including 256 laboratories on POPs. The databank is accessible via the UNEP website (UNEP n.d. c).

The reports for each of the four interlaboratory assessments are available online (UNEP n.d a). A report intitle "Organization and Outcomes of Four Interlaboratory Assessments on Persistent Organic Pollutants" (UNEP 2023a) presents a summary of the four interlaboratory assessments organized under the two rounds of UNEP/GEF GMP projects.

Briefly, the results showed that laboratories that participated more frequently including a broader spectrum of POPs and test matrices had improved their performance or performed better than laboratories that participated only once (Fiedler, van der Veen, and de Boer 2022). Although at the level of individual laboratories some progress was made, most laboratories in developing countries and countries with economies in transition still need to continue improving their analytical capacities. Improvement was observed for analysis of dioxin, PBDE and POPs in air in general. Dioxin laboratories are, however, mainly situated in the global north. High quality of POPs analyses requires not only instrumentation but also routine analyses, and all aspects of extraction, clean-up, materials, consumables and skilled personnel. To ensure sustainability and maintenance of the analytical capacities, a business plan of routinary analysis has been seen as important practice (UNEP 2023a).

While the average satisfaction rates of laboratories in developing countries and countries with economies in transition still lag behind those in developed countries, results have indicated a few highly capable laboratories, which could potentially support POPs monitoring for national hotspot monitoring or even regional background monitoring. Criteria should be established to enable future interlaboratory exercises to guide capacity enhancement for national and regional laboratories.

Interlaboratory assessment is a recognized method to guarantee quality of analytical, which is essential for ensuring data comparability (UNEP 2019). Guidance is needed to enable interlaboratory assessment to advice inclusion of high-quality data generated by broader researchers to support filling data gaps and addressing national priorities (UNEP 2022).

3. 2. Discussion

3. 2. 1. Comparing Interlaboratory Assessments and Accreditation: Methods for Ensuring Laboratory Quality and Competence

Calibrations such as interlaboratory assessments and accreditation are common approaches used to cross-verify whether a POPs laboratory can generate high-quality data. Interlaboratory assessments involve comparing the performance of multiple laboratories by analyzing the same samples, whereas accreditation is a formal recognition that a laboratory meets established standards and requirements.

Laboratories have several tools to their disposition to ensure the quality of their data. These tools are summarized under the concept Quality Assurance/Quality Control (QA/QC), which stands for 'All actions carried out to plan the proper performance of the analytical task' and for 'All operational techniques and activities that are used to fulfil requirements for quality'.

Two of the most important concepts within QA/QC are Precision and Trueness. Precision can be checked in the laboratory by e.g., analyzing a specific sample (a so-called laboratory reference material or LRM) a certain number of times and determining the variation in the results. An LRM is a large batch of homogeneous material, e.g., fish or sediment or milk, of which a sub-sample is also analysed, once the method has been set-up, in each series of samples to check if the analytical results are stable. Such a material is essential for each POP laboratory. The results of the LRM analyses are plotted in a so-called quality control (QC) chart. Trueness can only be determined by external comparisons. This can be done by using a certified reference material (CRM) or by participating in interlaboratory studies. A CRM is a reference material that is certified by a group of expert laboratories for certain contaminant concentrations with a given uncertainty. Although this a valuable tool, a drawback is that CRMs come with a certificate, from which the certified values can be read before the analysis is carried out. That might bias the analyst towards the right answer.

Therefore, interlaboratory studies are the only real blind tests in which the participating laboratories must analyse one or more unknown samples in which the concentrations of the target analytes are unknown. If successful, the laboratory can use the interlaboratory test results data to solicitate an accreditation body to give a certificate of accreditation.

However, not only the interlaboratory test result will convince an accreditation body. To obtain good results in an interlaboratory study and in their daily analyses, the laboratory must build an entire quality system (Figure 1). Some examples of what needs to be included is such a file are: a detailed description of the instruments, analytical method descriptions, description of the management of the laboratory, description of the data flow, validation of excel sheets, registration file of temperatures of refrigerators and freezers, registration of balance calibrations, among others. The entire file must be offered to the accreditation body, which will scrutinize it to check if the accreditation can be given. The amount of work to obtain an accreditation is truly substantial and is most likely underestimated by many POPs laboratories in developing countries. Laboratories in developed countries normally need 1-2 years before they can offer a complete file to the accredita-

tion body. Once the accreditation has been assigned, each year the assessment will be repeated to check if the laboratory maintains the same level of quality. Accreditation bodies will always ask if the laboratory has participated in national or international interlaboratory studies. If such studies are available for the target analyte, participation is mandatory to maintain the accreditation.

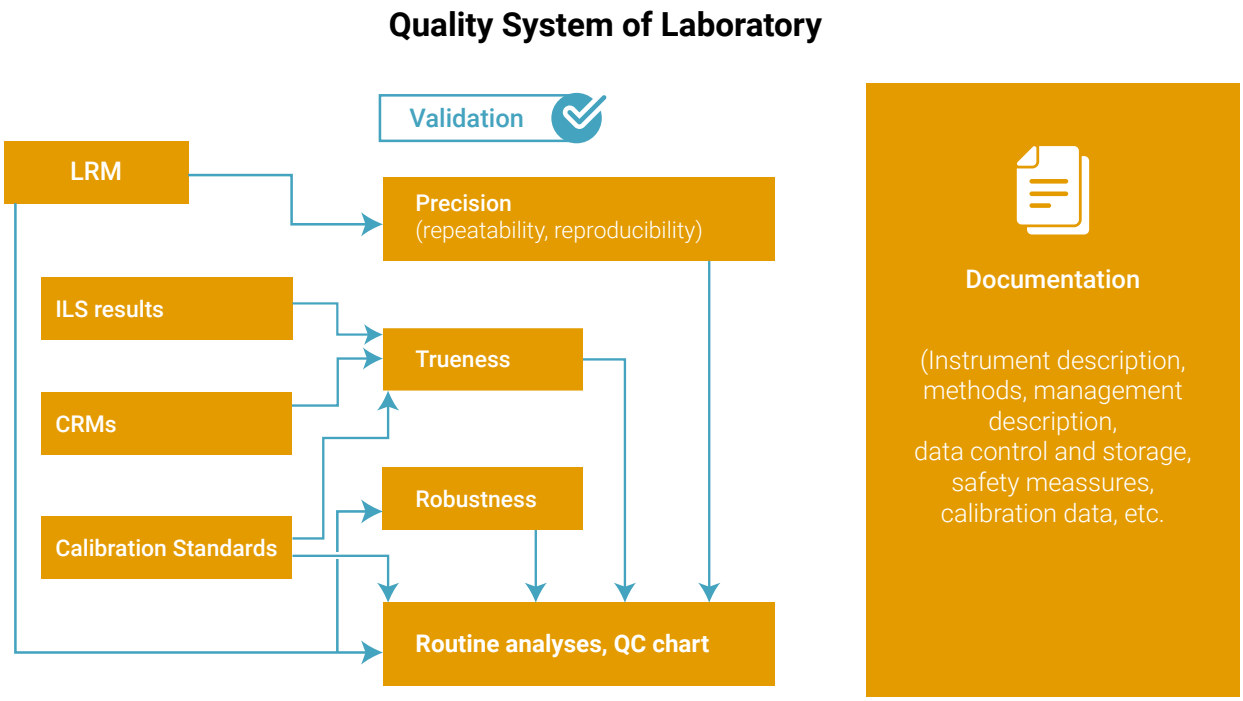

Figure 1: Overview of a quality system of a proper functioning laboratory, as required for accreditation. Note: LRM = laboratory reference material, CMR = certified reference material.

Accreditation is a great help in assuring comparable data. However, it is not always a mandatory requirement. Until now very few environmental laboratories, both in developed and developing countries, have obtained an accreditation.

Accreditation serves as a formal recognition that a laboratory meets established international standards and requirements for quality and competence. This process involves a rigorous evaluation by an independent accrediting body, ensuring that the laboratory's procedures, equipment, and personnel meet high standards of excellence.

While accreditation offers numerous benefits, it is not always a mandatory requirement for every laboratory. Several reasons explain why obtaining accreditation might not be essential in certain contexts. Some laboratories operate in specific contexts where accreditation is not required. For instance, research-focused laboratories may prioritize innovative methodologies over formal accreditation, as the latter can be resource-intensive, requiring significant investments in time, money, and personnel. Besides, not all clients or regulatory bodies require laboratory accreditation. In some cases, demonstrating competence through other means, such as consistent performance and reliability, may be sufficient. Laboratories can employ other robust quality assurance measures, such as participating in interlaboratory assessments, which provide valuable cross-verification without the need for formal accreditation. In conclusion, laboratories must weigh the benefits of accreditation against their specific needs, resources, and contexts to determine the most appropriate path for achieving and demonstrating high-quality performance.

Nevertheless, if laboratories have done a proper validation and determined the precision and trueness of their method, data can still be comparable and may be used for the GMP or other purposes. It is, therefore, essential to organize interlaboratory studies for POP analyses. Only then it can be seen which laboratories are good enough and produce reliable data that can be used for establishing temporal and spatial trends within the GMP.

3.2.2 Considerations

There are clearly several lessons to learn from the UNEP interlaboratory assessments during the last decade. Despite of various technical assistance provided, the lack of quality data in the laboratories in developing country emphasizes the need for a continuation of the POPs interlaboratory studies. From the paragraphs above a series of considerations emerges.

Training of laboratory staff

It is unrealistic to expect newly established laboratories in each developing country to generate high-quality data in the near future. A more feasible approach is to focus on one or two relatively advanced laboratories per region. These laboratories can contribute globally

comparable data to the GMP by continuously improving their analytical capacities and successfully participating in interlaboratory assessments.

Experience gained from similar training programs such as the regular trainings organized by the International Atomic Energy Agency (IAEA) and the targeted training partnership build between the Spanish National Research Council (CSIC) and the national laboratory in Colombia can be considered (see Appendix 2). In a second stage, the trained regional laboratories will be able to provide technical support to other POPs laboratories in the region.

When planning laboratory trainings, it is essential to consider gender integration and balance, as this fosters diverse perspectives, enhances collaborative innovation, and ensures equitable opportunities for all participants.

Interlaboratory studies

Ongoing interlaboratory studies on POPs are essential for all laboratories working on POPs, preferably once every two to three years. The size of these exercises could be trimmed in the following way:

- Matrices: Prioritize the core matrices of the Stockholm Convention GMP (air, water and human milk).
- Selection of POPs: Recent monitoring results show that many POPs have worldwide declined under detection limits. With that the need for intercalibration has recidivated. Some of the more recently added POPs are, obviously, more relevant. The new interlaboratory studies can therefore include: six indicator PCBs, (28, 52, 101, 138, 153, 180) PBDEs (47, 99, 209), and HBCD, PFAS, short and medium-chain CPs, dechloranePlus, lindane (-HCH), trans-chlordane, HCB, PeCB, HCBD, and endosulfan. All other POPs, including HxBB, toxaphene, mirex, dieldrin, endrin, aldrin, all other chlordanes, endosulfan suphate, heptachlor, cis and trans-heptachlor epoxide, chlorinated dibenzodioxins and dibenzofurans, and chlordecone can be re-considered because at most locations, concentrations have dropped to insignificant values.
- Selection of laboratories: Invitations for free-of-charge participation should be considered prior for laboratories which are relatively advanced with routinary monitoring of POPs, and are committed to contributing to the GMP.
- Collaboration: Joining forces between the UNEP interlaboratory assessments and relevant training programs provided by various institutes and organizations can be highly beneficial for cost-efficiency consideration and for continuous capacity improvement in laboratories. Different programs can cover various aspects of laboratory operations, including technical skills, analytical techniques, and quality assurance procedures. Such collaborations can help laboratories maintain and continually improve their analytical capabilities.

Photo: © Ministry of Environment / Mauritius

Solid Waste Management and Climate Change

SECTION:

4

CAPACITY BUILDING ON DATA AND KNOWLEDGE MANAGEMENT TO SUPPORT INFORMED DECISION MAKING

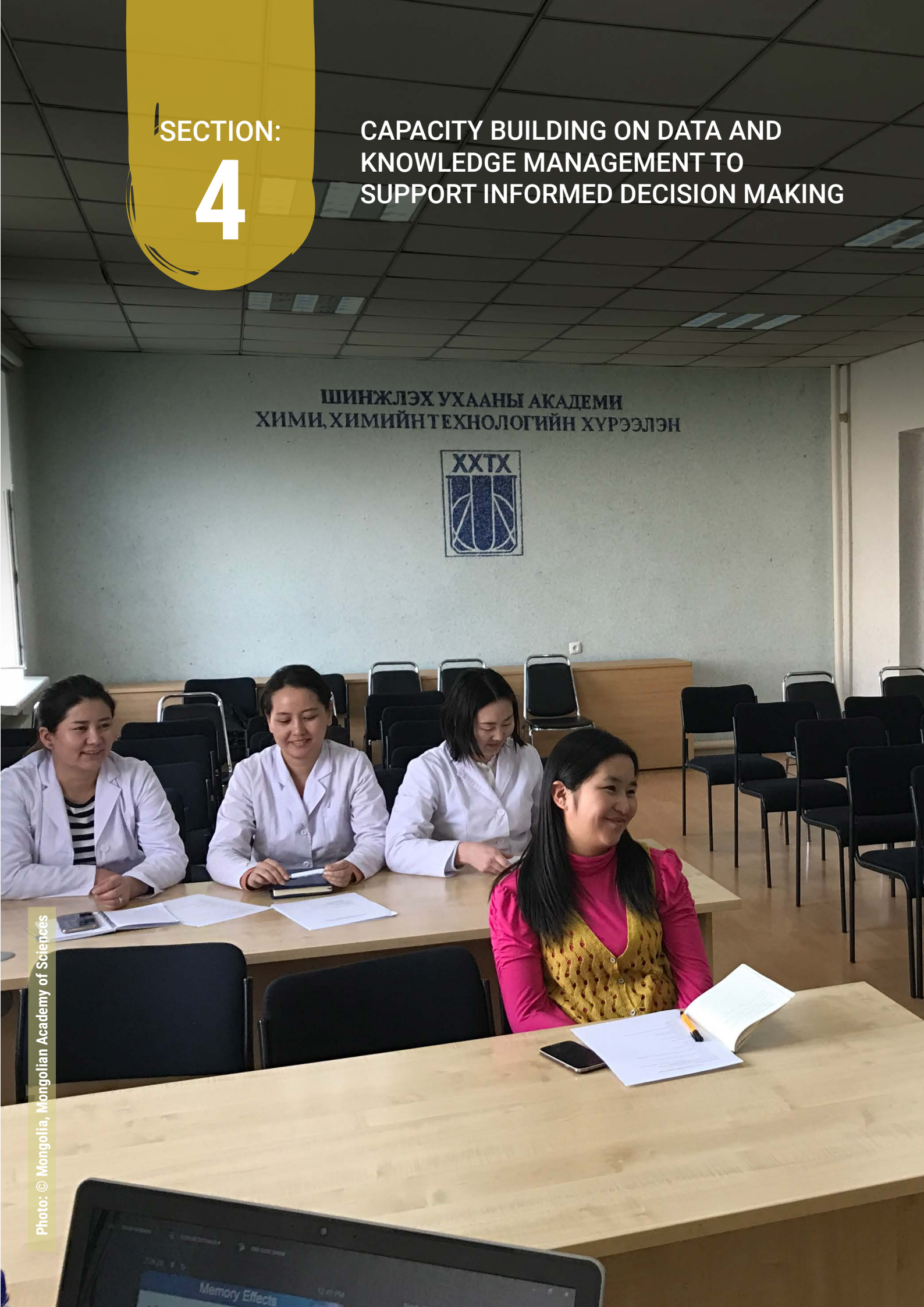

Photo: © Mongolia, Mongolian Academy of Sciences

4. Capacity building on Data and Knowledge Management to Support Informed Decision Making

Data and knowledge management are critical for the appropriate interpretation and use of scientific results, as it ensures that findings are accurately understood and effectively applied in decision-making processes. However, the capacity to effectively manage data and knowledge remains a barrier in many developing countries. To address this gap, technical support was provided through the UNEP/GEF GMP2 projects, including the development of guidance documents, the organization of workshops and training sessions, and the development of e-courses. Additionally, pilot studies were conducted in various countries to offer practical examples and hands-on experience. These efforts aim to build and strengthen the data and knowledge management capacities of developing countries, enabling them to better utilize scientific results for environmental monitoring and policy making.

4. 1. Guidance on Data Aggregation and Management

The Stockholm Convention GMP Data Warehouse requests specific data format to enable global data storage, comparison and trend analysis. To support project countries with data reporting in required units and formats, a document "Guidance for the Conversion of Data on POPs from mass/PUF to mass/m^3 using Tom Harner´s model and the Stockholm Convention Data Warehouse template" was prepared (Appendix 3). The document sketches the steps need to use the model for calculation of the concentration of POPs in air from the data in mass concentration per PUF to mass concentration per volume, and additionally how this data is reported in uniformized units to the Stockholm convention Data Warehouse template. The guidance was included in the UNEP/GEF GMP data dashboard as an instrumental document, which is accessible via the UNEP website (UNEP n.d. a).

4. 2. Regional Virtual Workshops to Present and Explain Results on POPs

Although the UNEP/GEF POPs GMP projects have generated valuable data on human and environmental exposure to POPs, the complexity of these chemicals, their isomers, congeners, and degradation products, along with the knowledge required for data cleanup, compilation, and statistics creates gaps in the ability of project countries to manage and use the POPs monitoring results in a national context. To address these gaps and to enhance the capacity of project countries to effectively utilize the data, seven regional virtual workshops were held to explain the analytical results on the levels of POPs in air, water, human milk and matrices of national interest and to discuss data usage in national reports (Table 7 and 8).

Table 7: Regional workshops on analytical results of air and Water

Africa	Asia	Pacific Islands	GRULAC
6 October 2020, 06:00-09:00 UTC online	5 October 2020, 06:00-09:00 UTC online	8 October 2020, 13:00-16:00 UTC online	9 October 2020, 13:00-16:00 UTC online
Number of Participants			
Male: 21 Female: 17 Total: 38	Male: 8 Female: 13 Total: 21	Male: 7 Female: 5 Total: 12	Male: 12 Female: 19 Total: 31
Objectives: Explain the analytical results on the levels of POPs in air and water shared with project countries, Provide clarifications on data, Discuss on including the data in national project final reports.			

Table 8: Regional meeting on analytical results of human milk and national samples

Africa	Asia-Pacific	GRULAC
23 November 2021, 07:00-09:30 UTC, online	25 November 2021, 06:00-08:30 UTC, online	22 November 2021, 13:00-15:30 UTC, online
Number of Participants		
Male: 32 Female: 12 Total: 44	Male: 10 Female: 11 Total: 21	n.a.
Objectives: Explain the analytical results on the levels of POPs in Human Milk and National Samples shared with project countries, Provide clarifications on data, Discuss on including the data in national project final reports.		

4. 3. Regional capacity building on data handling and management

Effective data management ensures accurate storage, interpretation and application of scientific results, which is essential for informed decision-making and policy development. However, many developing countries face challenges in this area, including limited technical expertise and inadequate infrastructure, due to the limited resources and the complex nature of environmental monitoring data. These barriers hinder the ability to systematically compile, store, analyze, and disseminate environmental data, ultimately affecting the quality and reliability of monitoring efforts. Addressing these challenges through capacity building, technical support, and the implementation of robust data management systems is vital for improving sustainable monitoring of POPs. Upon request by project

countries, capacity building activities on data handling and interpretation was organized to support communicating the result on POPs to national stakeholders and using the data for decision and policy making.

Two virtual trainings were jointly organized with the Basel Convention Coordinating Centre, Stockholm Convention Regional Centre, for Capacity Building and Transfer of Technology hosted by Uruguay (BCCC-SCRC Uruguay); one for eleven countries in the GRULAC region on advanced data handling and interpretation, and one for 6 countries in the Pacific Islands on basic management and use of the POPs monitoring results.

The trainings included five online sessions for each region, individual tutorials and consultations for participating countries, as well as the development of a guidance and an e-course on data handling and management. In some countries, this data management exercise has supported the preparation of national project reports and facilitated the use of POPs monitoring results to guide the updating of national implementation plans and reporting under the Stockholm Convention.

4. 3. 1. Guidance on Data Handling

The POPs data handling guidance (Appendix 4) developed under the trainings included introduction to the data handling, database configuration, data quality assurance, among others. The data handling guidance aims to assist regional countries in the processing, interpretation, and presentation of POPs monitoring data. The procedure for data handling is mainly based on the directions established by the Stockholm Convention GMP guidance (UNEP 2021) and tools used in the GMP Data Warehouse.

4. 3. 2. Tutorials and Consultations in the GRULAC and Pacific Regions

Five sessions of 2-hour online trainings were provided to six countries in the Pacific Islands on the management and interpretation of POPs monitoring data. The trainings were delivered by experts invited by BCRC-SCRC-Uruguay. Topics covered in the five training sessions include:

- Background and Introduction to data handling.
- Configuration and aggregation of POPs data.
- Stockholm Convention GMP Data Warehouse for data acquisition.
- Data quality assurance criteria.
- Use of Google Maps for location and classification of monitoring sites.
- Preparation of the database for analysis. Data visualization and elaboration of indicators.
- Data analysis tools (Excel Pivot Tables and Power Pivot).
- Analysis by monitoring site, country, and region. Using data from the regions and from the monitoring of POPs in air, breast milk and water matrices.
- Trend analysis.
- Interpretation and presentation of results.
- Resolution of questions.

4.3.3 E-course on Data Handling and Interpretation for the monitoring of POPs

To disseminate the guidance to a wider audience and facilitate self-paced learning and usage, with technical support from BCRC-SCRC-Uruguay and the Basel Convention Coordinating Centre, Stockholm Convention Regional Centre, for Capacity Building and Transfer of Technology in Asia and the Pacific hosted by China (BCRC-SCRC China), an e-course was developed based on the guidance on data handling. The data handling and interpretation course is designed to assist Parties of the Stockholm Convention and technicians involved in the POPs monitoring process and in the usage of these environmental monitoring results. The e-course is published on the UNEP website (UNEP 2023b).

To strengthen synergies and facilitate linkages with relevant data sources, the e-course was developed in coordination with four other e-courses on preparing inventories of PBDEs, chlorinated paraffins, HBCD and PFAS (UNEP 2023c; UNEP 2023d; UNEP 2023e; UNEP 2024f). These e-courses support the development, updating and reporting of National Implementation Plans (NIPs) under the Stockholm Convention.

4. 4. Data and knowledge sharing

Data and knowledge sharing are crucial for the effective environmental monitoring of POPs. By disseminating data and insights, countries can build a comprehensive understanding of POPs distribution, improve their monitoring techniques, and enhance data consistency and comparability. This collective knowledge enables more accurate assessments and informed decision-making, leads to better strategies for risk mitigation, and fosters collaboration and capacity building among nations, enhancing the global response to POPs management.

An up-to-date and inclusive database is essential to enable POPs monitoring to provide continuous support for informed decision making at the global, regional and national level (UNEP 2019). It remains a priority for future knowledge and data sharing to enable connections with relevant databases such as those of the National Implementation Plans and inventories, to enhance broader linkages with regional and national data generators, and to make data easily accessible and usable for wider stakeholders.

To share the data and results generated under the UNEP/GEF GMP projects with stakeholders and a broader audience, various tools were developed. This includes a webpage (UNEP n.d. a) that presents project related information, such as the guidance and reports prepared, activities conducted, and an interactive dash-

board consolidating all the POPs monitoring results generated under the projects. This dashboard enables data visualization, retrieval and spatial-temporal comparison at national, regional and global scales, with the full dataset available for download for further research and interpretation by scientists and stakeholders. Considering that POPs are chemicals with numerous associated precursors, isomers, congeners, and degradation products, the dashboard was designed to be user-friendly, providing consistent and comprehensive information for various data uses. It also includes links to relevant databases such as the Stockholm Convention Data Warehouse and the POPs Laboratory Databank (UNEP n.d. c).

Moreover, the results generated under the UNEP/GEF GMP projects were also included in the World Environment Situation Room of UNEP (UNEP n.d. d), which provides federated data system of the openly accessible environmental data, information, and knowledge to support decision-making, policy and action for sustainable development and national planning needs. This synergy aims to showcase data integration between inventories, waste management, and environmental monitoring of various contaminants such as POPs, mercury, and pharmaceutical pollutants, among others, to facilitate the effective use of scientifically sound evidence for policy and decision-making.

4. 5. Assessment of Existing Capacities and Needs

The diverse capacity building activities conducted under the UNEP/GEF GMP projects such as trainings and interlaboratory assessments aim to strengthen regional capacities for sustainable monitoring of POPs to support the implementation and effectiveness evaluation of the Stockholm Convention. Results from multiple rounds of interlaboratory assessments and the data generation in national laboratories indicate existing and growing capacities in developing countries and countries with economies in transition. Assessing these capacities, along with identifying capacity-building needs and plans for POPs monitoring, is crucial. This evaluation helps determine whether the necessary conditions are in place to sustain the built capacity and effectively use the analytical capacities for continued POPs monitoring.

During the implementation of the UNEP/GEF GMP projects, consultations and assessments conducted to guide capacity building activities in collaboration with project partners and countries. Insights from assessments conducted at the midterm of the projects (Appendix 5) and recommendations of the midterm review were incorporated into the second-half of the projects. This led to the organization of additional trainings, pilot studies and follow-up sampling of POPs in matrices of national interest in relevant countries (Chapter 5). Furthermore, an assessment of national capacities and capacity building needs was carried out in the later stage of the projects to ensure the sustainability of the impacts of the UNEP/GEF GMP projects and to support continued POPs monitoring in project countries and regions.

4. 5. 1. Assessment of National POPs Monitoring Capacity and Needs

To support the development of regional roadmaps for sustainable monitoring of POPs, an assessment of national POPs monitoring capacity and capacity building needs across Africa, Asia-Pacific and the GRULAC regions was organized in collaboration with the Basel Convention Coordinating Centres, Stockholm Convention Regional Centres, for Capacity Building and Transfer of Technology, located in Uruguay, China, and South Africa. Through this assessment, national implementation plans and national reports to the Stockholm Convention were reviewed; data and information collected from regional assessments, GMP regional and global reports and the Data Warehouse were analysed. A questionnaire was disseminated to regional countries through the regional centres to resolve doubts and inconsistencies in the information collected from various sources.

This assessment provided a comprehensive overview of the national capacities built based on the progress made in the UNEP/GEF GMP projects. This valuable information aids in developing strategies and actions for sustainable monitoring of POPs and the continuous improvement of monitoring capacities in regions and countries.

The assessment found that POPs monitoring, with support from national and international resources, was conducted in 104 (76%) parties of the Stockholm Convention. Out of which, 32 were from Africa, 43 from Asia-Pacific and 29 from GRULAC. The numbers of countries participated in global or regional POPs monitoring programs are 61 (45%) in air monitoring, 58 (42%) in WHO surveys and 47 (34%) in water monitoring. Ninety parties (66%) reported having laboratories capable of analysing some POPs, including 29 from Africa, 30 from Asia-Pacific, and 31 from GRULAC. However, this number varies significantly from the results reflected in the four rounds of interlaboratory assessments. Further verification is essential to ensure that these laboratories can generate globally comparable data. Therefore, it is considered that although there is evidence of countries' sampling capacity for POPs monitoring and analyses, most laboratories and countries need to be strengthened and equipped to analyse new POPs, since most NIPs include actions to improve their laboratories and very few laboratories in developing countries and countries with economies in transition can analyse PCDDs and PCDFs and almost none the new POPs, with the exception of some Asian laboratories. The assessment report is included in Appendix 6.

4. 6. Pilot Study to Support Strengthening Regional Coordination for POPs Monitoring through Regional Centres

In December 2019, a stakeholder consultation was organised under the UNEP/GEF GMP2 projects to discuss ways to strengthen conditions for sustainable monitoring of POPs (UNEP 2019). The consultation highlighted the importance of strengthening the role of Stockholm Convention regional centres in coordinating sustainable monitoring of POPs. Following this recommendation and the results of the above-mentioned assessment of national capacities and capacity-building needs, pilot studies were planned in collaboration with the Stockholm Convention regional centres located in South Africa for the Africa Region, in China for the Asia-Pacific Region and in Uruguay for the GRULAC region. Except for delays occurred in the Africa Region due to unexpected reasons, activities were conducted in the Asia-Pacific and the GRULAC regions.

4. 6. 1. Pilot study in the GRULAC region

In GRULAC, a one-day workshop on "Roadmap for POPs monitoring" was organized on 7 June 2023 in Mexico City. This workshop was held back-to-back with the final meeting of the UNEP/GEF GMP2 project in the GRULAC region on 8-9 June 2023 in Mexico City, Mexico. The workshop had 44 participants, 23 females and 21 males, representing 11 project countries, expert laboratories, regional executing agencies and other stakeholders.

The workshop content was developed based on the results of conducted assessments, focusing on assisting regional countries in effectively utilizing the capacity built through the UNEP/GEF GMP projects to organize regional monitoring activities. This includes enhancing collaboration with national environmental monitoring studies and independent research, towards filling in data gaps for informed national policy and decision making. Presentations covered guidance and good practices for developing POPs monitoring plans (Appendix 7), criteria for the selection of significant species, pilot studies in Ecuador and Mexico, and examples of POPs monitoring in Mapimí and Coatzacoalcos, Mexico. Additionally, there was an independent research presentation on POPs monitoring in turtles as an indicator species in Mexico. A discussion session was held to conclude the workshop.

Two case studies were conducted in Ecuador and Mexico, as presented in the workshop (Appendix 8). For these case studies, country-specific profiles were prepared, detailing national studies and networks of POPs monitoring, as well as national priorities. Based on the profiles, national roadmaps were developed, including monitoring targets and associated monitoring plans. These case studies provided concrete information tailored to the specific circumstances of each country, offering good examples of how to plan monitoring activities and use data to support answering questions on the sound management of POPs.

Figure 2**:** Infographics with information on the participation disaggregated by gender to the workshop. Source: BCCC-SCRC-Uruguay

4. 6. 2. Pilot study in the Asia-Pacific region

In parallel with the activities conducted in the GRULAC Region, assessments and pilot studies were also organized in the Asia-Pacific Region, focusing on strengthening regional coordination in POPs monitoring to fill in data gaps and address regional needs. A questionnaire on national POPs monitoring capacity and needs in the Asia-Pacific Region was prepared, and discussions were held with representatives from five countries regarding their monitoring capacities at the regional forum on POPs on 22 May 2023. Two regional countries, Myanmar and Maldives, worked closely with BCRC-SCRC-China to conduct a detailed assessment on the priority areas where assistance and coordination is needed from the regional centre. Case studies were prepared to explore possible technical collaboration between the regional centre and the countries to apply good practices in their monitoring of POPs to fill in data gaps for the region. A summary of POPs monitoring experience gained in China was prepared and shared as an example to facilitate development of strategic plans for Myanmar and Maldives, based on their national circumstances and needs. Details of this activity including results generated are included in Appendix 9.

SECTION:

5

CAPACITY BUILDING ON POPS MONITORING IN MATRICES OF NATIONAL INTEREST

Photo: © Nigeria, Federal Ministry of Environment

5. Capacity Building on POPs monitoring in Matrices of National Interest

Through the UNEP/GEF GMP projects, extensive data on environmental background levels of POPs in air and water were generated. Additionally, levels of POPs detected in national pooled samples of human milk highlighted the widespread presence of these contaminants and the extent of human exposure. These results provided crucial baseline data for 42 developing countries and countries with economies in transition, serving as the only source of POPs monitoring results for more than half of them.

With POPs widely detected in the environment and in humans, project countries are eager to understand the subsequent actions needed, whether it involves identifying the sources of emissions and exposure through follow-up monitoring or interpreting and utilizing the monitoring results to guide national policies and control measures to mitigate and prevent POPs pollution. In response to requests from project countries, additional monitoring and data analysis were conducted in selected countries where remaining resources were available. Some representative examples of these additional analyses in Kiribati, Egypt and Vanuatu are presented in Section 5.1 of this report.

Moreover, with the increasing awareness and importance of tackling plastic pollution, there has been a growing demand from stakeholders for baseline information on POPs in plastics. Given that POPs were widely used as additives in plastics, it is particularly important to study their presence in plastic recyclates, where significant data gaps exist. Consequently, a pilot study was organized, selecting plastic recyclates as a matrix of national interest for the analysis of POPs in 12 countries, including 2 in Africa, 3 in Asia, and 7 in GRULAC. As part of this pilot study, trainings and webinars were conducted, and guidance documents were developed to equip countries and broader laboratories with the knowledge needed to monitor POPs in this emerging area. The data generated and information compiled through this activity provided valuable background information to support discussions on plastics and the fulfilment of the obligations of the Stockholm Convention on the sound management of POPs. Details and results of this pilot study are presented in Section 5.2 of this report.

5. 1. Additional Monitoring and Data Analysis in Selected Countries

5. 1. 1. PFAS monitoring in Kiribati.

POPs monitoring in water under the UNEP/GEF GMP2 project detected high levels of Per- and polyfluoroalkyl substances (PFASs) in Kiribati, significantly exceeding the limits set by the European Union and the United States of America for drinking water. Notably, remarkable levels of PFASs were also found in human milk samples from Kiribati. Understanding the scope of contamination is critical to protecting the local community from the negative impacts of these toxic chemicals.

Within the scope of the project, a follow-up sampling campaign was organised in Kiribati with technical support provided by the University of Queensland in early 2024. This sampling campaign included a training to local staff on the collection of water samples using the SEP Pack method and collected 12 fish and seafood samples from 9 different species and 18 water samples from 10 different sites (Photo 1). The Ministry of Environment, Lands and Agricultural Development, the Ministry of Health and the Ministry of Fisheries of Kiribati participated in the sampling campaign.

Photo 1: Sampling of water and seafood for PFAS analyses.

Results generated were included in the UNEP/GEF GMP data dashboard and were shared with stakeholders including national and regional focal points, the BRS Secretariat and relevant initiatives on sound management of POPs in the Pacific Islands.

5. 1. 2. Source tracking in Egypt

Through the UNEP/GEF GMP2 project in Egypt, background data on POPs in air, water, human milk and matrices of national interest was generated. A national workshop was organized with participants from different national laboratories on capacity building and on data interpretation to support emission and release control. Based on further interpretation of the data, the national laboratories in Egypt identified potential sources of contamination. In order to verify this assumption and assess the extent of contamination, the government of Egypt proposed a follow-up sampling campaign to monitor POPs in environmental matrices.

In Egypt, farmers used sludge from wastewater treatment plants, after simple treatment by sun drying and wind rowing, to increase crop productivity. There are significant risks associated to the presence of POPs in the agricultural drainage water. This may explain the POPs detected in water and human milk samples in Egypt.

Therefore, POPs, including POPs pesticide residues, were analysed in sludge collected at various wastewater treatment plants located near agriculture areas, and in soils where air-dried sludge or sludge effluents were used as fertilizers. The data generated by the national laboratories were valued as scientific sound facts to support the establishment of POPs limits in the Egyptian health-related regulations, which contribute to controlling the levels of sewage sludge application. Additionally, the data highlighted the need for alternative sludge treatment methods before use as a soil amendment or fuel.

This study, building on the results of background monitoring of POPs and zooming into national circumstances and local practices, provided a good example of the importance of POPs monitoring to advice effective actions to prevent contamination.

Building on the results of background monitoring of POPs and focusing on national circumstances and local practices, this study provided a strong example of the importance of POPs monitoring in guiding effective actions to prevent contamination.

5. 1. 3. Data interpretation for informed policies and actions in Vanuatu

Vanuatu is a small island developing state, located in the South Pacific Ocean to the north-east of Australia, comprising an archipelago formed of 83 islands, with a population of approximately 300,000 inhabitants.

Through the UNEP/GEF GMP2 projects, samples of air, water, and human milk were collected in Vanuatu and analyzed for POPs listed under the Stockholm Convention. High levels of POPs were detected. For example, the highest levels of PFASs in water among the Pacific Island countries were found in Vanuatu. HBCD, a flame retardant commonly added to polystyrene materials in the 1980s for vehicles and buildings, was detected at the highest levels in air in Vanuatu within the Pacific region. Additionally, dioxin-like POPs were found at remarkable levels in human milk samples from Vanuatu.

The presence of POPs in the environment and in humans underscores the need for improved management of chemical pollution and waste. These scientific findings were communicated to the government and local communities to raise awareness. In response, the government of Vanuatu took proactive measures against chemical pollution. In June 2018, Vanuatu banned single-use plastics to combat plastic litter and ocean contamination. Local communities were encouraged to segregate rubbish and stop open burning to minimize the release of dioxins and furans, two unintentional POPs often emitted through incomplete combustion and entering air, water, soil, humans, and wildlife. Figure 4 shows an initiative by a group of local women, reusing oil containers and composting organic matter for vegetable growing to prevent open burning of rubbish and the emission of dioxin-like POPs.

Photo 2: Reusing oil containers and composting organic matter to prevent open burning and emission of dioxin-like POPs.

5. 2. Pilot Study of POPs Monitoring in Plastic Recyclates

With plastic pollution emerging as a significant environmental issue, monitoring POPs in plastics, particularly in plastic recyclates, has become essential. Given the widespread detection of POPs in environmental background monitoring and their common use as additives in polymer materials in the past, monitoring POPs in

plastic recyclates is crucial to prevent cross contamination. This approach provides scientifically sound evidence necessary for informing and guiding effective policymaking, especially amidst increasing discussions on plastic recycling.

POPs such as short-chain chlorinated paraffins (SCCPs), which were listed under the Stockholm Convention in 2017, were among the highest detected POPs in human milk in the UNEP/GEF GMP2 projects (UNEP 2023g). These chemicals were widely used as additives in plastics. Similarly, plastic flame retardants such as PBDEs and HBCD were detected in human milk samples, indicating potential exposure from plastic products and environmental releases throughout the plastic life cycle (Shaw et al. 2010). The detection of POP additives highlights the importance of monitoring these substances in plastic recyclates to understand and mitigate potential cross-contamination, environmental releases and exposure risks from plastic products.

Upon request from stakeholders, the UNEP/GEF GMP2 project conducted a pilot study to support countries with POPs monitoring in plastic recyclates. This includes sampling of 464 plastic samples recyclates as a matrix of national interest in 17 countries, and capacity to equip countries and broader laboratories with the knowledge needed to monitor POPs in this emerging area, covering trainings, webinars, development of guidance documents and technical reviews, among others.

5. 2. 1. Guidance documents on sampling and analysis

Four guidance documents were developed by the International Panel on Chemical Pollution (IPCP), the National Institute of Environmental Science of Japan (NIES) and the Spanish National Research Council (CSIC) to facilitate the sampling of plastic recyclates and to ensure consistent methods are used in various regions and countries. These include a protocol for sample collection of recycled plastic pellets in selected low- and middle-income countries; an information document on plastic recycling in selected countries to complement analysis and data interpretation of POPs in plastics; and a metadata sheet to record information of individual samples. Additionally, considering analytical methods are yet developed in many project countries particularly for newly listed POPs such as PFASs, a protocol and methodology for analysis of PFASs in plastic pellets was developed. The four guidance documents developed are included in Appendix 10.

5. 2. 2. Technical reviews of available knowledge and guidance documents on POPs monitoring and control in plastics

Monitoring POPs in plastics and understanding its linkages with environmental emission and human exposure to POPs is crucial for advising effective actions to control these pollutants. To equip project countries with comprehensive tools and insights into the life cycle of POPs in plastics, including the complementary roles of environmental monitoring and POPs monitoring in plastics, an overview report was prepared. The report summarized guidance documents from the Stockholm and Basel Conventions on POPs monitoring and POPs in plastics, including guidance on inventories and on Best Available Technology/Best Environmental Practices (BAT/BEP), as well as sector-specific guidance where POPs in plastics are found.

Furthermore, a report titled "State of knowledge and gaps on sampling and analysis of POPs and POP candidates in major plastic use categories and related recycled pellets, including practical guidance to assess POPs in plastics for better control" was developed. It briefly describes gaps in monitoring POPs in plastics and provided information supporting the use of POPs monitoring results to prevent the recycling of POP-containing plastics. The report also discussed major sectors where POPs plastic additives were primarily used, as flame retardants or plasticizers in electrical and electronic equipment, the transport and construction sectors, and certain textiles. Additionally, the report compiles information on best practice studies in these sectors, developed sampling methods, and gaps in sampling methodologies and monitoring. It notes that the recently listed UV adsorbents (UVA) (UV-328) under the Stockholm Convention were used in the aforementioned sectors, in plastic packaging including food packaging, and in the agricultural sector. These findings highlight the need for monitoring and control of listed POPs. These two reports are included in Appendix 11.

5. 2. 3. Trainings on POPs monitoring in plastics recyclates

5. 2. 3. 1. Webinars

As part of the capacity building activity, a series of webinars were organized in collaboration with IPCP on three main topics. Each webinar was around 4 hours including questions and discussions. All 5 webinar days had 139 to 299 registered participants with between 53 and 175 participants actual participation. The average female participation was 60%. All planned webinar days have been delivered and were recorded and are online accessible (IPCP n.d).

- Webinars on "Understanding POPs in Plastics"

A two-day webinar was organized. The first day covered background information on POPs in plastics, including related environmental pollution at hot spots of plastic management and human contamination, which were compared to GMP background data. It also introduced the function of additives in plastics and the drivers for using POPs additives, such as regulatory requirements for certain types of additives like flame retardants, which many POPs were used for.

On the second day, presentations focused on individual POPs in plastics, their listing and exemptions under the

Stockholm Convention, and their main uses in plastics. This included information on their total production volumes, periods of use, and the service life of major products. This knowledge base helped the audience understand the relevance of individual POPs in recycling and the implications for pellet production.

Table *9*: Webinars on "Understanding POPs in Plastics".

Date	Duration	Registered	Attended	Additional recorded views
24 April 2023	4 hours	278	175	234
25 April 2023	4 hours	299	148	106

- Webinar on "Sampling of plastic from major sectors to monitor POPs in plastics".

Presentations were given on screening and sampling strategies for major POPs use sectors, including electrical and electronic equipment, the transport sector, and buildings and construction. Understanding the presence of POPs in these major sectors helps identify and eliminate plastics containing POPs from recycling and the production of plastic pellets. Additionally, screening strategies for preselection of samples were introduced. Presentations also covered plastic pellet sampling and shared experiences from current plastic pellet sampling activities.

Table *10*: Webinars on "Sampling of plastic from major sectors to monitor POPs in plastics".

Date	Duration	Registered	Attended	Additional recorded views
19 May 2023	4 hours	190	97	75

- Webinars on "Extraction, clean-up, and analysis of POPs in plastic"

Presentations covering the three major steps—extraction, clean-up, and analysis of POPs in plastics—were delivered across two-day webinars for the individual POPs. The importance of clean-up to prevent contamination of analytical instruments (e.g., GC/MS) was emphasized, as this is crucial for developing countries where equipment repairs and spare parts are rare and expensive. The webinars also introduced the instrumental analysis of major POP groups present in plastics, including brominated flame retardants (PBDEs, HBCD, HBB), chlorinated paraffins, listed perfluoroalkyl substances (PFOS, PFOA, PFHxS, and related compounds), and UV-328 and Dechlorane Plus, which were listed under the Convention in May 2023.

Table *11*: Webinars on "Extraction, clean-up, and analysis of POPs in plastic".

Date	Duration	Registered	Attended	Additional recorded views
22 May 2023	4 hours	139	98	52
23 May 2023	3.5 hours	139	53	57

5. 2. 3. 2. Training for National Laboratories in the GRULAC Region

A training on sampling and analysis of POPs, including emerging compounds, in plastics and other matrices of national interest was organized by BCRC-SCRC-Uruguay in collaboration with the Institute of Environmental Assessment and Water Research of the Spanish National Research Council (IDAEA-CSIC) on 15-19 May 2023 in Barcelona, Spain. Eleven participants from national laboratories in nine project countries in the GRULAC Region attended the training. The training included theoretical introductions to methodologies for POP analysis, laboratory demonstrations, and hands-on analysis of POPs using high-resolution mass spectrometry, among other topics. This training contributed to strengthening capacities for the sampling and analysis of POPs in matrices of national interest in countries in the GRULAC region.

Table *12*: Training for National Laboratories from the GRULAC region.

Date of training	Participating Countries	No. of Participants	Gender disaggregated
15 – 19 May 2023	Antigua and Barbuda, Argentina, Brazil, Chile, Colombia, Ecuador, Jamaica, Perú and Uruguay.	11	Female (4) 36% Male (7) 64%

5. 3. POPs monitoring in Plastic Recyclates in Seventeen Countries

As part of the pilot study, samples were collected in seventeen countries in the Africa, Asia, and GRULAC regions, to provide a global snapshot of POPs presence in plastic recyclates.

Overall, 464 plastic samples, mainly domestically recycled pellets and shreds, were collected in Argentina (n=36), Antigua and Barbuda (n=2), Barbados (n=2), Brazil (n=49), Chile (n=33), Colombia (n=6), Ecuador (n=17), Jamaica (n=2), Mexico (n=6), Peru (n=6) and Uruguay (n=4) in GRULAC; in Ghana (n=12) and Nigeria (n=115) in Africa; and in Indonesia (n=25), Mongolia (n=40), Thailand (n=72) and Viet Nam (n=37) in Asia. Additionally, 16 recycled pellets and one shred sample previously collected in Argentina, Brazil, and Chile were analysed. Some samples were sourced from domestic virgin plastic materials while others were imported into the project countries.

The samples were collected in three regions and analyses by several international laboratories. Not all the samples were analysed for all the chemicals and by all laboratories, detailed information about the collection of samples and how they were distributed between the laboratories is presented elsewhere (UNEP n.d. e). The National Institute of Environmental Science in Japan (NIES) that received most plastic recyclates and acted as a distributing laboratory, conducted screening of plastics pellets for bromine and chlorine content with

x-ray fluorescence spectroscopy (XRF), and analysed PBDEs and HBCD in the bromine positive samples and chlorinated paraffins in the chlorine positive samples. The screening technology for brominated POPs and chlorinated paraffins developed by the National Metal and Materials Technology Centre of Thailand was also tested. The Fraunhofer Institute for Process Engineering and Packaging IVV (Freising, Germany) analysed the newly listed POPs Dechlorane plus and UV-328 in over 100 pellet samples and conducted migration tests of additives and non-intentionally added substances in plastics. Migration and toxicity tests of other selected samples collected from some countries in Africa, Asia and GRULAC were conducted by Bio Detection Systems (BDS, Amsterdam/Netherlands), a laboratory specialized on measuring endocrine effects and other toxicity with bio-assays. PFASs were analysed in Institute of Environmental Assessment and Water Research of the Spanish National Research Council (IDAEA-CSIC).

In summary, 110 biotests have been conducted under the pilot study. More than 270 samples were screened with XRF for bromine and chlorine content and 800 individual shreds or pellets were screened for PBDEs and other brominated flame retardants. Furthermore, more than 50 PVC samples were screened with pyrolysis GC/MS for chlorinated paraffins and other PVC plasticizers.

The monitoring data of POPs measurements, POPs screenings and toxicity assessment of selected recyclates samples were compiled into one report (UNEP n.d. e). This report includes the analytical results for bromine and chlorine screening of selected pellet samples gathered in the 17 countries and the quantitative results of all POPs analysis performed include:

- PBDE and HBCD in bromine positive samples (above 30 mg/kg).
- Testing of screening technologies for PBDEs and chlorinated paraffins.
- Chlorinated paraffins in PVC pellet samples.
- Migration and toxicity tests of newly listed POPs UV-328 and Dechlorane Plus.
- PFASs in plastic pellets and shreds.

Results of the plastic analysis will be included in the data dashboard of the UNEP/GEF GMP2 projects and were shared with stakeholders to support relevant discussions.

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SECTION: 6 DISCUSSION

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6. Discussion

From 2016 to 2024, UNEP, in collaboration with the Secretariat of the Stockholm Convention, regional and global partners, and project countries, successfully implemented the UNEP/GEF GMP2 projects across 42 countries in the Africa, Asia-Pacific, and GRULAC regions to support the effectiveness evaluation of the Stockholm Convention. A primary objective of these projects was to strengthen regional capacities for POPs monitoring in both humans and the environment.

Throughout the implementation period, comprehensive capacity building activities were conducted, encompassing sampling, laboratory analysis, data management, interpretation, and knowledge sharing. Additionally, further analyses and trainings were organized to address national priorities and support policy and decision-making based on background monitoring results. This multifaceted approach has significantly enhanced the ability of participating countries to generate scientifically sound evidence on the environmental presence and human exposure to POPs. It has also raised awareness and garnered political support for using POPs monitoring results to guide the sound management of chemicals and waste.

The interlaboratory assessments conducted under the UNEP/GEF GMP2 projects have provided critical insights into the progress of analytical capacities over the past decades, demonstrating an increase in the number of POPs laboratories in developing countries and countries with economies in transition. However, the results of these assessments also revealed persistent gaps in the generation of high-quality, globally comparable data and in the analysis of complex and newly listed POPs. These findings underscore the need for ongoing capacity strengthening and enhanced global collaboration to ensure comprehensive data coverage that accurately reflects the extent of POPs contamination worldwide. To generate high-quality and globally comparable data, it is essential to enhance collaboration among networks and researchers and to continue improving analytical capacities. Interlaboratory assessments as recognized methods for ensuring the quality of analysis should be maintained in future POPs monitoring.

The capacity-building activities conducted in response to the requests of project countries and stakeholders—including trainings, development of guidance and courses on data management and interpretation, pilot studies on strengthening regional coordination, and the analysis of POPs in matrices of national interest—reflect the active participation of regions and countries. This active engagement also demonstrates their heightened awareness of the importance of POPs monitoring as a reliable source of scientifically sound evidence to inform national policy and decision-making. Notably, the additional analyses proposed in Egypt, Kiribati, and Vanuatu serve as concrete examples of how the training has been applied in real-world contexts, using POPs monitoring results to support national actions, understand sources of exposure and emission, and trigger effective interventions. These commitments indicate regional and national willingness for sustainable monitoring of POPs, underscoring the lasting impact of the UNEP/GEF GMP2 projects and illustrating the tangible benefits that countries have derived from these initiatives.

Data management, sharing, and interpretation remain critical for empowering the use of scientifically sound evidence for policy and decision making at all levels. Establishing links across relevant databases—such as national implementation plans, inventories and waste management—can support the effective control of emissions and exposure. An up-to-date and inclusive database will enhance knowledge sharing and collaboration among global researchers in relevant areas.

SECTION: 7

CONCLUSION

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7. Conclusion

In conclusion, the UNEP projects have significantly contributed to the implementation of the Stockholm Convention Global Monitoring Plan in developing countries and countries with economies in transition. The capacity-building activities conducted have notably advanced regional capabilities to conduct POPs monitoring in humans and the environment. Continued capacity building is necessary to ensure the sustainable generation of high-quality and globally comparable data, supporting informed policy and decision-making at international, regional, and national levels. This also requires enhanced capacities in data management, sharing, and interpretation, as well as strengthened collaboration among laboratories, monitoring networks, and researchers. Addressing these needs will optimize POPs monitoring in developing countries and countries with economies in transition, significantly supporting the effectiveness evaluation of the Stockholm Convention.

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Appendixes:

Appendix 1: National training reports.

Appendix 2: POP monitoring in developing countries, optimization, intercalibration and accreditation for delivering high quality data

Appendix 3: Guidance for the Conversion of Data on POPs from mass/PUF to mass/m3 using Tom Harner´s model and the Stockholm Convention Data Warehouse template.

Appendix 4: POPs Data handling Guidance.

Appendix 5: UN Environment survey on analytical capacities on POPs monitoring in Africa.

Appendix 6: Assessment of national POPs monitoring capacity and needs of Africa, Asia and Pacific, and Latin America and the Caribbean countries.

Appendix 7: Roadmap for the design of national POPs monitoring programs.

Appendix 8: National Road maps from two pilot countries, Mexico, and Ecuador.

Appendix 9: Assessment of national capacity on POPs monitoring and technical support to strengthen regional coordination on sustainable monitoring of POPs in the Asia Pacific Region.

Appendix 10: Procedure for the Analysis of PFAS in Pellets

Appendix 11: Reviews of available knowledge and guidance documents on POPs monitoring and control in plastics

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