Overview of the outputs and outcomes of the UNEP/GEF POPs GMP project

POPs in plastic pellets – Day 2

Final meeting of the UNEP/GEF POPs GMP projects
in the Africa region

Casablanca, Morocco 28-30 November 2023

Capacity Building on POPs in Plastic & Monitoring of POP in Plastic Recycling in Low- & Middle-Income Countries to Support the Stockholm Convention Implementation (part of UNEP Global Monitoring Plan project)

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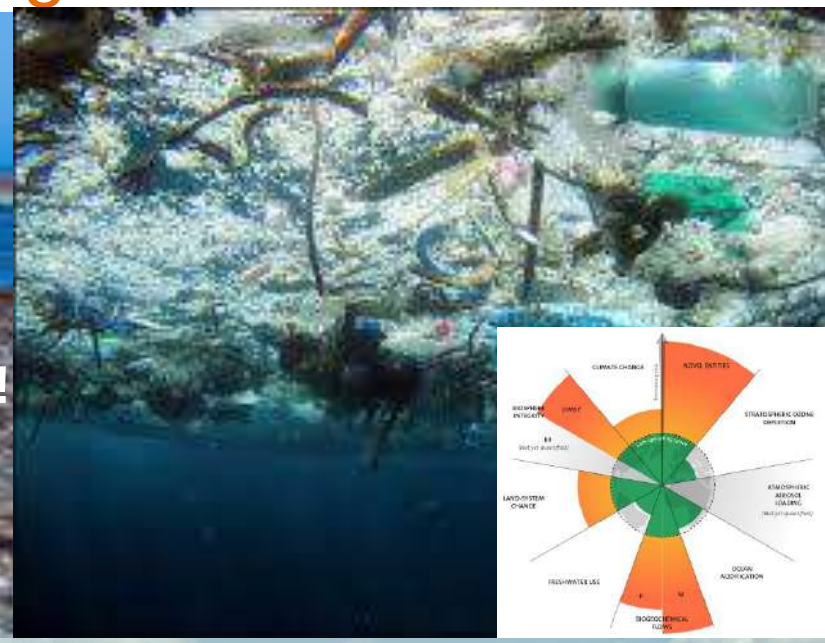
The increasing production & consumption and the linear economy result in a waste/plastics nightmare crossing global boundaries



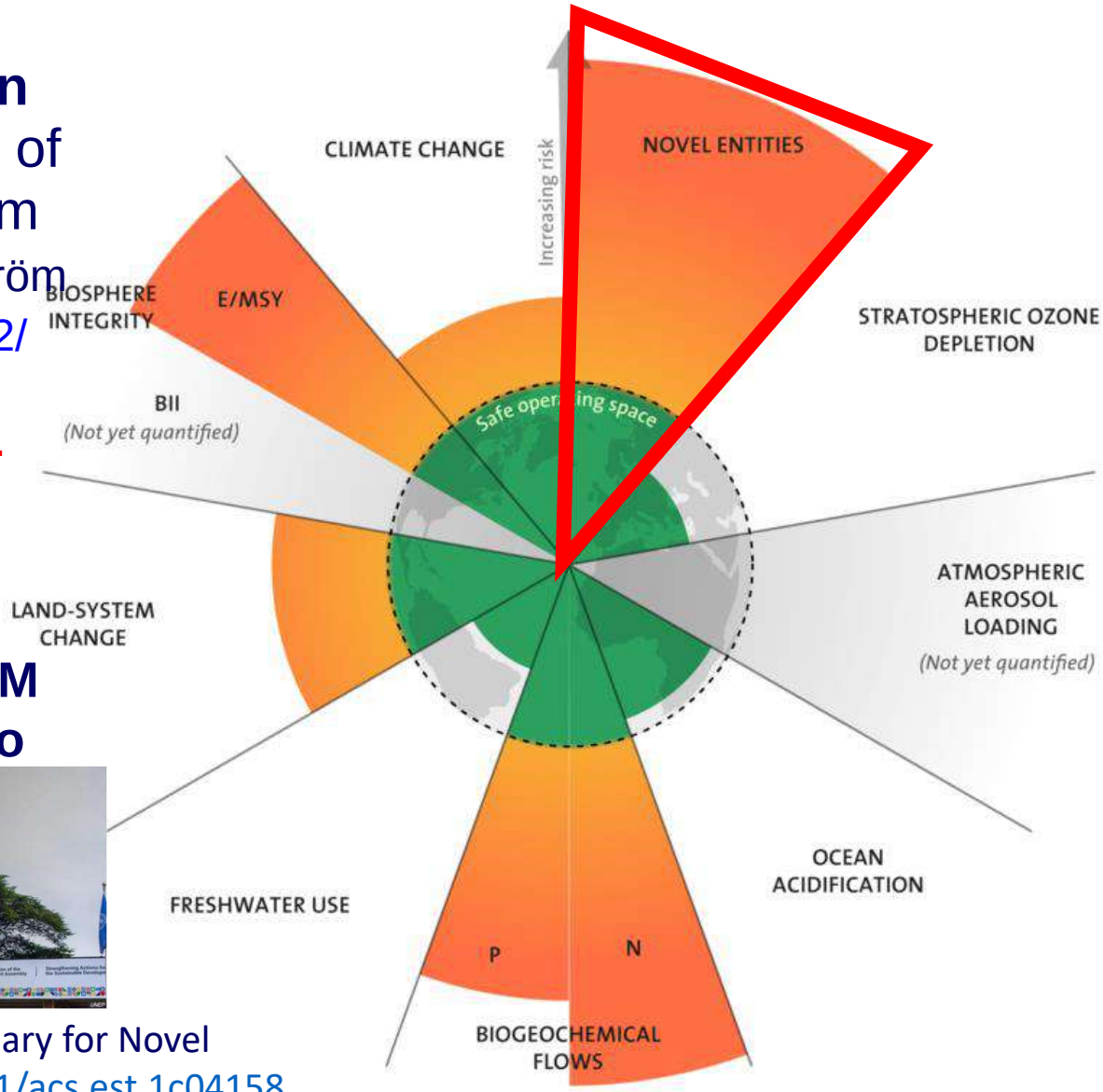
Plastic Waste Trade Crises in South East Asia

Persson et al. (2022) Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. ES&T 2022, https://doi.org/10.1021/acs.est.1c04158 Richardson

"Novel Entities" plastic & chemicals crossed Planetary Boundaries

- The planetary boundaries **– which define the environmental limits within which humanity can safely operate –** have been evaluated for a range of critical anthropogenic pressure on the Earth System (climate, phosphorus, nitrogen; biodiversity; Rockström et al. 2009). http://www.ecologyandsociety.org/vol14/iss2/art32/

- **Also "Novel entities" including plastic and chemical pollution have crossed planetary boundaries and is therefore a concern for humanity and several ecosystem services.**
- **The implementation of Chemical Conventions, SAICM and the Plastic Treaty is therefore urgently needed to improve this situation.**



Persson et al. (2022) Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. Environ. Sci. Technol. 2022, 56, 3, 1510–1521. https://doi.org/10.1021/acs.est.1c04158

Rockström et al. (2009) Ecology & Society 14(2): 32
Update Richardson et al. & Rockstroem (2023): https://www.science.org/doi/10.1126/sciadv.adh2458

34 POPs listed in the Stockholm Convention (05/2023)

Chemical	Pesticides	Industrial chemicals	Unintentional production	Annex
DDT	+			B
Aldrin, Dieldrin, Endrin, Chlordane, Chlordecone, Toxaphene	+			A
Alpha-, Beta-, Gamma-HCH	+		By-product of lindane	A
Endosulfan, Heptachlor, Mirex	+			A
PCP, Dicofol, Methoxychlor	+	+		A
Commercial PentaBDE		+		A
Commercial OctaBDE (Hexa/HeptaBDE)		+		A
Commercial DecaBDE		+		A
Hexabromobiphenyl (HBB)		+		A
Hexabromocyclododecane (HBCD)		+		A
PFOS, its salts and PFOSF	**+**	+		B
PFOA and related compounds				
PFHxS and related compounds		+		A
SCCPs, Dechlorane Plus		+		A
UV-328		+		A
PCB, PeCBz, HCB, PCN, HCBD	**+**	**+**	+	A/C
PCDD, PCDF			+	C

Now 34 POPs listed with 22 newly listed since 2009.

Many new listed POPs are plastic additives or are otherwise related to plastics.

5 brominated flame retardants and two chlorinated plastic additives (Dechlorane Plus and SCCPs) have been listed.

PFOS/PFOA/PFHxS were used in side-chain fluoropolymers and PFOA used in polymer production.

The first **non-halogenated** POP was listed in 2023 (**UV-328**)

Currently 3 more POP candidates are evaluated by the POPs Review Committee:
Chlorpyrífos, MCCP, LC-PFAA.

POP plastic additives listed in the Stockholm Convention, main use and provisional Basel Convention low POP Content Limit

	Main use	Listing year to the Stockholm Convention	Contents added to products	Low POP content for waste under the Basel Convention
PentaBDE	Polyurethane foam, printed circuit board	2009 (tetra- to heptaBDEs)	1% to 25% by weight	[50 mg/kg] or [500 mg/kg] or [1,000 mg/kg] as a sum
OctaBDE	Electronic casing			
DecaBDE	Electronic casing, textile coating, building insulation	2017 (decaBDE)		
HBCD	Textile, building insulation	2013	Up to 5% by weight in textile, ~0.7% in EPS, ~1-4% in XPS	100 mg/kg [or 500 mg/kg] or 1,000 mg/kg
HBB	Electronic casing, vehicles	2009	1% to 25% by weight	50 mg/kg
SCCP	PVC, rubber, coatings/paint, sealants, adhesive *etc*.	2017	Up to 20% by weight	[100 mg/kg] or [1,500 mg/kg] or [10,000 mg/kg]
Dechlorane Plus	EEE, vehicles, building materials, *etc.*	2023	Up to 40% by weight	TBD
UV-328	EEE, vehicles, building materials, *etc.*	2023	0.1 to 3 % by weight ;	TBD

Kajiwara et al. 2023, 43rd International Symposium on Halogenated Persistent Organic Pollutants (POPs) September 10-14, 2023 I Maastricht, The Netherlands

Project component POPs in plastics within GMP

The short term GMP project part on POPs in plastics (March-July 2023) had 3 major components:

I. A webinar series to strengthen capacities on POPs monitoring in plastics and related environmental and indoor pollution;

II. An assessment of the state of knowledge and gaps on monitoring POPs and POP candidates in plastic in major use sectors, and

III. Monitoring selected POPs in plastic pellets and shreds of recycled plastic.

STOCKHOLM CONVENTION

BASEL CONVENTION

Component 1: Webinar Series POPs in plastic and monitoring approaches

5 days Webinars hosted by International Panel on Chemical Pollution (IPCP) in 3 Parts:

Part I: Understanding POPs in plastics

Part II: Sampling of plastics from major sectors to monitor POPs in plastics

Part III: Extraction, clean-up, and analysis of POPs in plastics

The webinars were recorded and are available on the IPCP Website (https://www.ipcp.ch/) and on Youtube.

https://www.ipcp.ch/activities/ipcp-webinar-series-pops-in-plastic-and-monitoring-approaches

Day 2: Tuesday, May 23, 2023 recording

Component 2: Assess of state of knowledge and gaps on monitoring POPs in plastic

Two reports were developed on assessment of state of knowledge and gaps on sampling and analysis of POPs and POPs candidates in plastic pellets in major use sectors

- Part A: Assessment of available guidance documents for practical understanding and controlling POPs in plastics.
- Part B: 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 monitor POPs in plastics for a better control.

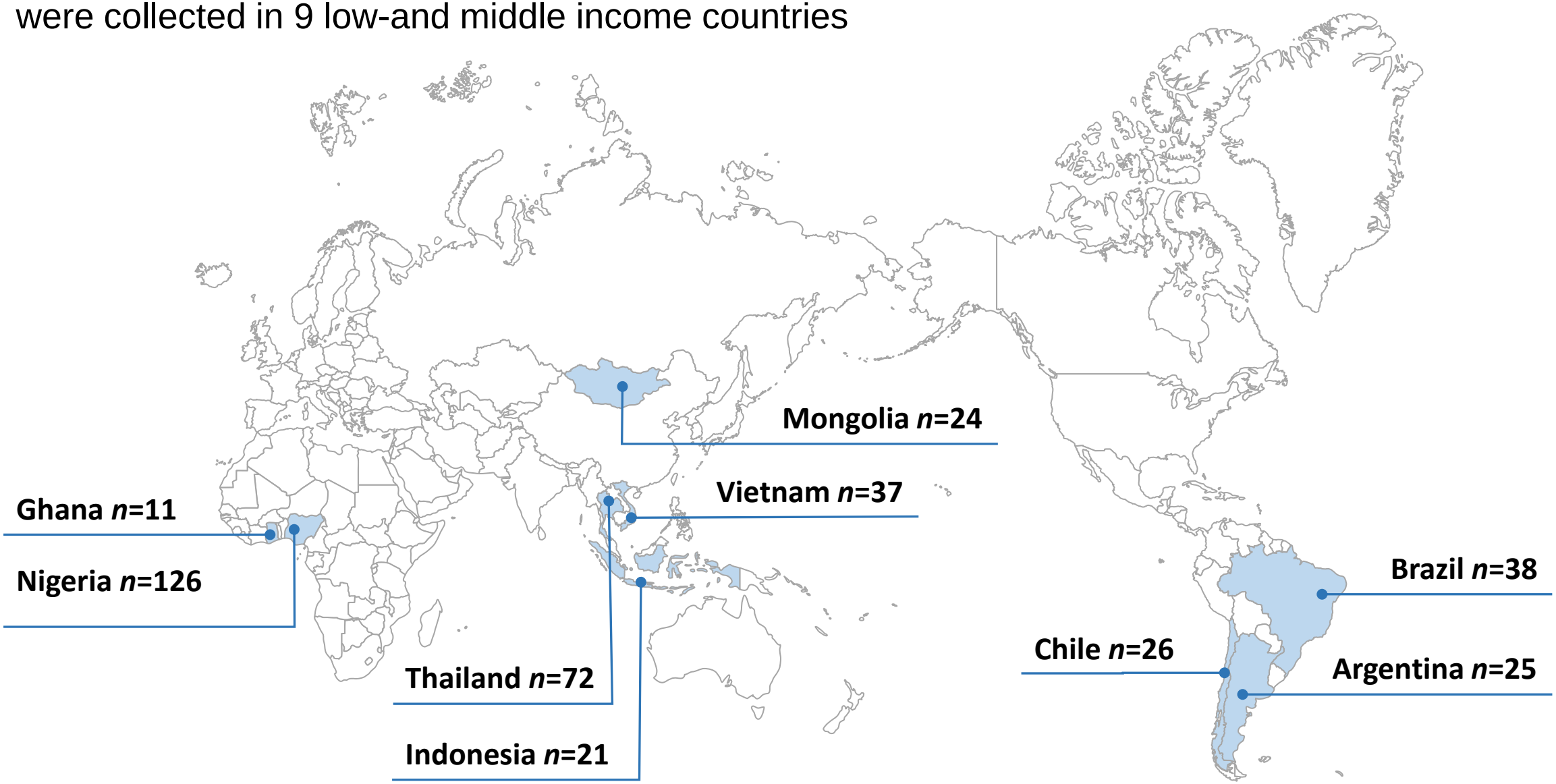
Component 3a: Pellet and shred samples collection

- To get a first insight into the plastic recycling situation in low- and middle-income (LMIC) countries and the presence of POPs in plastic recycling, plastic pellets and shreds were sampled in 9 countries in different UN region (Africa, South America/GRULAC, Asia/Pacific).
- For the sampling, partners were selected which were able to sample recyclates in short time.
- A questionnaire was developed and distributed to the sampling partners to collect also information on plastic recycling situation in the respective countries.
- An Excel was developed and distributed to the partners where information on collected plastic pellets and shred POPs in the recycled plastic pellets obtained from developing countries were investigated.
- Target polymers where those in which POPs were/are mainly used
  - ✓ Acrylonitrile butadiene styrene (ABS)
  - ✓ Polystyrene (PS) including high-impact polystyrene (HIPS)
  - ✓ Polyethylene (PE) including high density polyethylene (HDPE)
  - ✓ Polypropylene (PP)
  - ✓ Soft polyvinyl chloride (PVC)

but countries where encouraged to collect also other polymers recycled in the country (but to avoid to mainly collect the major recycled plastics PET and HDPE).

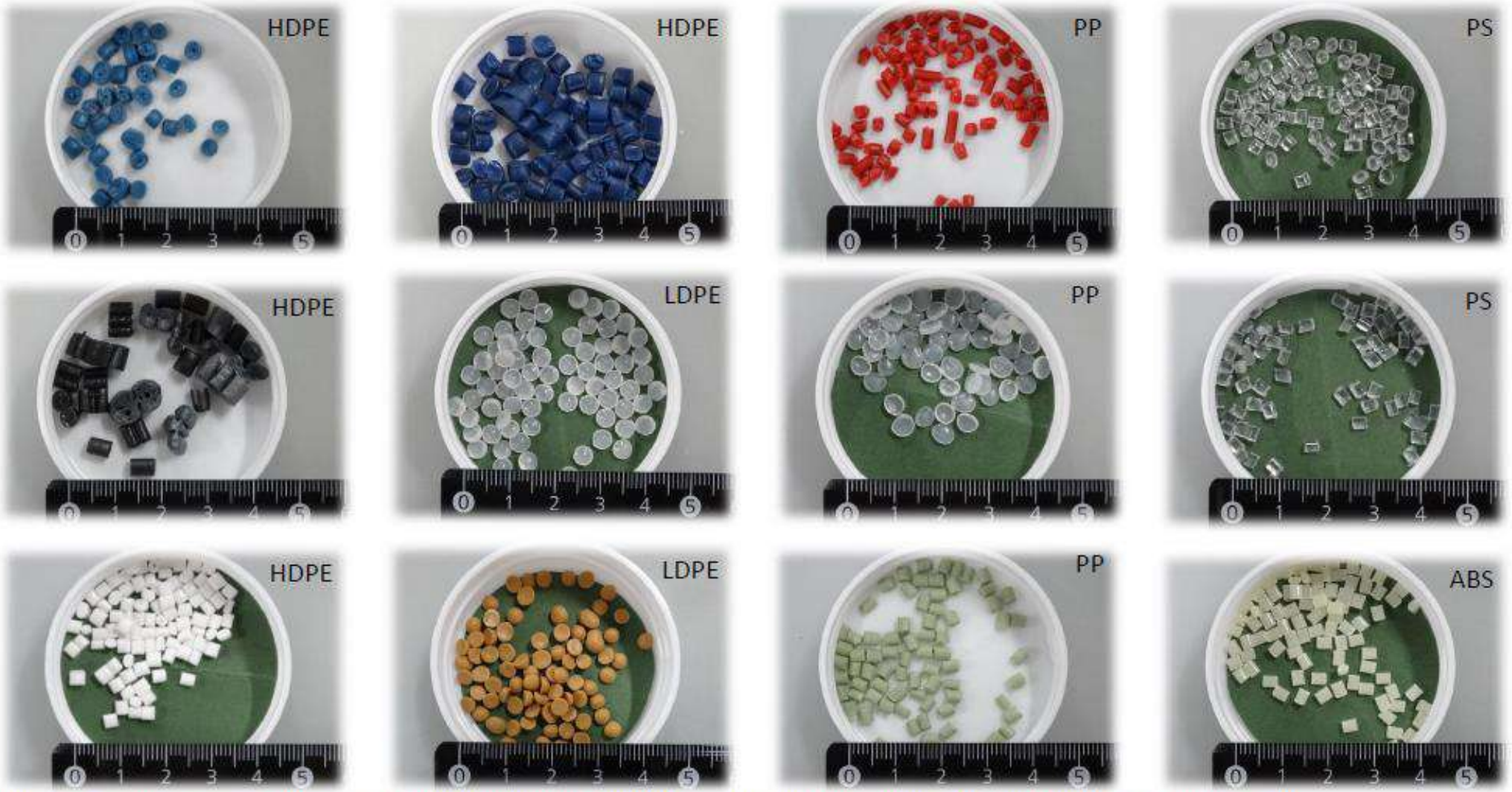
Component 3a: Pellet and shred samples collection

✓ 272 plastic pellets samples
✓ >100 plastic shreds used in recycling
were collected in 9 low-and middle income countries



Component 3a: Pellet and shred samples collection

- In the beginning the plan was to collect plastic pellets from recycling in the countries.



HDPE: High density polyethylene; LDPE: Low density polyethylene; PP: Polypropylene; PS: Polystyrene; ABS: Acrylonitrile butadiene styrene

Pellet and shred samples collected in the GMP study (Nigeria)

- We discovered during the sampling that often directly shreds were used to produce new plastic products.

Shreds to produce new plastic products

Pellets from recycled plastic

Pellets imported (recycled plastic)

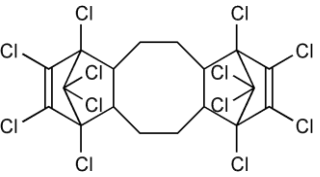
In the sampling and assessment of plastic recycling in Nigeria 126 recycled plastic samples were collected

- 36 as pellets
- 90 as shreds

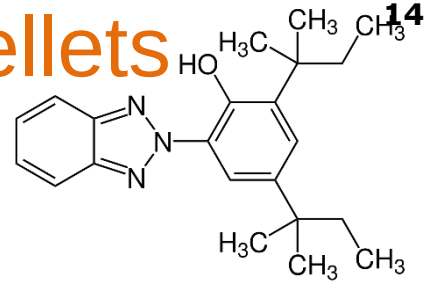
Component 3b: Analysis of POPs and screening toxicity in recycled plastic pellets and shreds

- Selected pellet and shred samples were sent to collaborating laboratories for instrumental analysis of plastic-related POPs and for screening toxicity.

Laboratories	POPs groups analysed
National Institute for Environmental Studies (NIES), Tsukuba, Japan	SCCPs, MCCPs and LCCPs PBDEs and HBCD
Fraunhofer Institute IVV, Freising Germany;	Dechlorane Plus and UV-328
Tokyo University of Agriculture and Technology	UV-328 and other major triazole UV-stabilizer
Spanish National Research Council CSIC, Barcelona, Spain	PFOS, PFOA, PFHxS and other PFAS
National Metal and Materials Technology Centre, Thailand	Screening SCCPs/MCCPs with pyrolysis GC/MS Screening BFRs with FT-IR
BioDetection Systems, Amsterdam, The Netherlands	Screening for Toxicity (Cytotoxicity, genotoxicity, endocrine toxicity: estrogen, androgen, PAH-like)



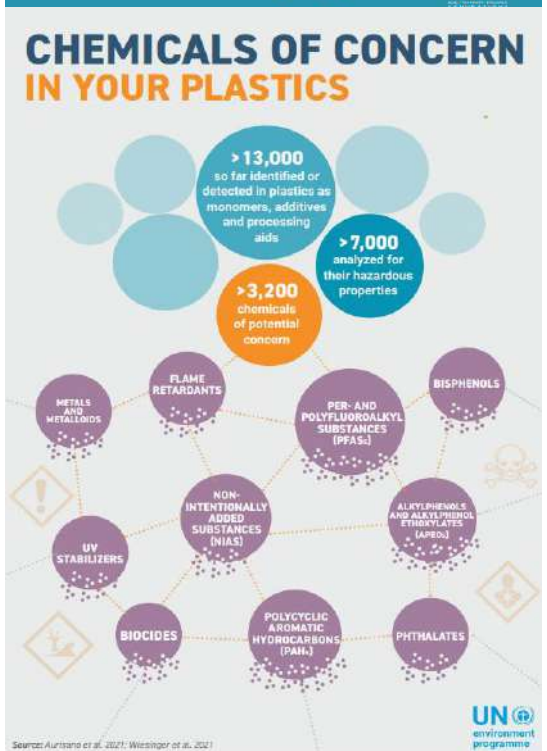
Dechlorane Plus & UV-328 in recycled plastic pellets



- **Dechlorane Plus** was mostly below the limit of quantification (LOQ) of 1 mg/kg.
- From 117 recycled plastic pellet sample analysed for **Dechlorane Plus**, only three samples (**2.6%**) exhibited measurable contents, with values of 1.0 mg/kg in a PP recyclate, and 1.2 and 3.4 mg/kg in two HIPS recyclates - all from the sampling campaign in Thailand.
- These pellets were produced using local feedstocks derived from automotive parts, electronic wastes, and post-consumer plastic waste.
- Out of the 117 samples analyzed for **UV-328**, only 20 (17%) displayed UV-328 concentrations above 0.1 mg/kg (ranging from 0.11 to 17.5 mg/kg).
- Only 3 recycled pellet samples (2.6%) were above 1 mg/kg including a PE (1.05 mg/kg), HIPS (3.6 mg/kg), and a PVC (17.5 mg/kg) pellet sample.
- ABS, EPS, HDPE, LDPE, PET had UV-328 contents below 1 mg/kg.
- We also analysed other benzotriazole UVSs like UV-320, UV-327, and UV-350, classified as Substances of Very High Concern (SVHC) in Europe in 6 pellets. Levels ranged from 0.01 mg/kg to 2.8 mg/kg with higher levels & detection frequency of the unrestricted UV-326 and UV-329.

Some major findings

- The **plastic recycling** in several of the assessed low income countries is largely **uncontrolled**. **Recycled plastic is partly used in food contact products, toys and skin contact products**.
- Most companies have some management measures especially of their plastic shreds & pellets.
- **PBDEs and SCCPs/MCCPs are detected** in the **major related polymers sometimes above Basel Convention provisional low POP content & unintentional trace contaminant limits**.
- **Dechlorane Plus and UV-328** were **frequently below detection limits** (1 mg/kg; 0.1 mg/kg). This is considerably below other Basel Convention low POPs content limits or EU limit for unintentional POP trace (appropriately regulated?). PFAS were mainly detected in ng/kg level.
- **Bioassays** for EDC- (agonists & antagonists for estrogenic, androgenic, thyroid etc.), cytotoxic, genotoxic-, dioxin-like/PAH-effects are an **important complement** to the instrumental analysis **giving information on integrative toxicity for selected endpoints**. Regulatory approach?
- **Plastic recycling is a field for monitoring**, **assessment and regulatory control**. Currently major plastic additives (PBDE, SCCP, HBCD) have several provisional low POPs content limits. It would be interesting if the science community could develop science-based low POPs limits!
- **POPs are only the tip of the iceberg** in the recycled pellets. How to control and regulate other hazardous plastic additives not (yet) internationally regulated (global plastic treaty?).



Chemicals in Plastics : A Technical Report - Main content

A "**Chemical in Plastic" report** has been developed by UNEP in cooperation with the BRS Secretariat with lead authors from the Intern. Panel on Chemical Pollution.

Describes the various chemicals-related issues of plastic pollution:

1) **Chemicals of concern and impacted sectors that use plastics.**
   - Over 13,000 substances have been associated with plastics.
   - More than 3200 are chemicals of potential concern.
2) Environmental fate and health effects of plastic-associated chemicals
3) Problems with the current state of chemical risk assessments
4) Options for addressing chemicals of concern in plastics
5) Strategies for substituting problematic chemicals
6) Managing existing plastic waste and plastics in a circular economy.

- The report is available with a summary and key findings : https://www.unep.org/resources/report/chemicals-plastics-technical-report

INF doc INC2: https://www.unep.org/events/conference/second-session-intergovernmental-negotiating-committee-develop-international/documents#OtherDocuments

Thank you for your attention !

Acknowledgement:
The financial support of UNEP/GEF to the Global Monitoring Plan (GMP) projects (GEF 4894, GEF 4886 and GEF 6978) is acknowledged.

More Information:

UNEP Global Monitoring Plan: https://www.unep.org/explore-topics/chemicals-waste/what-we-do/persistent-organic-pollutants/global-monitoring

UNEP Chemical in Plastics: www.unep.org/resources/report/chemicals-plastics-technical-report

UNEP Plastics Treaty: https://www.unep.org/about-un-environment/inc-plastic-pollution

Basel Convention: www.basel.int

Stockholm Convention: http://chm.pops.int/

SAICM: http://www.saicm.org/ http://www.oecd.org/chemicalsafety/

Science: www.ipcp.ch; www.foodpackagingforum.org/; www.isde.org/; https://ikhapp.org/scientistscoalition/

Industry: https://endplasticwaste.org/; https://plasticseurope.org/; http://www.suschem.org/

NGO: www.ipen.org; www.ciel.org/; www.ban.org; www.chemsec.org; www.wecf.org; https://chemtrust.org/

Better-world-links: http://www.betterworldlinks.org/; https://www.plasticstreaty.org/scientists-declaration/

Screening of Brominated and Chlorinated Additives in Plastic Pellets

Natsuko Kajiwara[1], Yago Guida[1], Roland Weber[2]

[1]National Institute for Environmental Studies, Japan

[2]POPs Environmental Consulting, Germany

Today's Presentation

1. *Introduction*
2. *XRF screening of bromine (Br) and chlorine (Cl) contents*
3. *Ongoing project on recycled plastic pellets*

Stockholm Convention on Persistent Organic Pollutants (POPs)

	2001	COP4 2009	COP5 2011	COP6 2013	COP7 2015	COP8 2017	COP9 2019	COP10 2022	COP11 2023
Pesticides	Aldrin, Chlordane, DDT, Dieldrin, Endrin, Heptachlor, Mirex, Toxaphene	Chlordecone, HCH, lindane	Endosulfan		PCP		Dicofol		Methoxychlor
Fluorinated compounds		PFOS PFOSF					PFOA	PFHxS	
Brominated flame retardants		HBB POP-BDEs		HBCD		DecaBDE			
Chlorinated compounds	HCB PCB	PeCB			HCBD PCN PCP	SCCP			Dechlorane Plus
UV stabilizer									UV-328
Unintentional POPs	HCB PCB PCDD/DF	PeCB			PCN	HCBD			

Most of the newly added POPs for global elimination are plastic additives

Brominated additives

Chlorinated additives

POPs Used as Plastic Additives

	Main use	Listing year to the Stockholm Convention	Contents added to products	Low POP content for waste under the Basel Convention
PentaBDE	Polyurethane foam, printed circuit board	2009 (tetra- to heptaBDEs)	Up to 40% by weight (1% = 10,000 mg/kg)	[50 mg/kg] or [500 mg/kg] or [1,000 mg/kg] as a sum
OctaBDE	Electronic casing			
DecaBDE	Electronic casing, textile coating, building insulation	2017 (decaBDE)		
HBCD	Textile, building insulation	2013	Up to 5% by weight in textile, ~0.5% in EPS, ~5% in XPS	100 mg/kg [or 500 mg/kg] or 1,000 mg/kg
SCCP	PVC, rubber, lubricant, *etc*.	2017	Up to 20% by weight	[100 mg/kg] or [1,500 mg/kg] or [10,000 mg/kg]
Dechlorane Plus	EEE, vehicles, building materials, *etc.*	2023	Up to 40% by weight	TBD
UV-328	Paints, coating, sealants, EEE, vehicle, building material, food packaging, *etc.*	2023	Up to 10% by weight	TBD

POPs Used as Plastic Additives

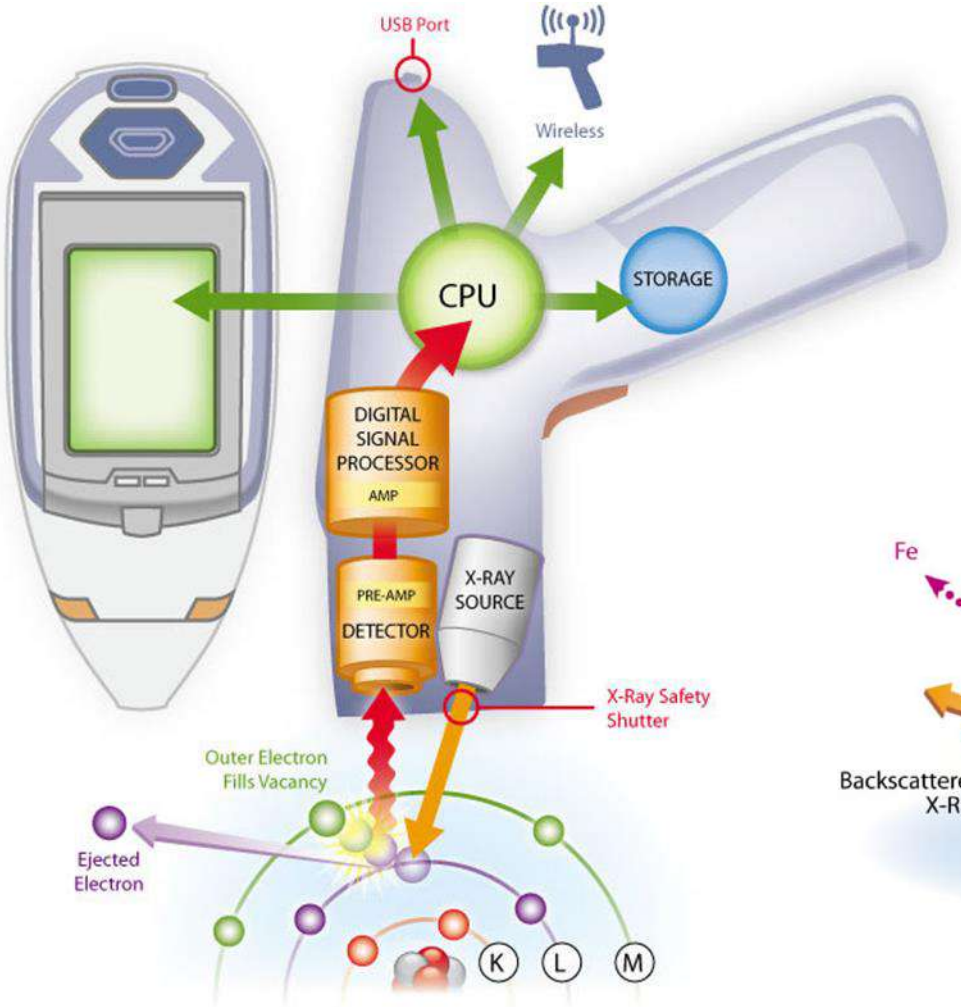
	Main use	Listing year to the Stockholm Convention	Contents added to products	Low POP content for waste under the Basel Convention
PentaBDE	Polyurethane foam, printed circuit board	2009 (tetra- to heptaBDEs)	Up to 40% by weight (1% = 10,000 mg/kg)	[50 mg/kg] or [500 mg/kg] or [1,000 mg/kg] as a sum
OctaBDE	Electronic casing			
DecaBDE	Electronic casing, textile coating, building insulation	2017 (decaBDE)		
HBCD	Textile, building insulation	2013	Up to 5% by weight in textile, ~0.5% in EPS, ~5% in XPS	100 mg/kg [or 500 mg/kg] or 1,000 mg/kg
SCCP	PVC, rubber, lubricant, *etc*.	2017	Up to 20% by weight	[100 mg/kg] or [1,500 mg/kg] or [10,000 mg/kg]
Dechlorane Plus	EEE, vehicles, building materials, *etc.*	2023	Up to 40% by weight	TBD

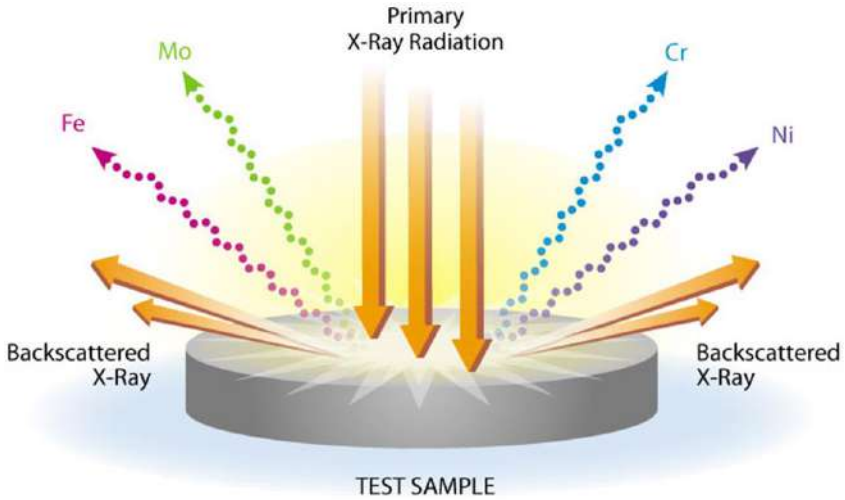
➔ Br or Cl contents as indicators of the presence of POPs in plastic

➔ Quick screening of Br and Cl by using a handheld X-ray fluorescence (XRF) analyzer

XRF screening of bromine (Br) and chlorine (Cl) contents

How Does XRF Work?





Notes on XRF Measurements

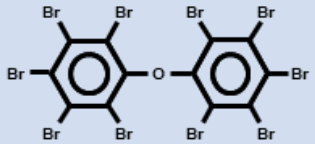
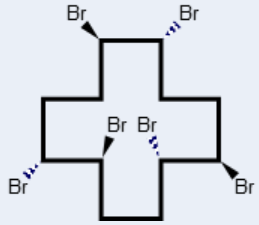
1. The sample should completely cover the measurement window.
2. The sample should be homogeneous.
3. The sample should be thick enough that additional material will not affect the result. For plastic samples, the thickness should at least 1.5 cm. Or the area to be measured should not be in contact with any other materials.
4. XRF analysis is limited to the detection of elements including Br and Cl in the test samples, without any capacity to identify the type of additives.

a non-destructive method

5 cm

5 cm

Br Contents in BDE 209 and HBCD

	Molecular structure	Molecular formula	Molecular weight (g/mol)	Br content
BDE 209 (Decabromodiphenyl ether)		$C_{12}Br_{10}O$	959.2	83% = (79.9 x 10 / 959.2) x 100
HBCD (Hexabromocyclododecane)		$C_{12}H_{18}Br_6$	641.7	75% = (79.9 x 6 / 641.7) x 100

➔ For example, if the Br concentration measured by XRF was 1,000 mg/kg by weight, all derived from BDE 209 or HBCD, it corresponds to 1,200 mg/kg of BDE 209 and 1,300 mg/kg of HBCD, respectively.

➔ Conversely, for example, to ensure that PBDE and HBCD concentrations are below 1,000 mg/kg, Br concentrations should be below 830 mg/kg and 750 mg/kg, respectively.

Cl as an Indicator for Chlorinated Additives?

	Main use	Contents added to products	Low POP content for waste under the Basel Convention
SCCP	PVC, rubber, lubricant, *etc*.	Up to 20% by weight	[100 mg/kg] or [1,500 mg/kg] or [10,000 mg/kg]
Dechlorane Plus	EEE, vehicles, building materials, *etc.*	Up to 40% by weight	TBD

1. The detection limit of Cl concentration in XRF measurements is several orders of magnitude higher than that of Br.
2. Since PVC originally contains a large amount of Cl (up to 70% by weight), it is difficult to determine the presence/absence of SCCP or Dechlorane Plus based on the XRF screening of Cl concentration.
   - XRF screening may be effective for polymer products that do not originally contain Cl.
   - Need to accumulate case studies of such cases in the future.

Ongoing project on recycled plastic pellets

The Aim of This Study

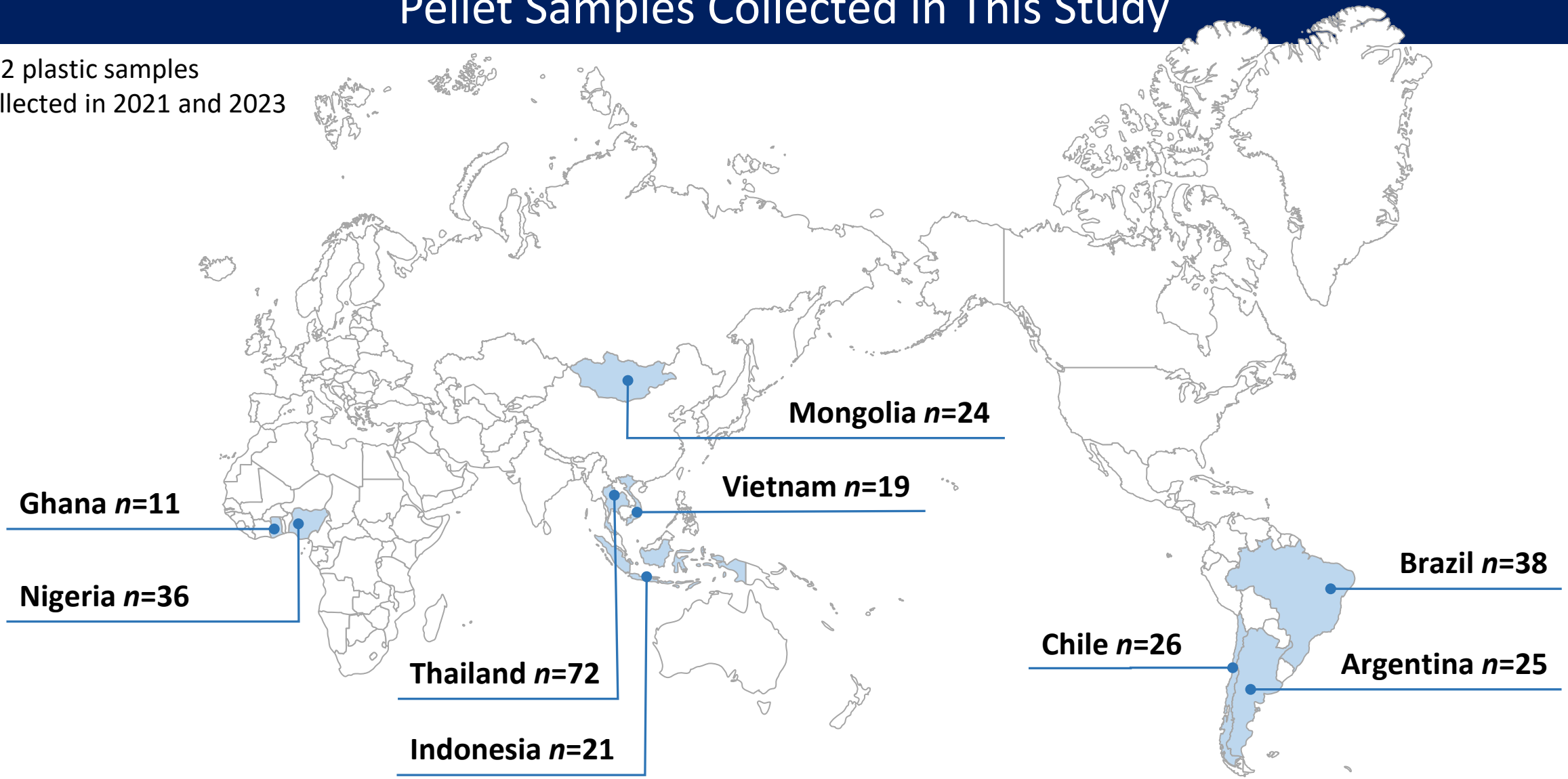
- Plastic products and their unsounded management, including recycling of POP-containing material, play a key role in the global spread of POPs.

- To understand the actual situation of presence of POPs in plastic recycling, POPs in the recycled plastic pellets obtained from developing countries were investigated.

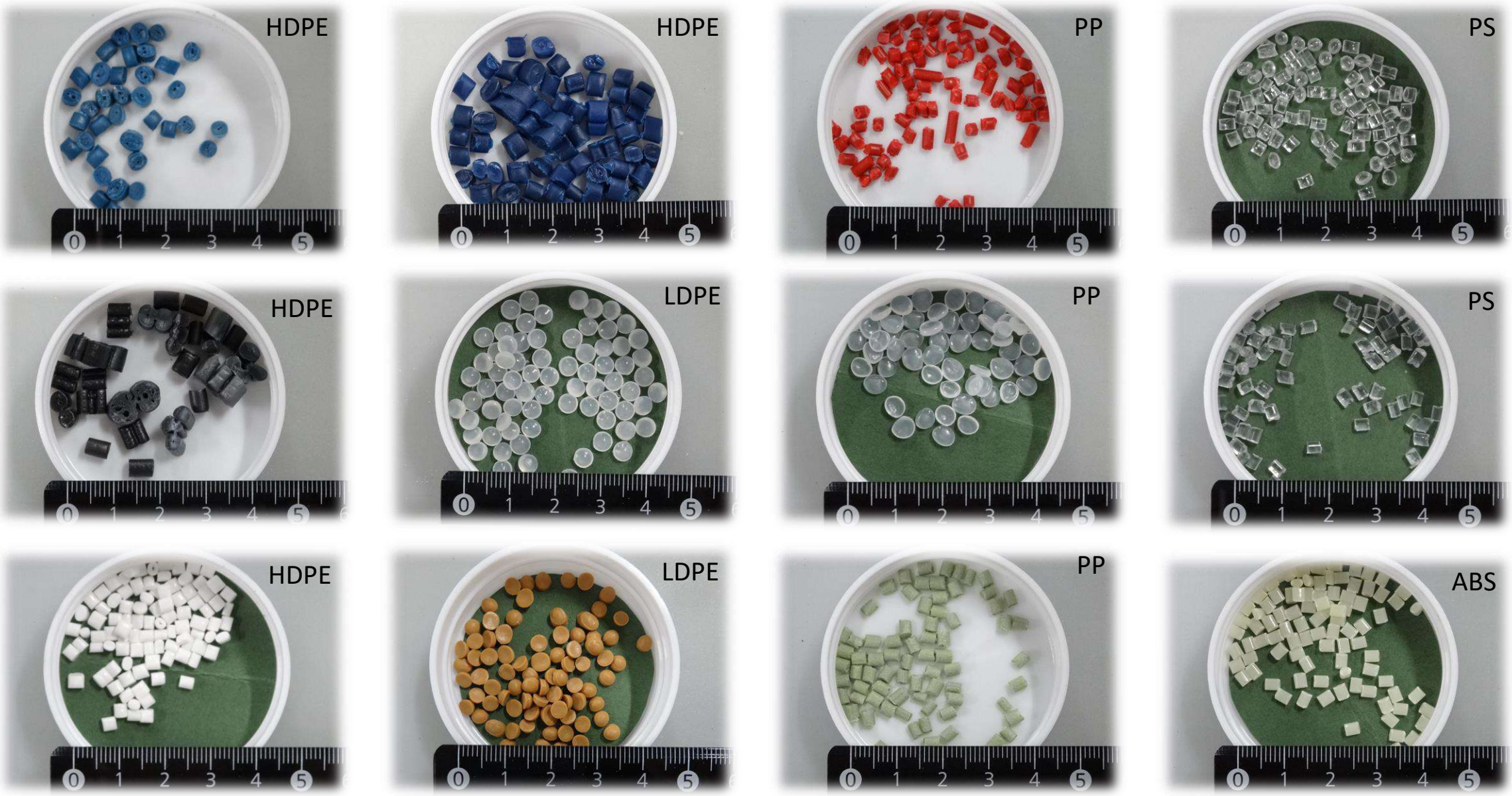
- Target polymers:
  - ✓ Acrylonitrile butadiene styrene (ABS)
  - ✓ Polystyrene (PS) including high-impact polystyrene (HIPS)
  - ✓ Polyethylene (PE) including high density polyethylene (HDPE)
  - ✓ Polypropylene (PP)
  - ✓ Soft polyvinyl chloride (PVC)

Pellet Samples Collected in This Study

- ✓ 272 plastic samples collected in 2021 and 2023



Recycled Plastic Pellets from Various Developing Countries



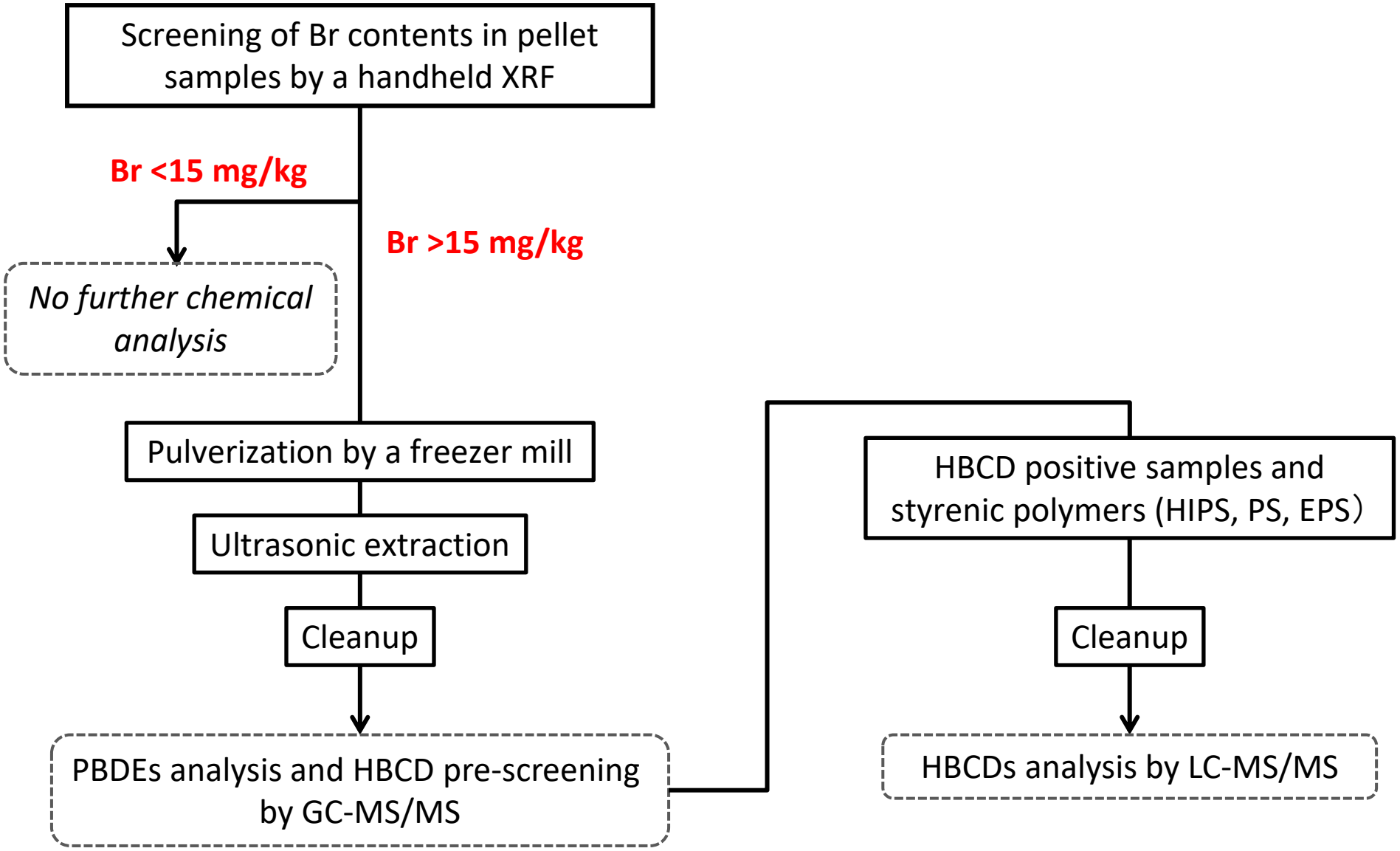
HDPE: High density polyethylene; LDPE: Low density polyethylene; PP: Polypropylene; PS: Polystyrene; ABS: Acrylonitrile butadiene styrene

Variation of Br Concentrations (mg/kg) in Plastic Pellets

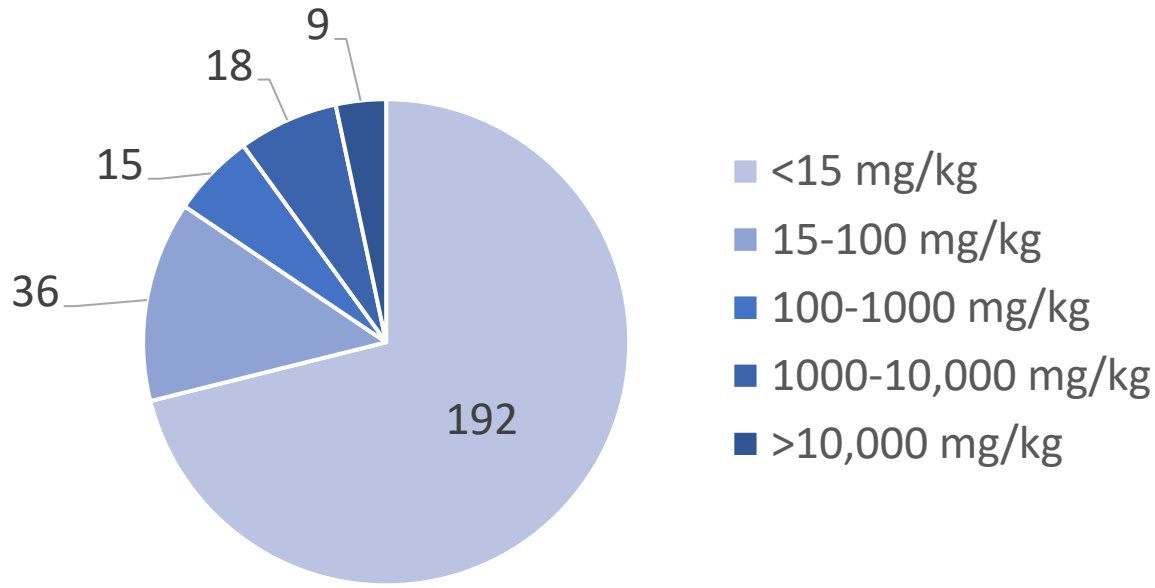
	n	Average	Range	CV (%)
Pellet A	5	110,000	110,000–110,000	1.2
Pellet B	6	84	77–89	5.5
Pellet C	6	30	27–32	5.9

➔ Br concentration in pellet sample can be considered homogeneous

PBDE and HBCD Analysis

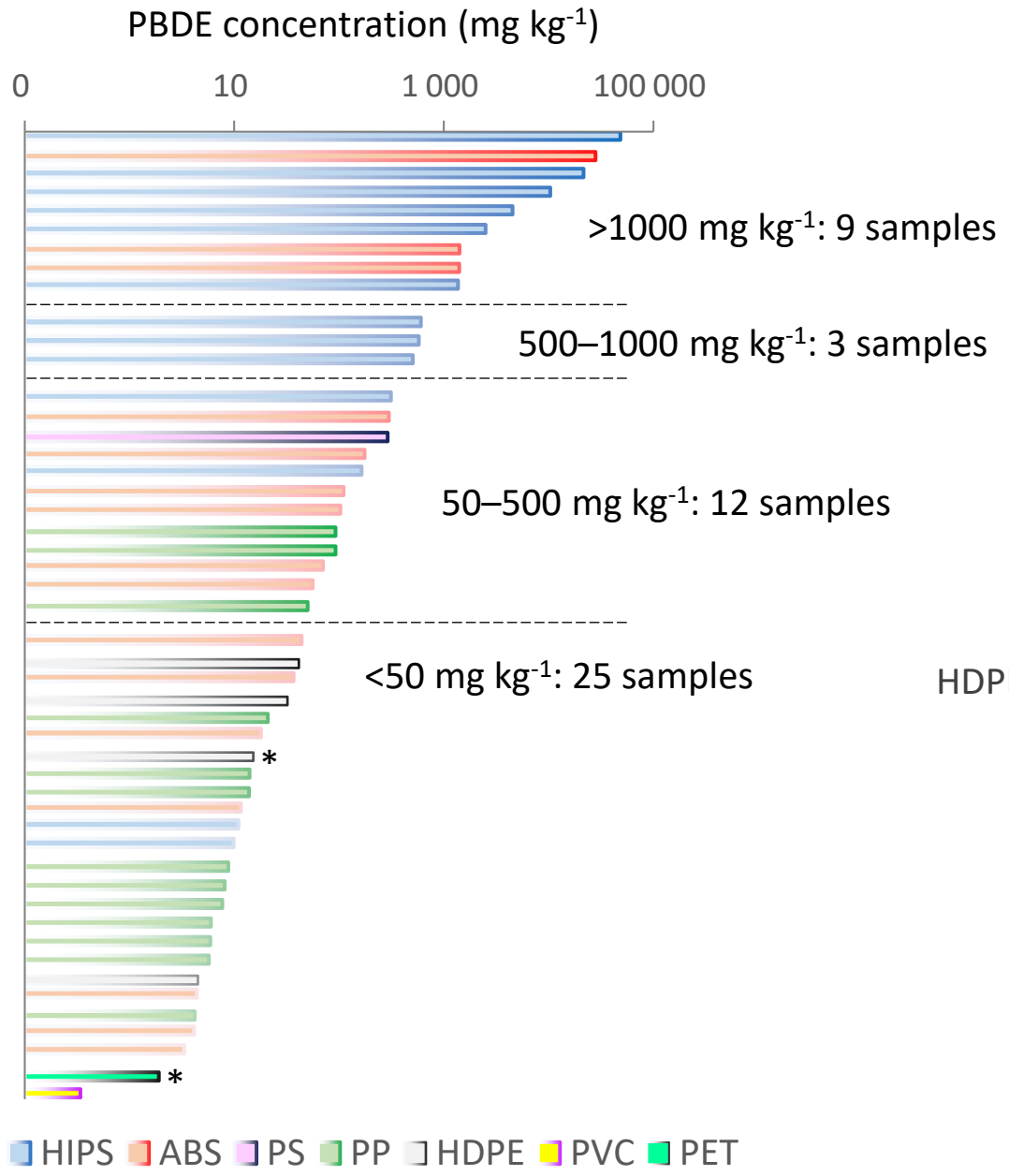


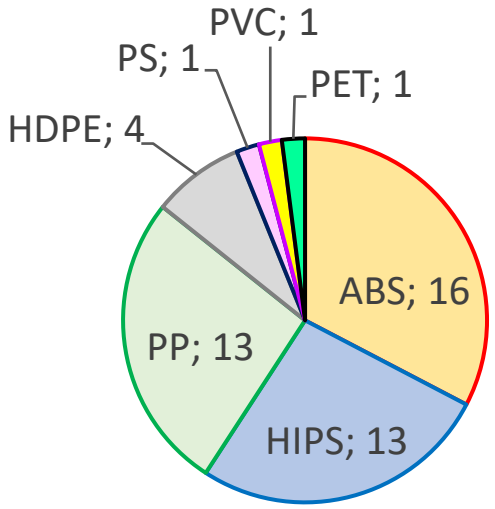
Br Contents in Pellet Samples (*n* = 270)



➔ *78 pellet samples with >15 mg/kg Br (29% of the original samples) were selected for further PBDE analysis*

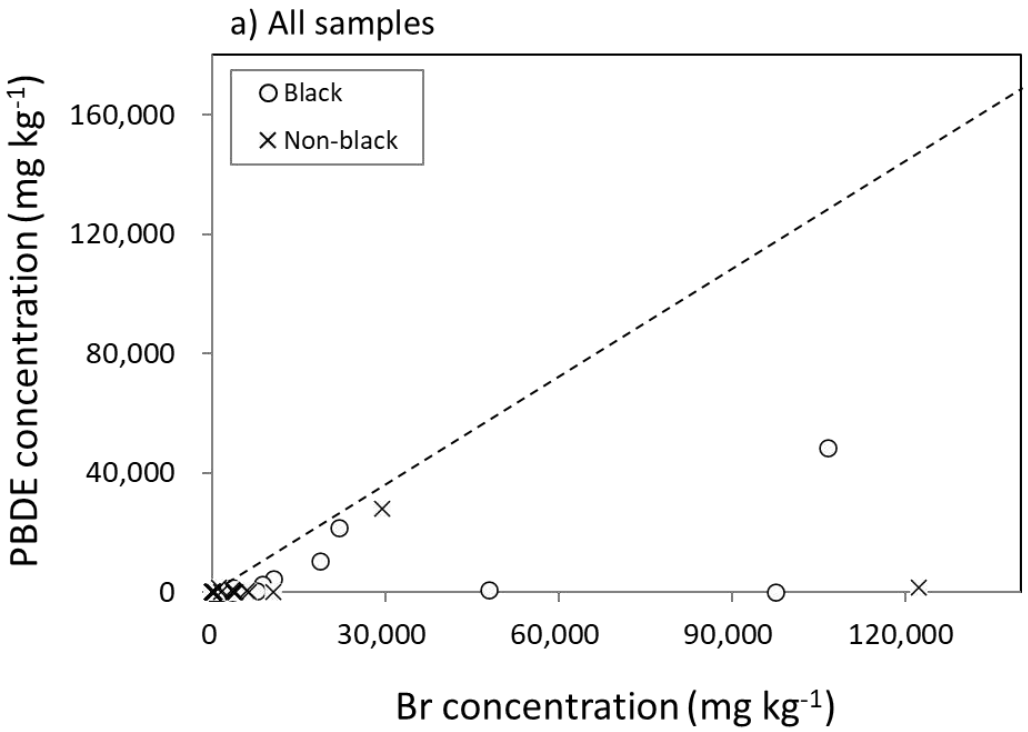
PBDE Concentrations in Plastic Pellets (*n* = 49)

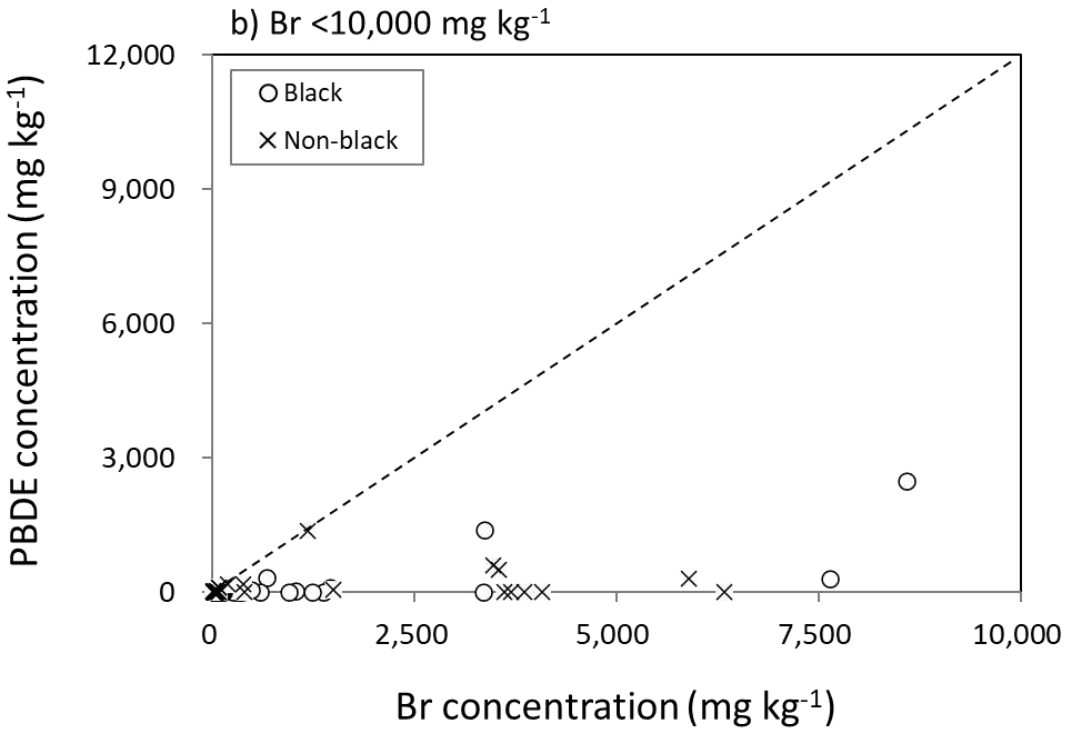




*Virgin material

Br Content vs. PBDE Concentration

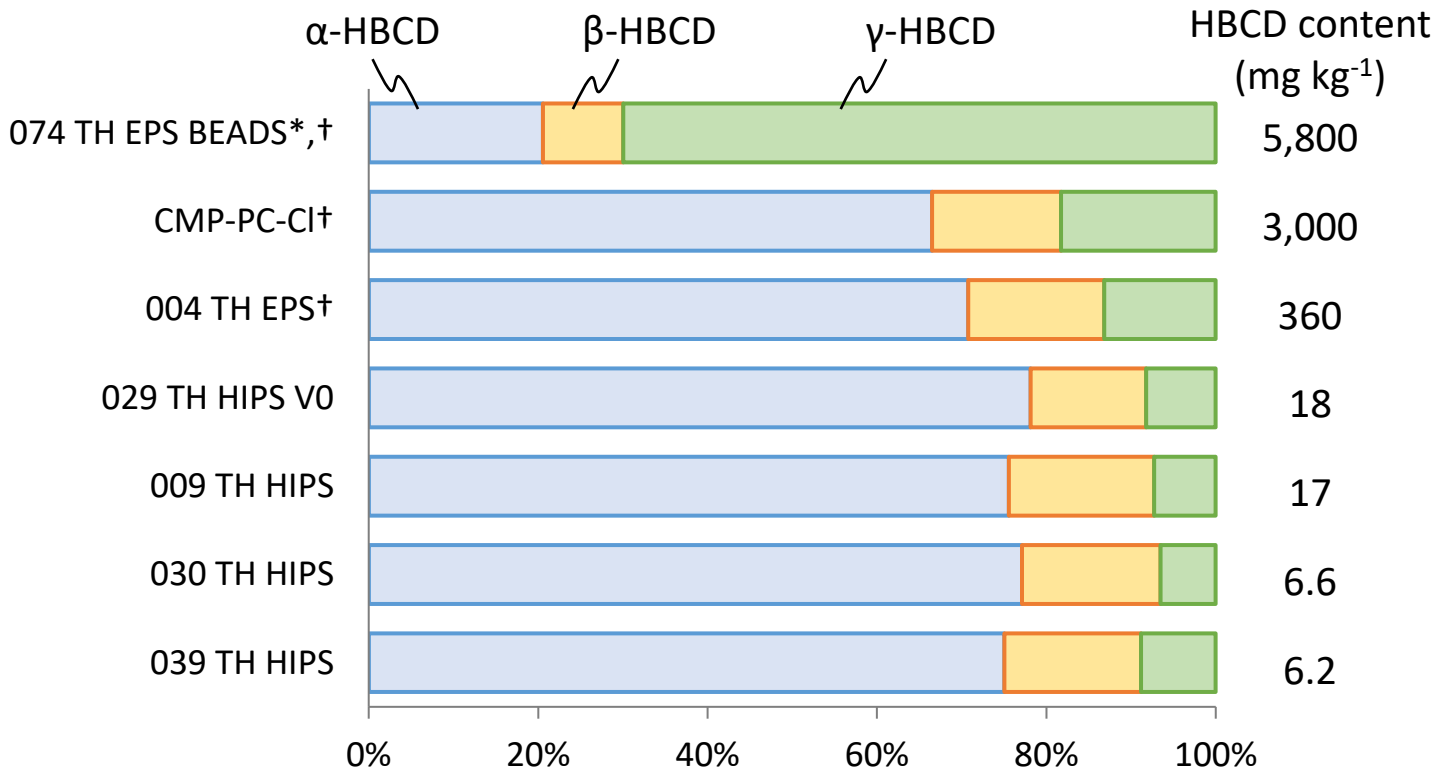




➔ Most of Br positive samples contained non-PBDE flame retardants.

➔ Other unregulated BFRs are mixed and recycled together.

HBCD Contents and Isomer Profiles (*n* = 7)

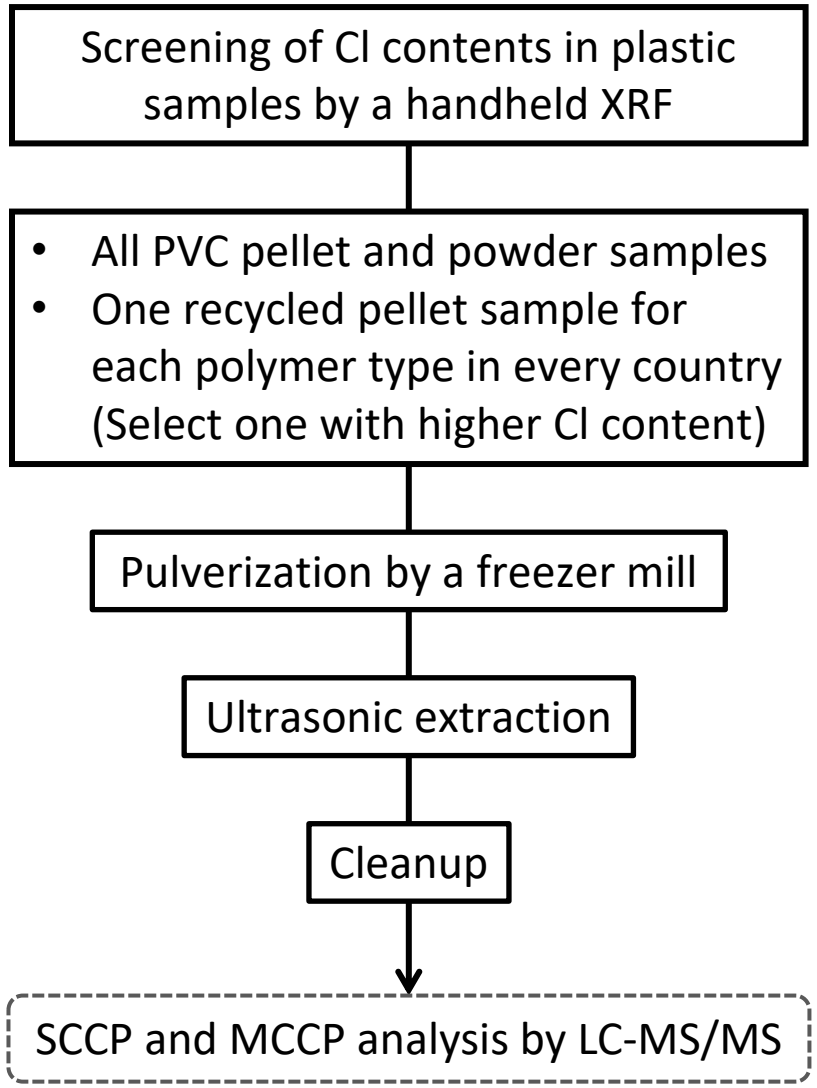


➔ HBCD containing EPS beads were still on the Thai market in April 2023.

➔ Some recycled pellets originated from E-waste plastics contained HBCD.

*Virgin material; †Samples where GC/MS pre-screening suggested the presence of HBCD.

SCCP and MCCP Analysis

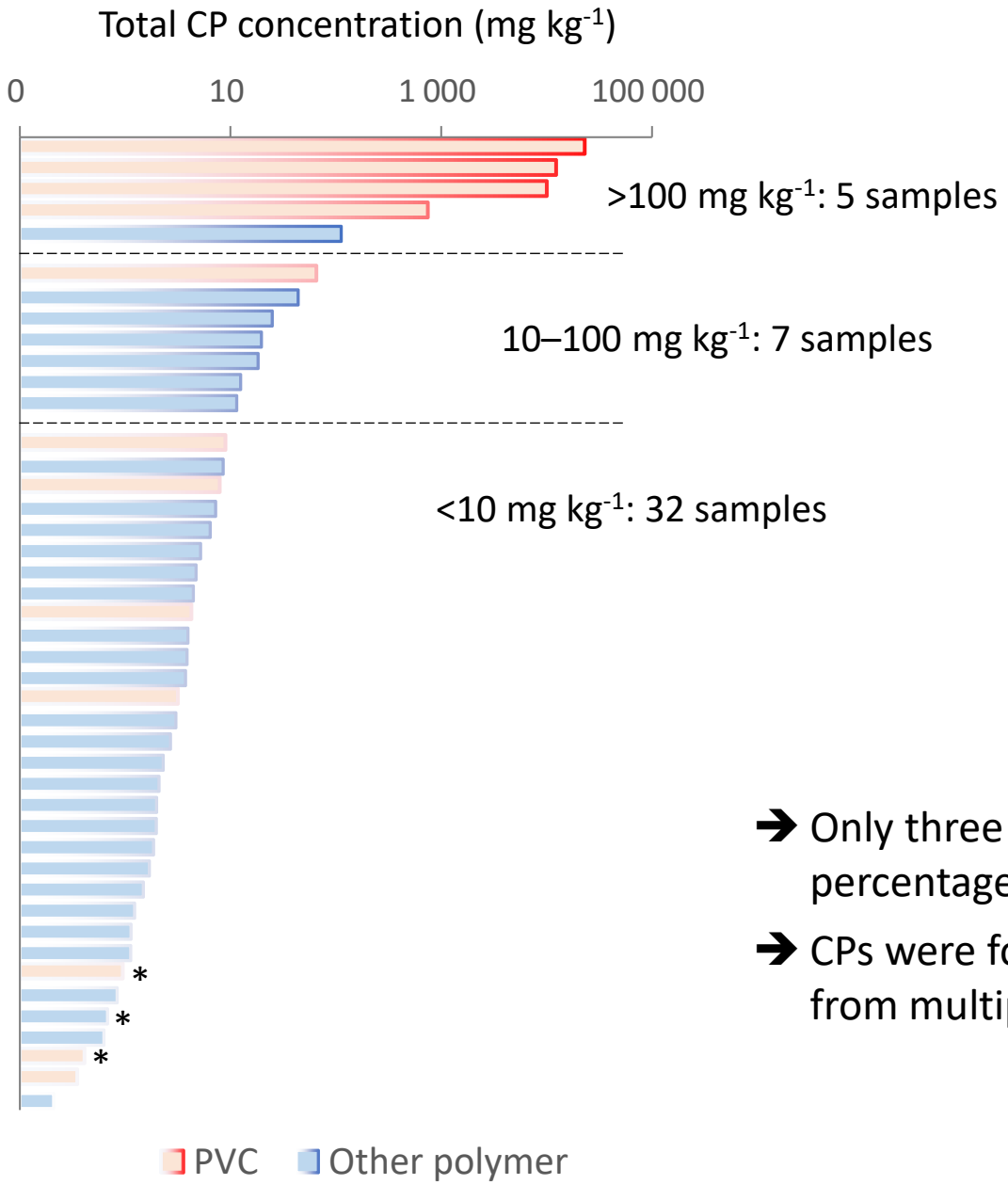


Initial total of 272 plastic samples

65 samples were selected:

- ✓ 58 pellets (incl. 7 PVC pellets)
- ✓ 5 PVC powder
- ✓ 2 shredded PET

SCCP and MCCP Concentrations in Plastic Pellets (*n* = 44)



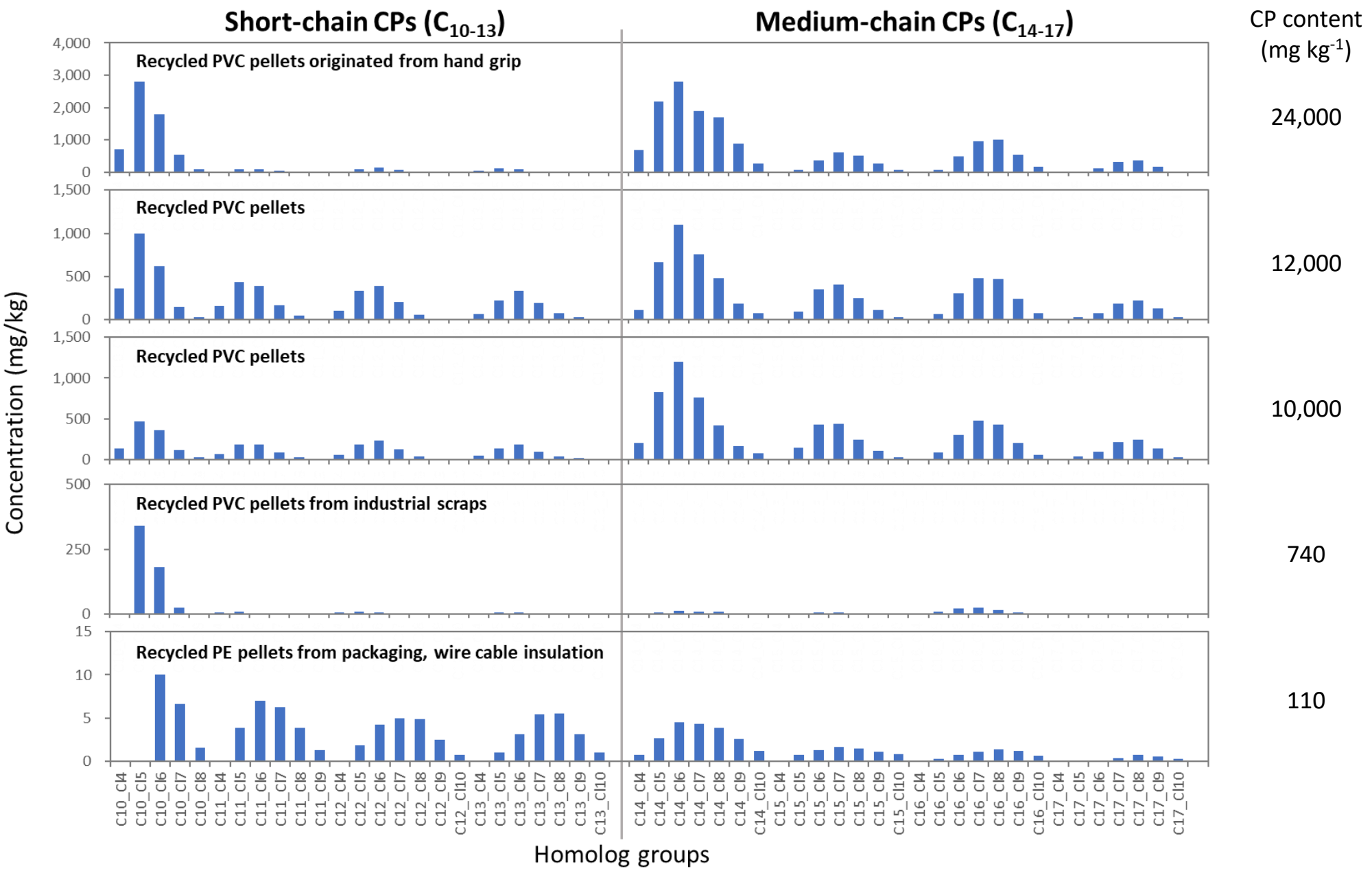
Recycled PVC pellets

➔ Only three PVC samples showed CP contents in the percentage range.

➔ CPs were found in various polymers other than PVC from multiple countries, even in low concentrations.

*Virgin material

CP Contents and Homolog Group Profiles



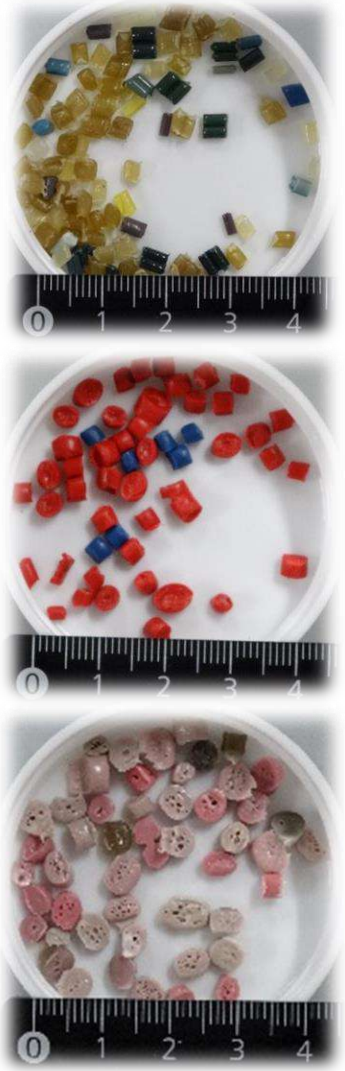
Summary and Future Perspectives

- Plastic additives listed as POPs have been detected in recycled plastics from developing countries (PBDE: 18% of the investigated samples; HBCD: 2.6%; CPs: 68%).
- Need to pay more attention to unintentional contamination of POPs in the downstream recycling to consumer products.

➔ Important to develop methods to separate polymers treated with POPs in recycling processes

➔ The quality of the recycled products should be improved (Need to avoid contamination of different pellets; need to improve the accuracy of determining the type of recycled polymer)

➔ Need for a mechanism to transfer information on chemical substances in products…



Acknowledgement

Research funds:

- *UNEP/GEF Global Monitoring Plan (GMP) projects (GEF 4894, GEF 4886 and GEF 6978)*
- *Environment Research and Technology Development Fund [grant numbers JPMEERF20193001 and JPMEERF20233001] of the Environmental Restoration and Conservation Agency provided by Ministry of the Environment of Japan*

Thank you very much for your kind attention!

Basel Convention Coordinating Centre for the African Region
(BCCC-Africa) in Nigeria

ABIA STATE UNIVERSITY

UNEP/GEF POPs GMP project in the Africa Region: Report of Plastic Sampling in Nigeria and Ghana

Nnorom Innocent C

Basel Convention Co-ordinating Centre for Africa, Ibadan, Nigeria.

Abia State University, Uturu, Nigeria.

Final Meeting of the UNEP/GEF project "Continuing Regional Support for the POPs Global Monitoring Plan under the Stockholm Convention in Africa Region"

28-30 November, 2023; Casablanca, Morocco

Plastics: the Situation Ghana and Nigeria

- Reliable data is not available on:
  - local production, importation, consumption/products POM
  - plastic waste generated or plastic waste collected and recycled.
- Supply of recycled plastic is low (estimated at 6% in Nigeria).
- Collection infrastructure inadequate
- Recently, increasing quantities of plastic bottles are collected by the informal operators.
- The most recycled plastics included polyethylene (HDPE & LDPE), Polyethylene terephthalate (PET), Polypropylene (PP)
- Few facilities handle Polyvinyl chlorine (PVC), High-impact polystyrene (HIPS) etc.

Recycling of Food Grade PET

- Food Grade PET – some companies (in Nigeria) buy and pre-process PET (crush and hot wash) before export.
- Some companies locally process PET into fibre for export while other use the fibre to produce mattress, pillow etc.
- Nigeria targets 50% recycling of all plastic waste and the Nigerian Government has licensed a company to recycle food-grade PET. The company is yet to commence operation.
- The 2021 *Study On Plastics Value Chain In Nigeria* reported the following as the top five used plastic item collected for recycling :
  - Food containers;
  - Beverage (PET) bottles, their caps and lids;
  - Sachet beverage packaging;
  - Used plastic are collected at:
  - Plastic bin bags

Informal Plastics Recycling Sector

- Profit oriented, no consideration of data collection, poor HSE etc.
- The facilities are often located withing rural inhabited areas.
- Do not follow routine operational steps (do not produce pellets but products).
- Poor house keeping, waste plastics dumped around the facilities
- They crush and sieve plastics – residents use sieved out waste to start fire or for cooking using locally fabricated stoves.
- In Lagos, a company that initially handled WEEE plastics stopped. They crush e-waste plastics before mixing with virgin polymers and used in making chairs.

Informal Recycling

Waste plastics displayed for sale in a market

Sieving crushed plastics

Sorted and ready for use

Hopper - moulding

Finished product

Informal recycler using shreds to directly produce new products without making pellets

Small-Scale Formal Recycler

Sampling Approach: Formal Sector

- Made a list of formal recyclers from desk study
- Consulted local collection centres and updated the list
- Field work to the formal recyclers but encountered challenges
  - Difficulty accessing the facilities,
  - Response of most facilities
    - Raw materials are expensive
    - Raw materials are in short supply
- Sampling was delayed; few samples collected from formal sector
- Resorted to networking
  - Engaged friends, present/former staff of plastics companies
  - used incentives to get samples (paying for pellet samples)

Sampling Approach: Informal Sector

- Networked with waste plastic collection centres to
  - Collect samples from formal recyclers
  - Collect already crushed samples from them
  - Request for crushing of selected polymer types/products
- Liaised with informal recyclers
  - Very accessible and readily volunteered samples
  - Gave permission to take pictures and make videos
  - Toured the facilities and created awareness on HSE
- Discovered an open market for waste plastics

Open Market for Waste Plastics

Some cities have open market for waste plastics. Different plastic types are sold including HDPE, LDPE, PVC, PP, etc. Dealers also display e-waste and ELV plastics (e.g. HDPE and LDPE) mostly black plastic from engine and interior of ELV

Summary of Sample Materials

- Forms: pellets, shreds, imported pellets, waste plastics
- Plastics types: HDPE; LDPE; ABS, GPPS; PP; PVC, and HIPS
- Cities sampled: Aba, Lagos, Nnewi, Onitsha, Uturu, Umuahia, Enugu, Benin
- Sources of samples: E-waste plastics, household plastics, food contact plastics, construction plastics, ELV
- Uses of recycled plastics:
  - household wares: cups, plates, carpets, chairs, crates etc.
  - Food contact plastics: bottles, water tanks, buckets etc
  - Auto parts: containers for vehicle products (e.g. grease), motorcycle parts

Plastic Samples (Nigeria)

Crushed

Recycled pellet

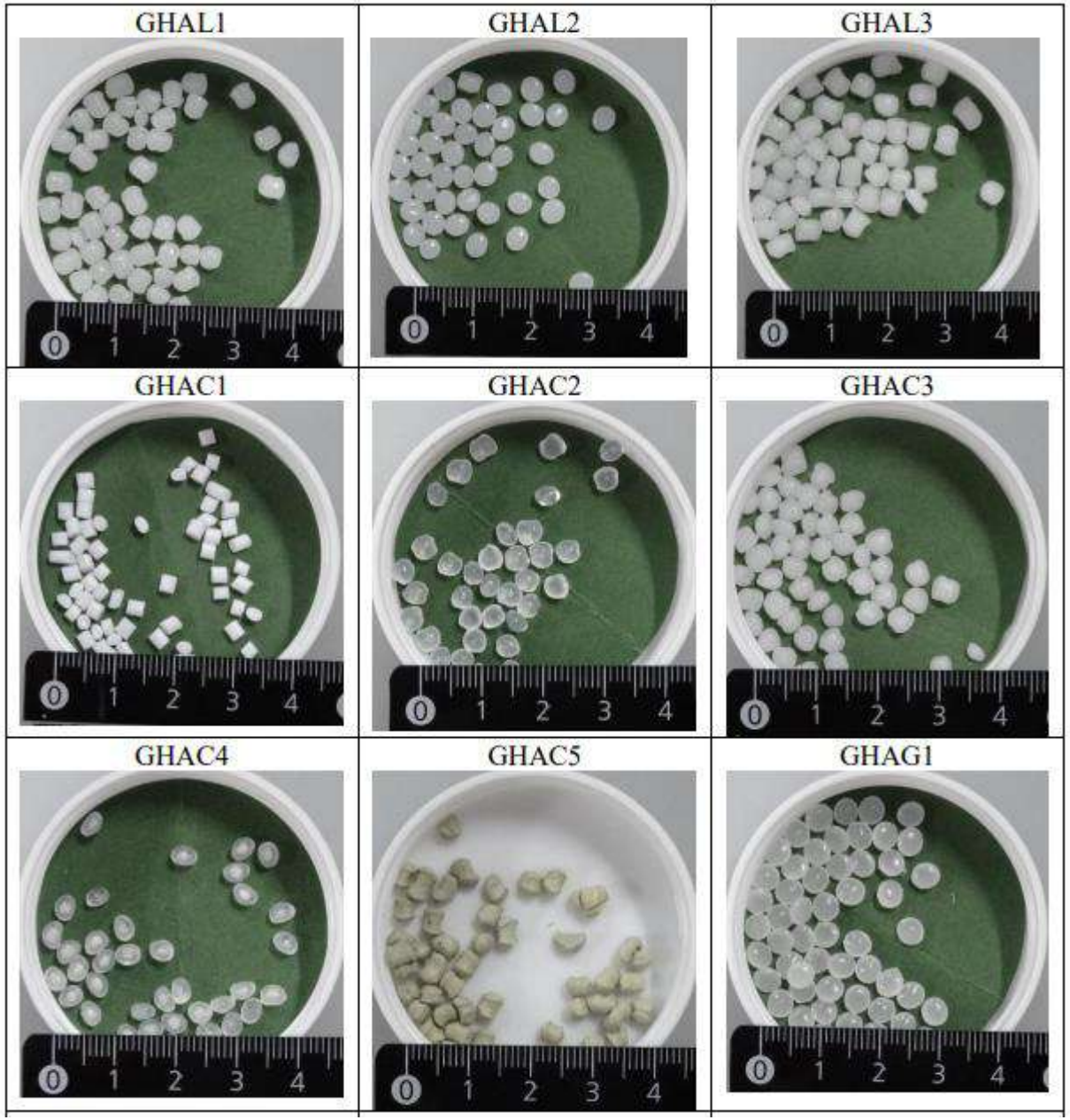
Imported pellets likely from recycled plastics

Collected Samples (Nigeria)

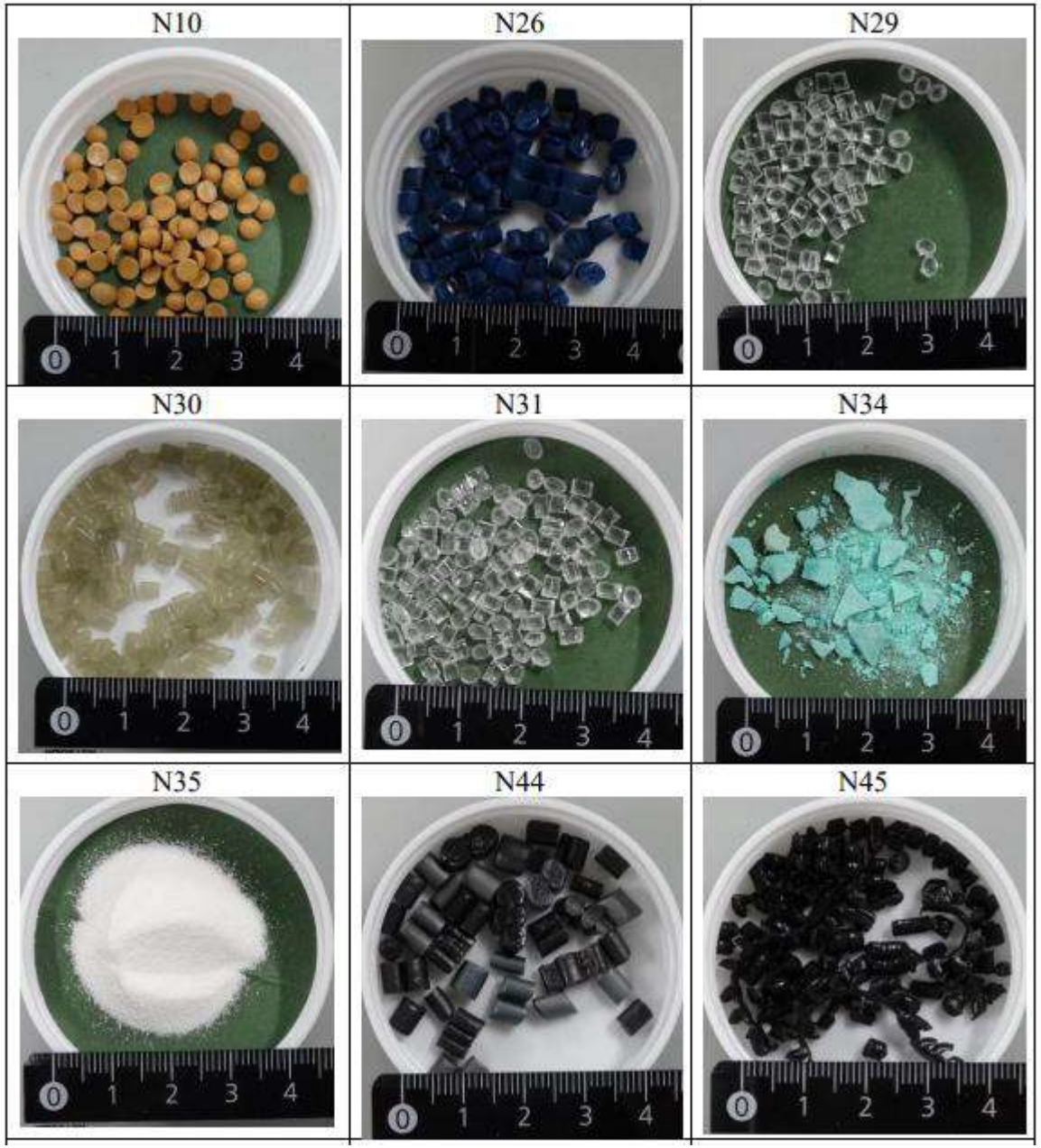
Polymer Type	Total Number	Number of Pellet	Number of Shred	Number of Virgin
Low Density Polyethylene (LDPE)	12	2	6	4
High Density Polyethylene (HDPE)	58	12	42	4
Polyvinyl Chloride (PVC)	10	0	9	1
Polypropylene (PP)	11	1	4	6
Acrylonitrile Butadiene Styrene (ABS)	4	1	3	0
General Purpose Polystyrene (GPPS)	2	2	0	0
Polyethylene Terephthalate (PET)	14	0	12	2
High-impact polystyrene (HIPS)	4	2	2	0
	115	20	78	17

Samples were sent to laboratories in the Netherlands, Germany, Spain and Japan

Samples from Ghana



Samples from Nigeria



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Phone : +234- (0)813- 8060935

Monitoring of PFASs in recycled plastic pellets

Marinella Farré

Casablanca 2023

Outline

1

Presentation

3

PFASs in recycled plastic pellets

2

Legacy and emerging PFASs, multiple exposure sources

4

Conclussions and take-home message

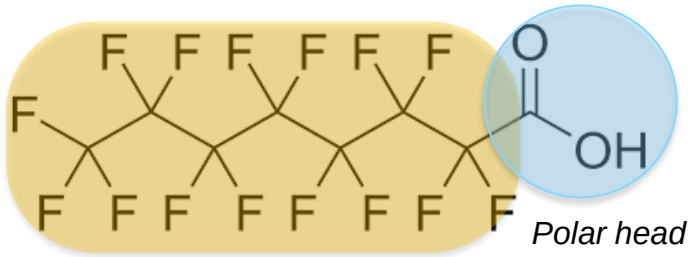
Introduction- Contaminants of emerging concern (CECs)

- **CECs** are chemicals that are currently not regulated, but may be under scrutiny for future regulation.
- **CECs** may pose adverse effects on the environment and human health.
- **CECs** are not necessarily newly developed chemicals: most of them are substances or materials that have entered the environment for years, but their presence has only recently begun to be investigated.

Per- and polyfluoroalkyl substances (PFASs)

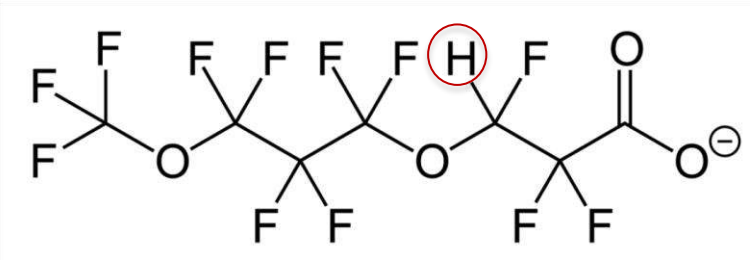
PFASs are large group of anthropogenic chemicals extensively used in industrial and consumer applications since the 1950s

Perfluorinated = fully fluorinated



e.g., PFOA

Polyfluorinated = partially fluorinated

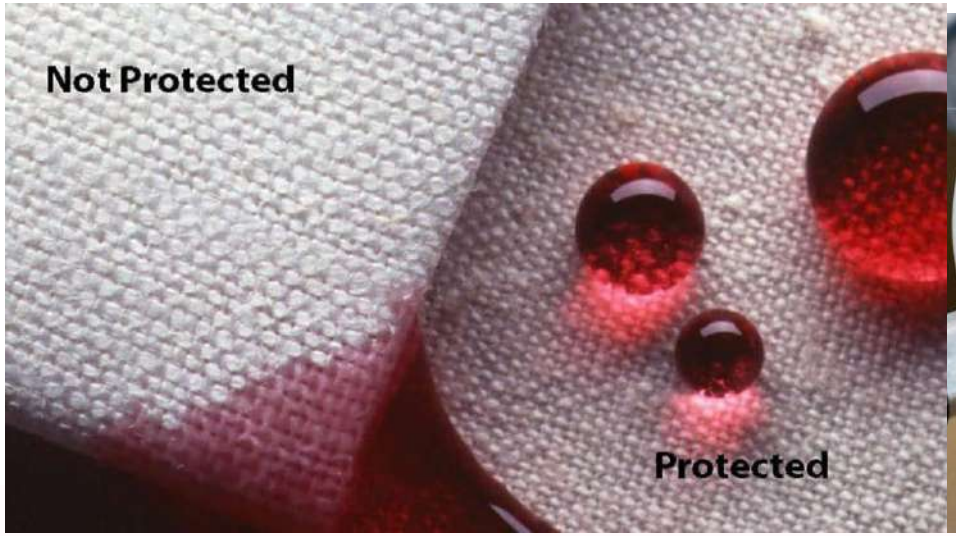


e.g., ADONA

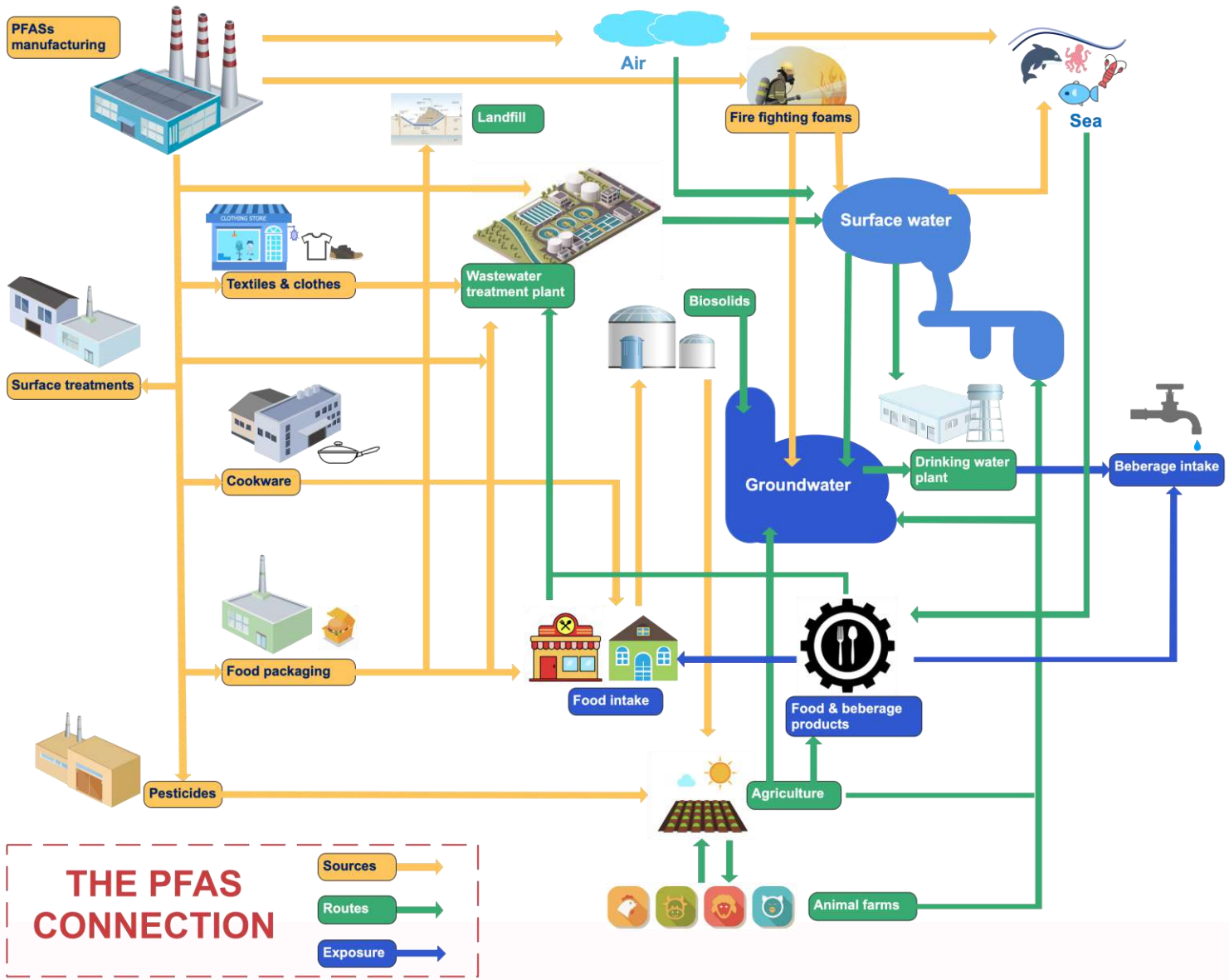
Very stable (C-F bond energy 485 kJ/mol)

- Thermally stable (in excess of 150 ºC)
- Resists degradation (acid, alkali, oxidizing agents, bio…)
- Hydrophobic and oleophobic (3 phases in Kow)
- Good surfactants, lubricants
- Non-flammable
- Chemically inert

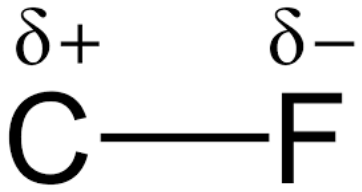
Per- and polyfluoroalkyl substances (PFASs)



PER- AND POLYFLUOROALKYL SUBSTANCES (PFASs)

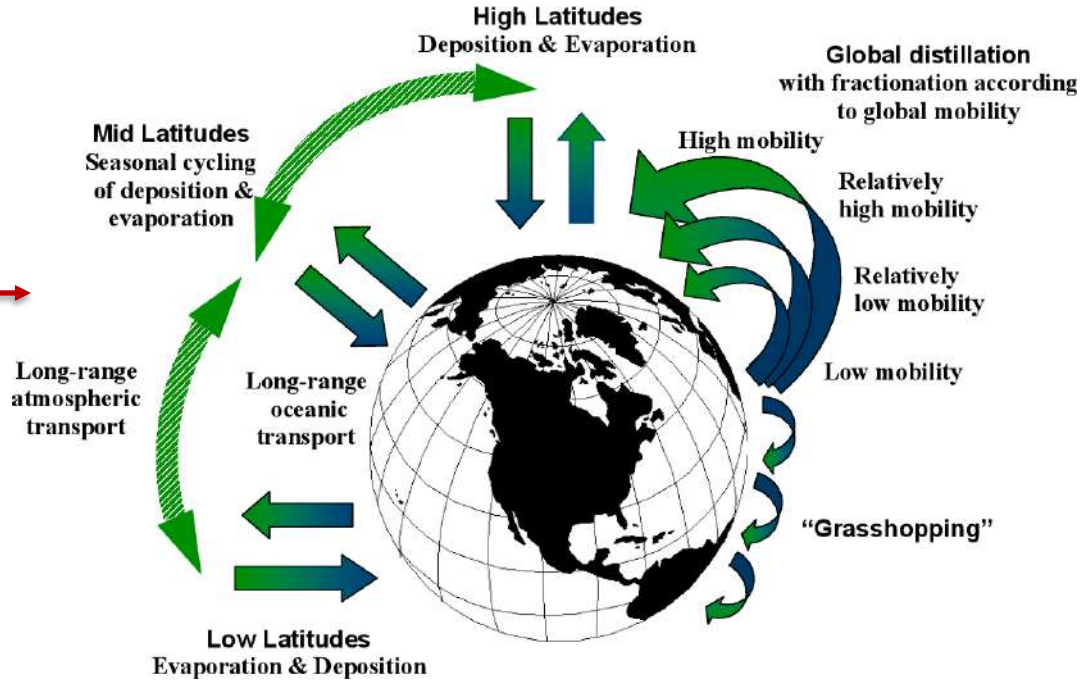


Per- and polyfluoroalkyl substances (PFASs)

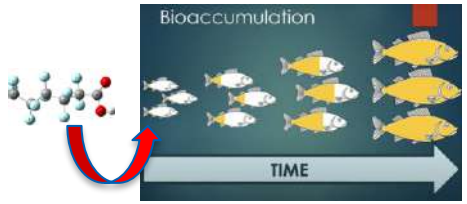


Highly persistent compounds

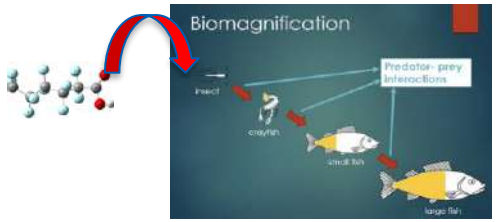
Long-range environmental transport



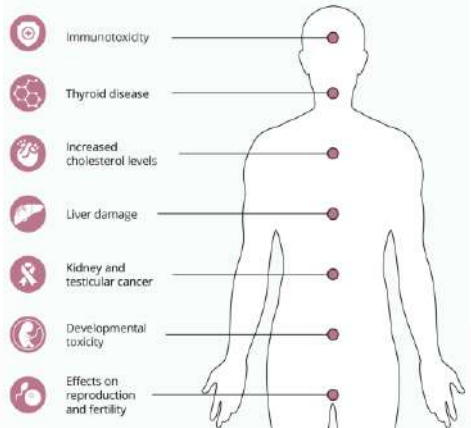
Bioaccumulated



Biomagnified



Toxic



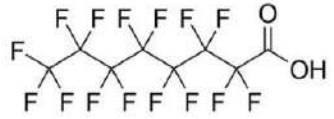
- Harm immune system
- Harm the reproductive system
- Increase the risk of cancer

Forever Chemicals

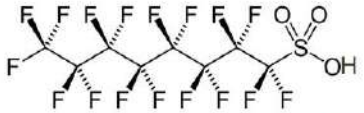
Per- and polyfluoroalkyl substances (PFASs)

4700 chemicals on the market

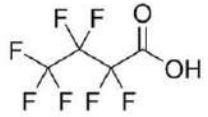
Where it began…



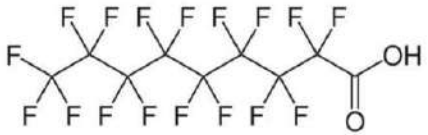
Perfluorooctanoic Acid
(PFOA)
≈ "Teflon®"



Perfluorooctanesulfonic Acid
(PFOS)
≈ "Scotchguard®"

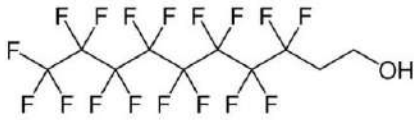


Perfluorobutanoic Acid
(PFBA)

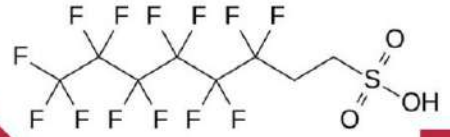


Perfluorononanoic Acid
(PFNA)

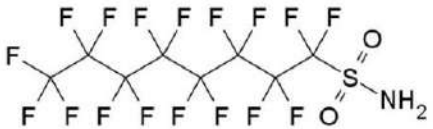
Precursors



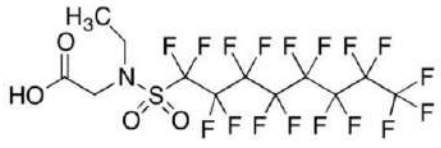
8:2 Fluorotelomer Alcohol
(8:2 FTOH)



6:2 Fluorotelomersulfonic Acid
(6:2 FTS)

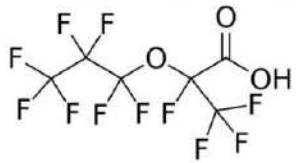


Perfluorooctanesulfonamide
(PFOSA)

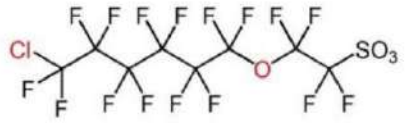


N-Ethylperfluorooctanesulfonamidoacetic Acid
(EtFOSAA)

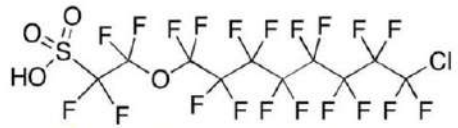
Replacements



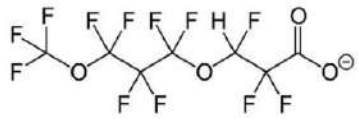
2,3,3,3-Tetrafluoro-2-
(heptafluoropropoxy)propanoic acid
(GenX)



9-Chlorohexadecafluoro-3-oxanonane-1-sulfonate
(F53B major)



11-Chlororeicosafluoro-3-oxaundecane-1-sulfonic Acid
(F53B minor)



Dodecafluoro-3H-4,8-dioxanoate
(ADONA)

5000+
Compounds

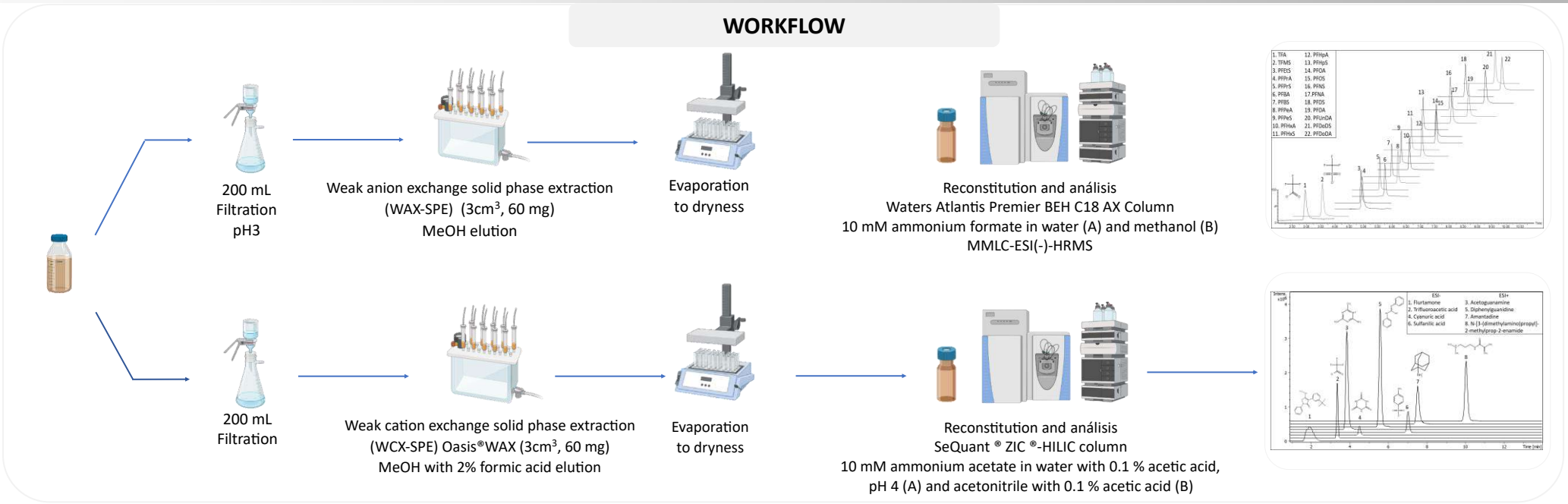
THE DARK
SIDE

5000+ compound

60 Standards

2-20 Under regulation

Emerging PFASs



Column: MMLC column Atlantis™ Premier BEH C18 AX column (2.1 mm id, 100 mm length, 2.5 µm particle size) based on reversed-phase LC combined with anionic exchange chromatography

Mobile phase:

A) MeOH (10 mM $AcNH_4$)

B) H_2O (10 mM $AcNH_4$)

Flow rate *0.3 mL/min*

Ionization*: ESI (-/+)*

The gradient of the mobile phase started with an initial B concentration of 5 % for 1 min.

This was then increased to 45 % over 4 min and then increased to 95 % over 4 min and held for 3 min and finally re-conditioned at 5 % for 3 min .

The plastic era

Advantages:

- Plastic saves lives. Plastic has revolutionized the health industry and facilitates drinking water.
- Plastic reduces gas emissions and saves on fuel.
- Plastic is sustainable and long-lasting.
- Plastic improves safety.
- Plastic is affordable.
- Plastic is reusable.

THE PROBLEM

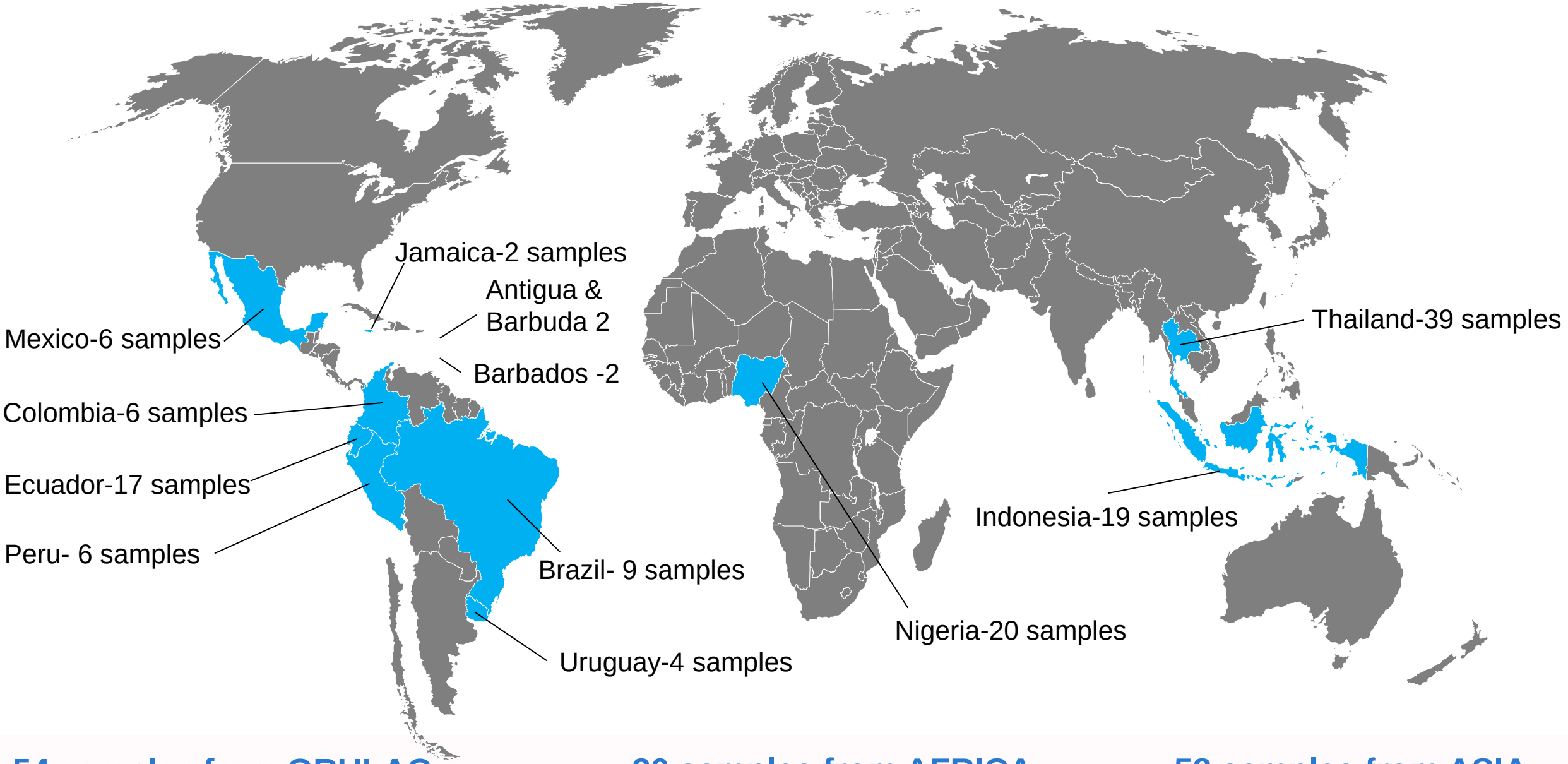
THE SOLUTIONS

The solution

Study of PFASs adsorbed onto MNPLs for recycling

Study of PFASs adsorbed onto MNPLs for recycling

132 SAMPLES



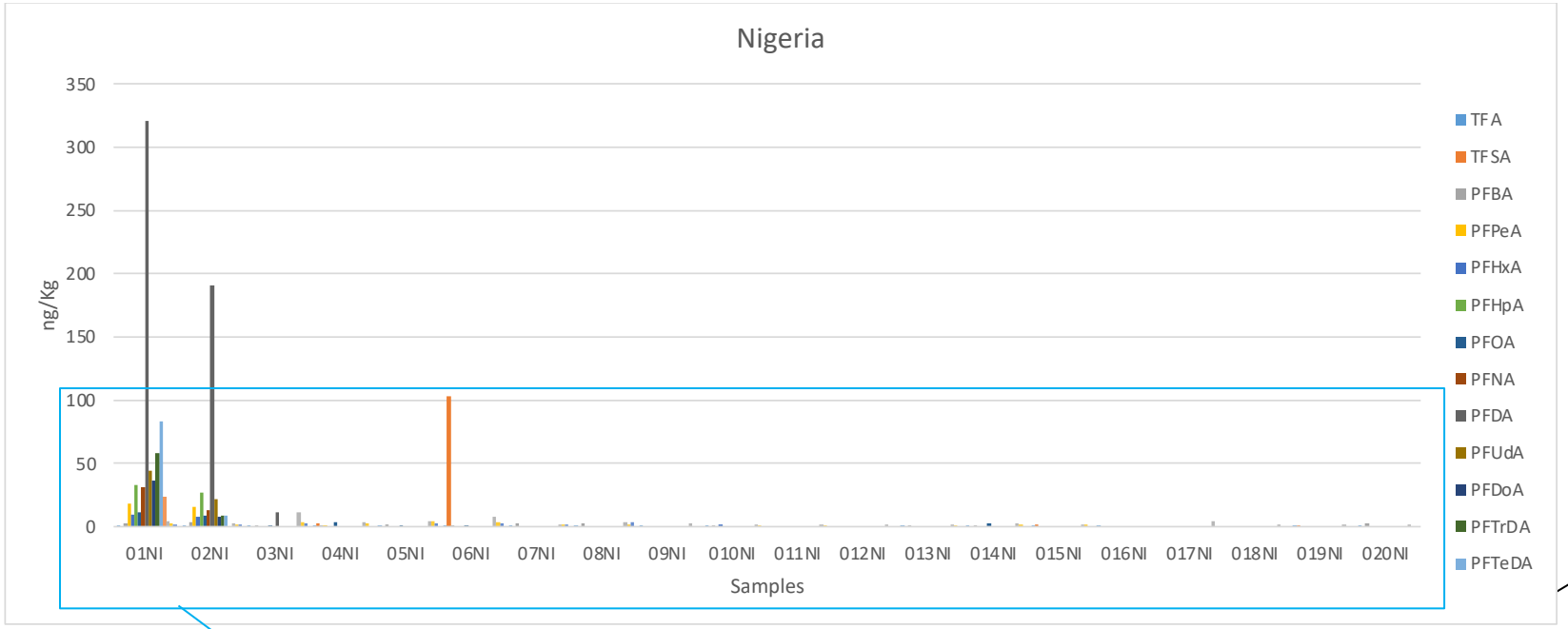
54 samples from GRULAC

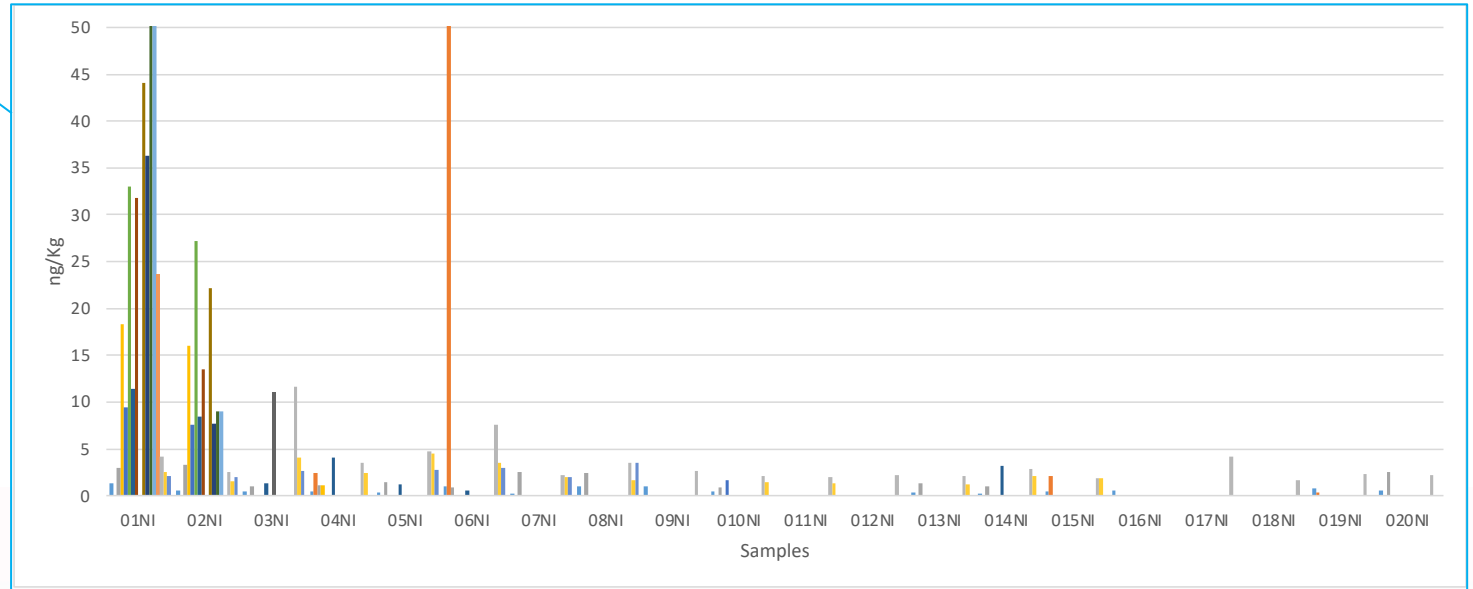
20 samples from AFRICA

58 samples from ASIA

Study of PFASs adsorbed onto MNPLs for recycling

3-363 ng/Kg
20 samples, 2 of them with high concentrations and high diversity of compounds
PFBS in 19 samples (95%)
PFHxS in 13 samples (65%)

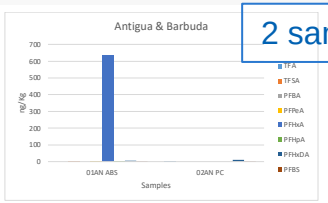




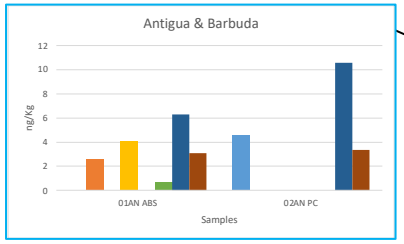
Nigeria-20 samples

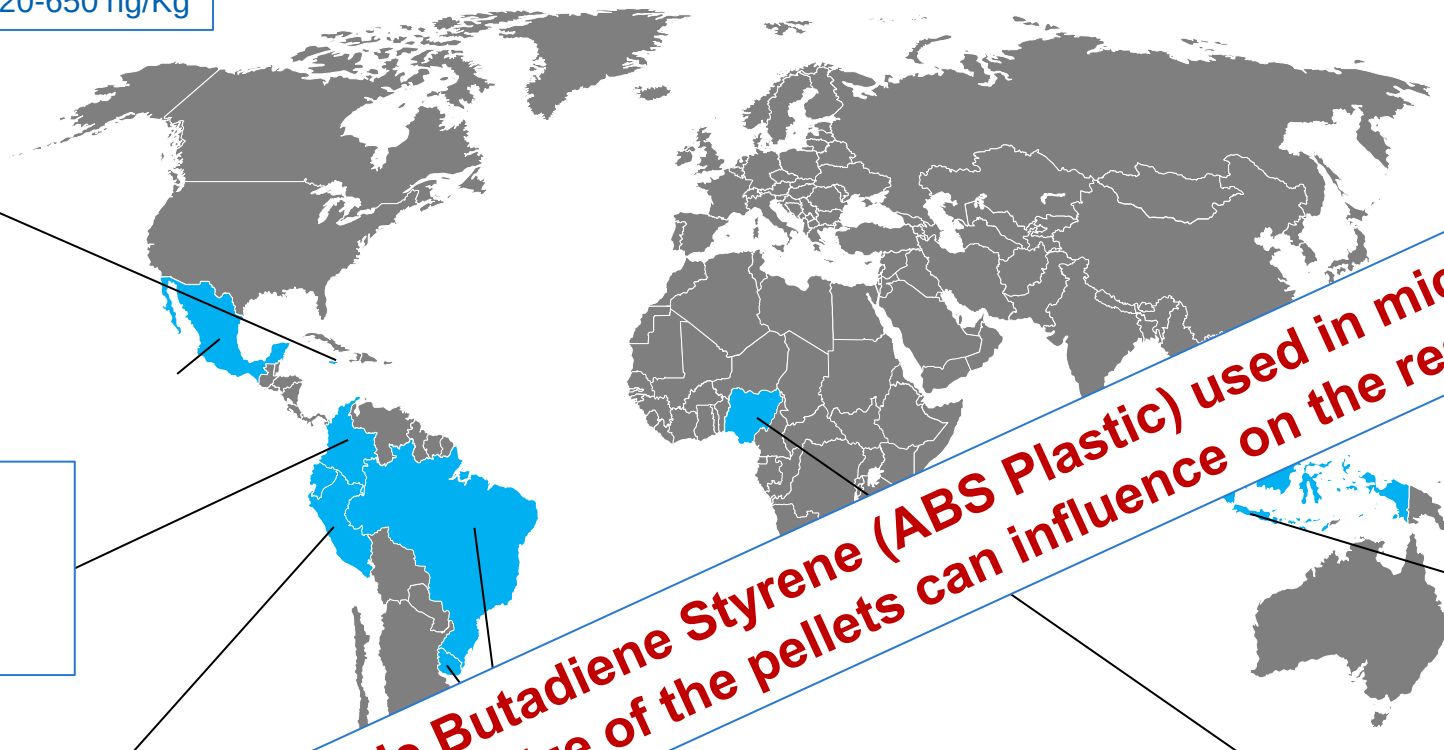
100% of the samples analysed

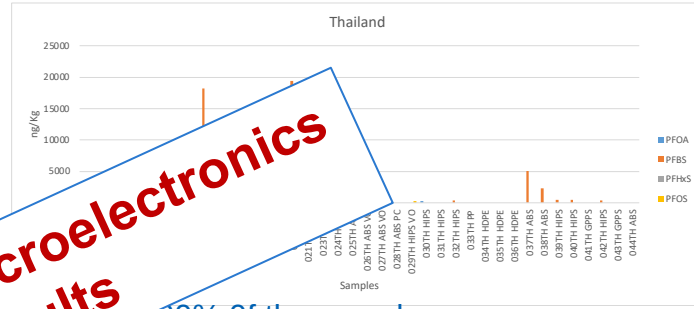
Study of PFASs adsorbed onto MNPLs for recycling



2 samples 20-650 ng/Kg



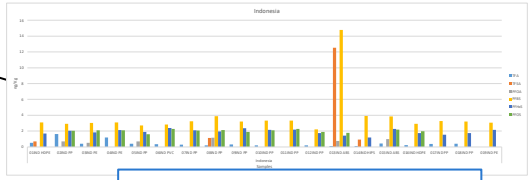




…n 60% 0f the samples
…FBS the most detected compound (46%)
and also the one at higher
concentrationsreaching a máximum value of
about 5 πg/Kg

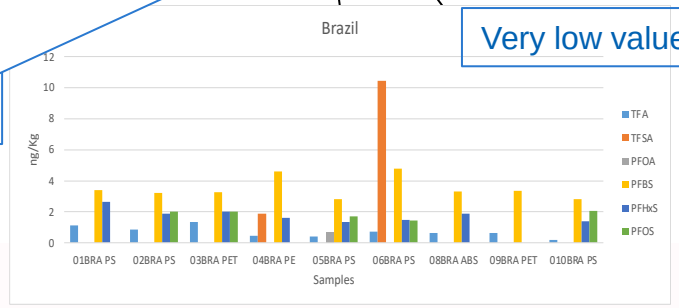
6 samples 4-2326 ng/Kg
Mean 631 ng/kg
Median vale 386 ng/Kg
TFSA>PFBS
PFOS 2-11 ng/Kg

Acrylonitrile Butadiene Styrene (ABS Plastic) used in microelectronics
The size of the pellets can influence on the results



5-32 ng/Kg
19 samples
PFBS and PFHxS the more frequent compound
And TFSA the one at higher concentration but reaching only 12 ng/Kg

6 samples 15-684 ng/Kg
PFBS and PFHxS 100 % of sample
PFBS>PFHxS
PFOS and PFOA in 4/6 samples



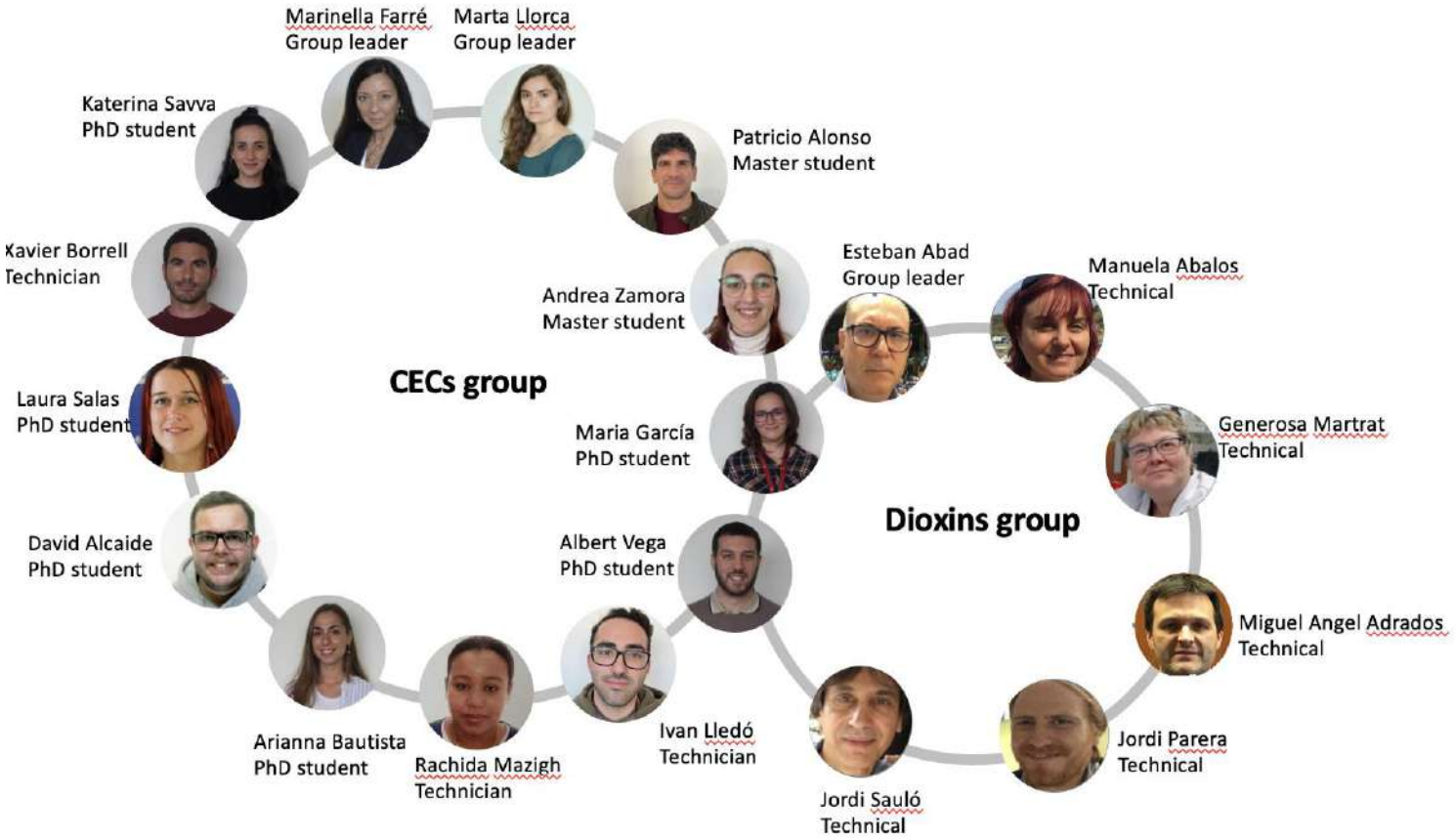
Very low values

3-363 ng/Kg
20 samples, 2 of them with high concentrations and high diversity of compounds
PFBS in 19 samples (95%)
PFHxS in 13 samples (65%)

Current and future trends

1. ABS pellets presented in general higher concentrations
2. The different sources cannot be compared because the size of pellets were different
3. Shorter chain PFASs were those more frequently present, AS EXPECTED
4. Extend the study to other PFASs maybe should be also considered
5. The study should be extended to bulk materials
6. Different plastic sources should be considered in separate for future studies

Acknowledgements



Thank you very much for your attention

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