Chemical migration and PET food packaging: Implications for circularity

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Why focus on PET?

- **Application:** the most widely used type of plastic in beverage bottles
- **Characteristics:** short shelf life (around 6 months) and single-use nature
- **Socioeconomic and cultural factors:** on-the-go consumption and poor or absent waste management infrastructure at the regional level
- One of the **most commonly found plastic litter items**
- The **highest value plastic for recycling** – can be **used in food-contact applications**

PET beverage bottle recycling

In 2019, 58% of PET bottles were collected and sorted for recycling across the UK and the EU – Regulatory changes will bring an increase in the amount of PET bottle waste that is recycled.

- Directive on single-use plastics (2019/904): PET bottles shall contain at least 25% of recycled content by 2025
- Directive on Packaging and Packaging Waste (2018/852): 55% of all plastic packaging should be recycled by 2030
- EU Packaging Levy: in 2021, a tax on non-recycled plastic packaging has been introduced

BUT – are we prepared to use and/or maximise recycled content in food contact materials? Do we know enough about the quality of rPET?

Reality check

The increased use of rPET in food contact materials (FCMs) could be introducing a safety challenge that requires attention.

- European Regulation (EC) No 1935/2004: general requirements on FCMs and food contact articles at the stage of manufacturing and processing
- **Commission Regulation (EU) 2020/1245**: list of authorised substances, known as the Union list, that can be added to plastic packaging materials under stipulated usage conditions and Specific Migration Limits (SML)

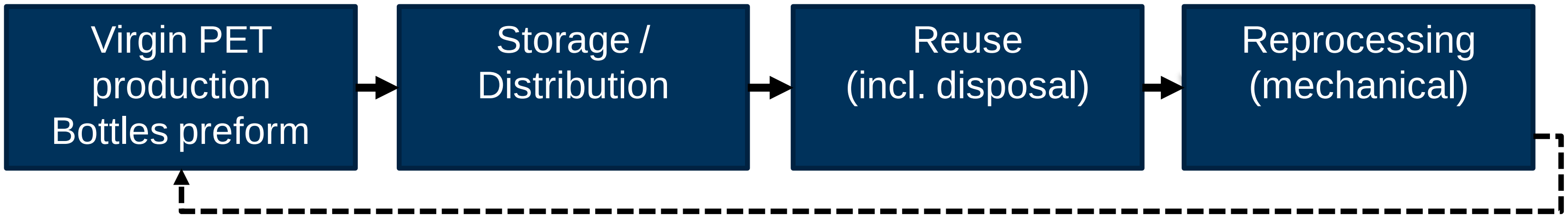
*authorised substances of the **Union List: OML = 60 mg/ kg**; for NIAS classified as not CMR: threshold limit = 10 µg/ kg; and for potentially genotoxic NIAS (or unknown contaminants): threshold limit = 0.017 µg/ kg (EFSA)*

- Commission Regulation (EU) No 282/2008: authorisation of recycled plastic FCMs introducing quality assurance requirements for recycling processes (under revision)

Unpacking the evidence

28 June 2022

Exploration and a better understanding of the FCCs migrating from PET and rPET beverages across all stages of a PET drink bottle's lifecycle could provide insights into the potential quality of the rPET.



PET beverage bottles lifecycle stages

Two strands of focus:

- Food contact chemicals (FCCs) found in PET and/or rPET that have exceeded the current SML under specific test conditions at least once, and those that have been most frequently analysed
- The influential factors, practices, and conditions on the presence of IAS and NIAS across all stages of the lifecycle of PET beverage bottles

Systematic evidence mapping

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Literature search
15915 records

Title & abstract screening
2783 records

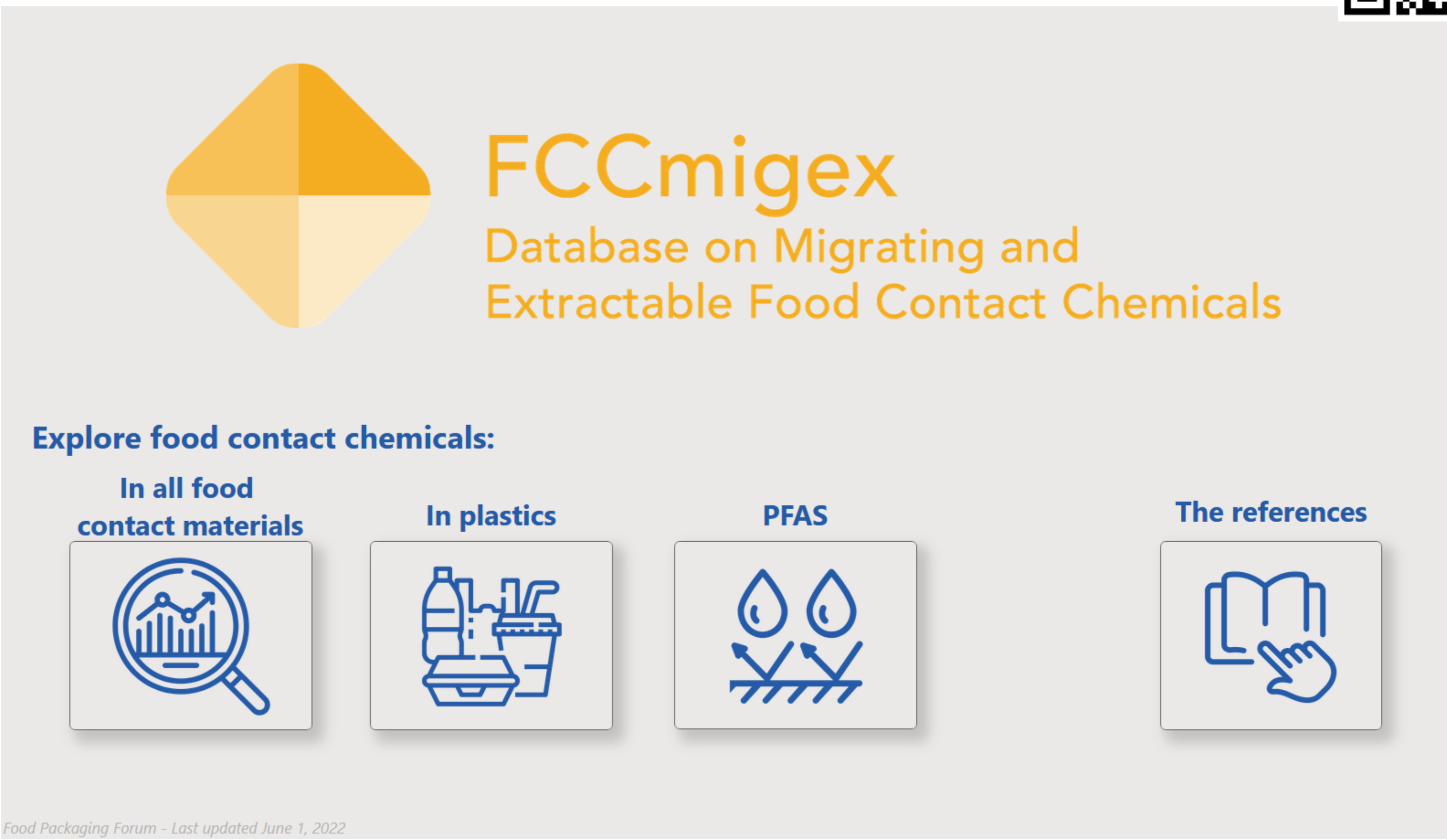
Full-text screening
1210 records

Data extraction

Post-processing

22,522 database entries

2881 FCCs were detected in the extracts/migrates of FCMs/FCAs



Foodpackagingforum.org/fccmigex

Known and unknown FCCs

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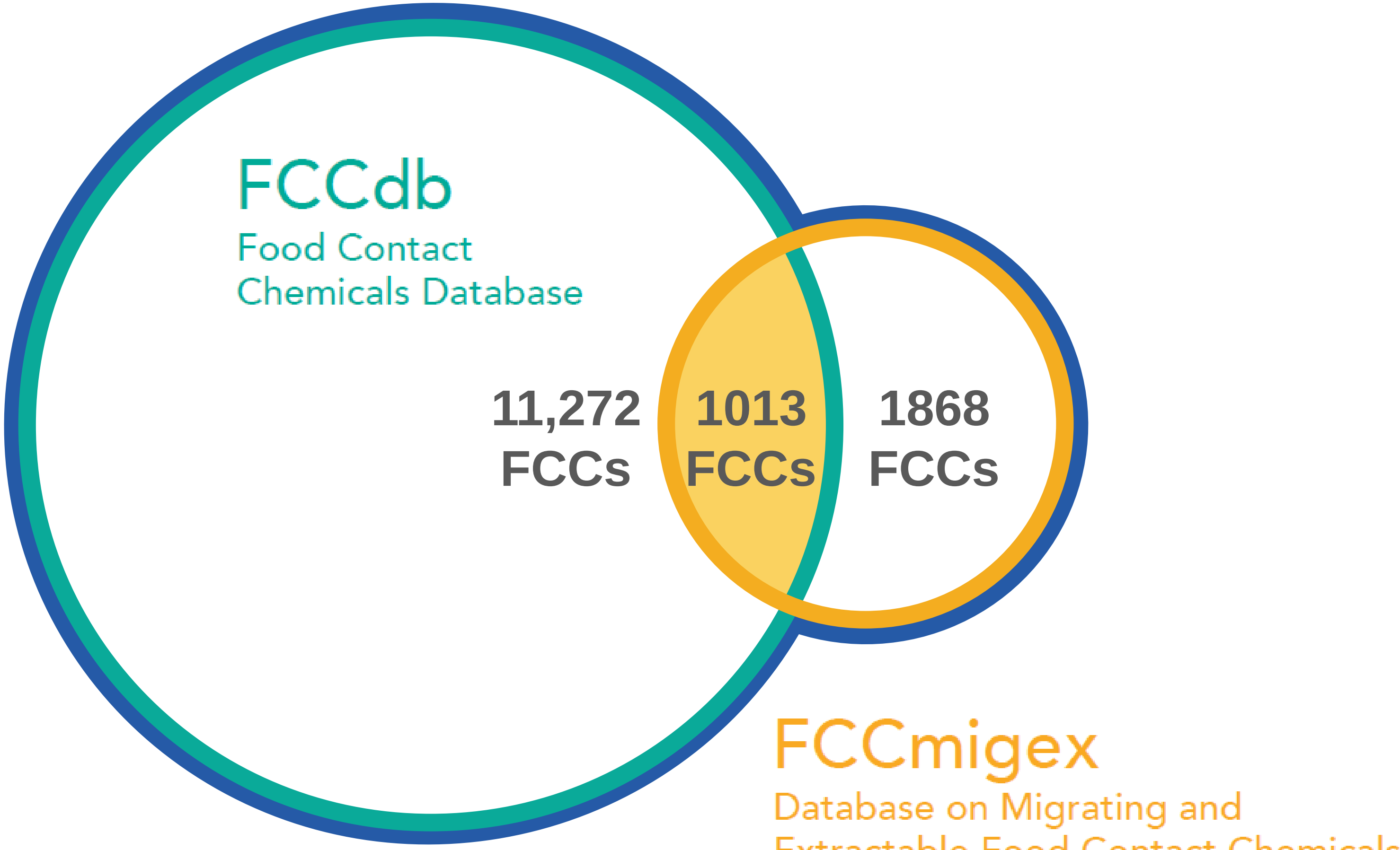
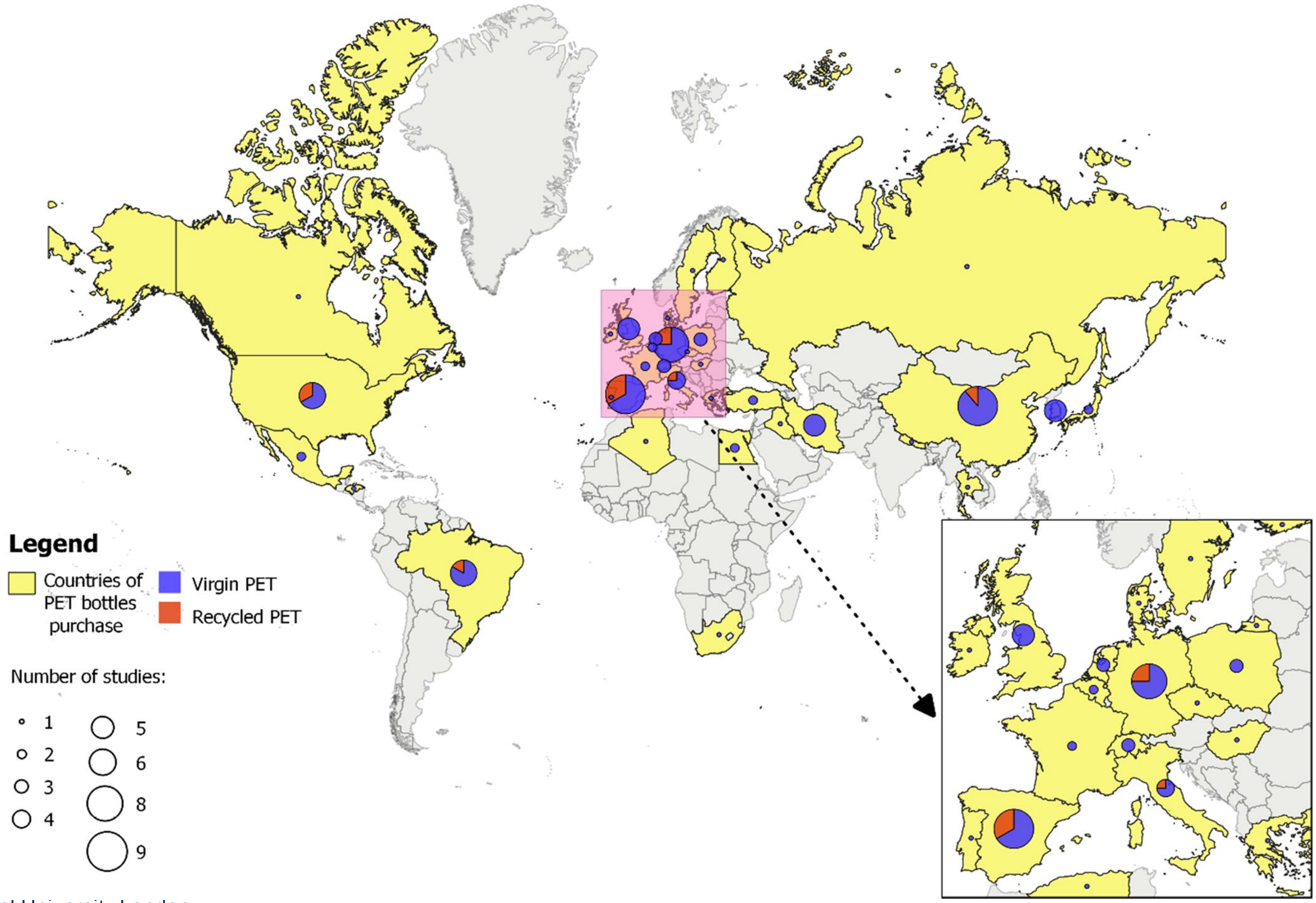


Distribution of studies and focus

Migration experiments were conducted around the globe, including both virgin and recycled PET samples from beverage bottles



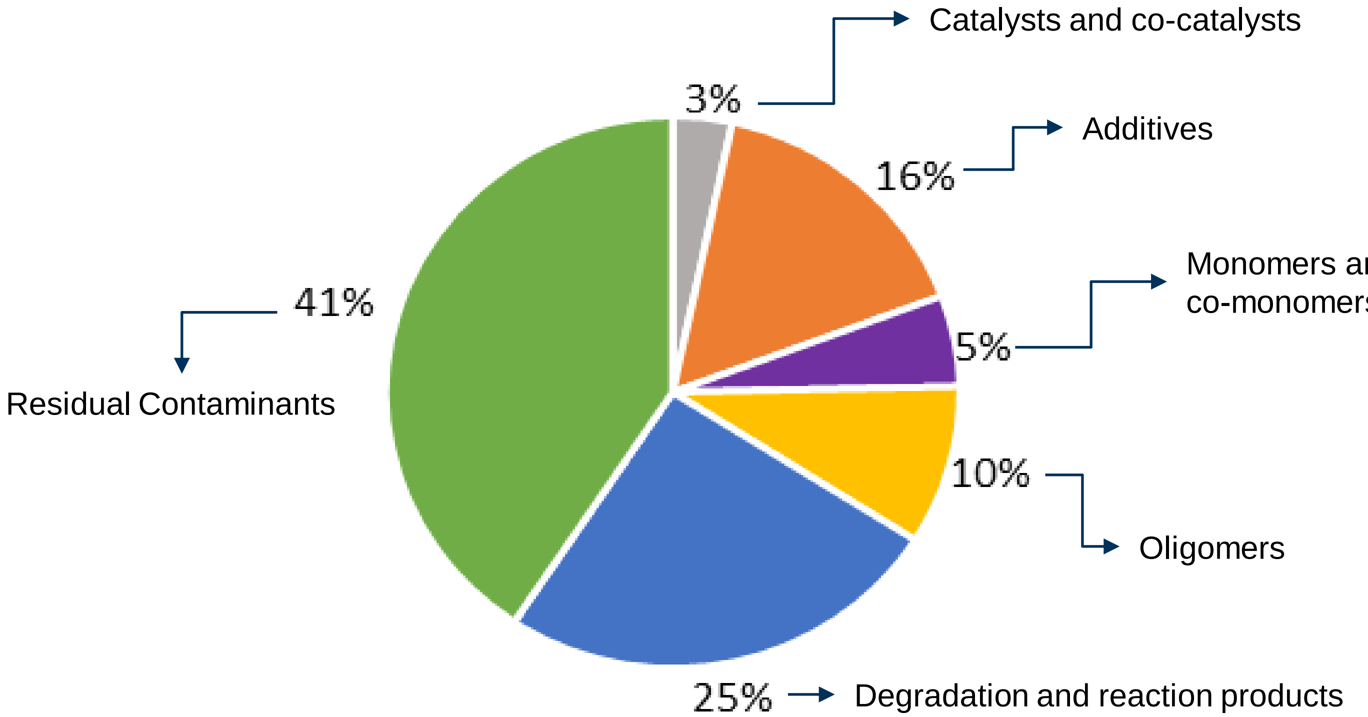
Food contact chemicals (FCCs)

Six types of FCCs were found to be migrating from PET drink bottles into food simulant/food samples.

- Catalysts and co-catalysts
- Monomers and co-monomers
- Degradation and reaction products
- Additives
- Oligomers
- Residual contaminants

Food contact chemicals (FCCs)

Proportional distribution of specific types of FCCs to the total number of FCCs that have been detected to migrate from PET drink bottles into food simulant/food samples.



FCCs migration: Analysis and Detection

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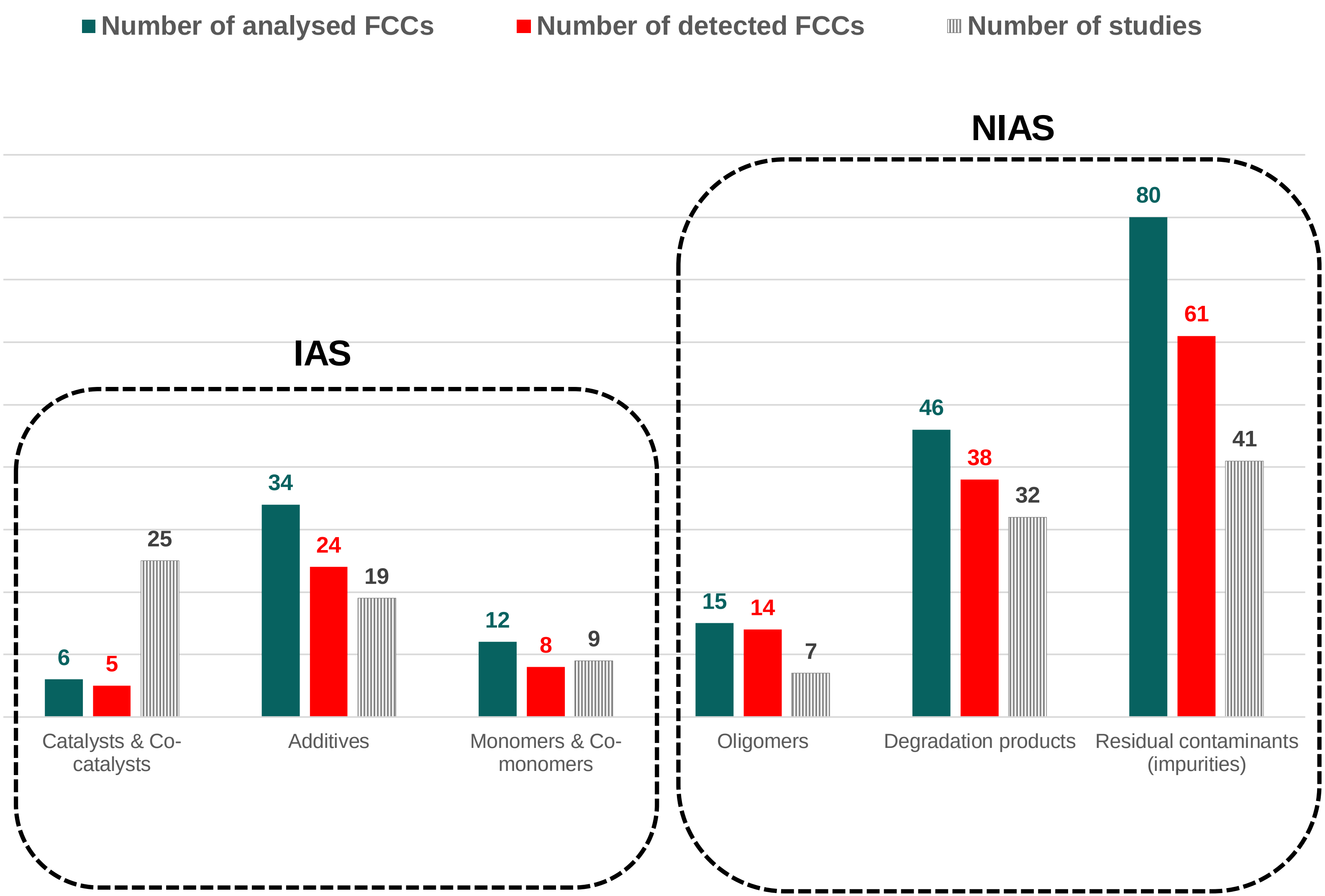

Inclusion of measured FCCs in two databases

Total number of FCCs measured and detected in migration experiments of PET bottles and the number (of them) included in FCCdb and CPPdb and with specified relation to PET

	Evidence map	FCCdb[1]		CPPdb[2]	
		Included	Related to PET	Included	Related to PET
Number of analysed FCCs in PET bottles	193	131	13	133	33 (55% considered as NIAS in PET)
Number of detected FCCs in PET bottles	150	102	8	106	29 (59% considered as NIAS in PET)

[1](FPF, 2021); [2](Groh et al., 2019)

FCCs exceeded regulatory limits

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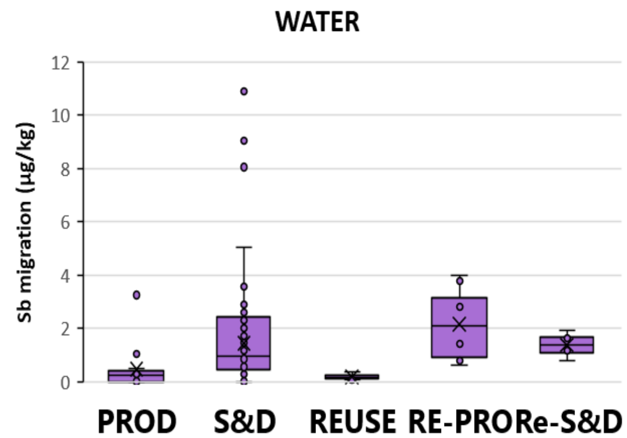
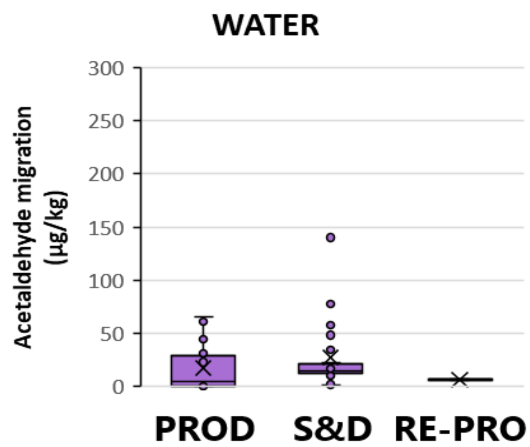
FCC type	Virgin PET production	Storage / Distribution	Reuse (incl. disposal)	Reprocessing (mechanical)
Residual contaminants	Diethyl phthalate (DEP) (Egypt and Korea) Di-n-octyl phthalate (DnOP) (Egypt and Italy)	Diethyl phthalate (DEP) (Egypt and Korea) Di-n-octyl phthalate (DnOP) (Egypt and Italy) Dimethyl phthalate (DMP) (Thailand, Korea, Egypt)		Nickel (Ni) (Brazil)
Oligomers	Cyclic and acyclic oligomers			
Degradation products	4-Aminobiphenyl (China) Acetatelhyde (Turkey and the Netherlands)	Acetatelhyde (Turkey and the Netherlands)		
Additives	Tinuvin 328 (China)	Quinophthalone (SY 114) (China)		2-aminobenzamide (UK and Germany)
	Anthraquinone (SB 104) (Europe)	2-aminobenzamide (UK and Germany)		
	Quinophthalone (SY 114) (China)	Butylated hydroxytoluene (BHT) (Brussels)		

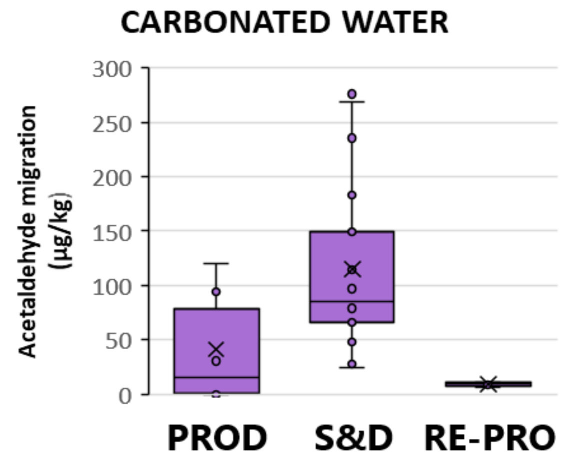
FCCs getting increased attention

- **Antimony: IAS used as catalyst**



- **Acetaldehyde: NIAS found thermal degradation by-products at the stage of preform production**





- **Endocrine-disrupting chemicals (EDCs): NIAS found as residual contaminants mostly DEHP (89.6% frequency of detection) followed by DBP (93.3%), DMP (43.9%), DEP (52.9%) and BPA (52.9%)**

Unpacking the evidence

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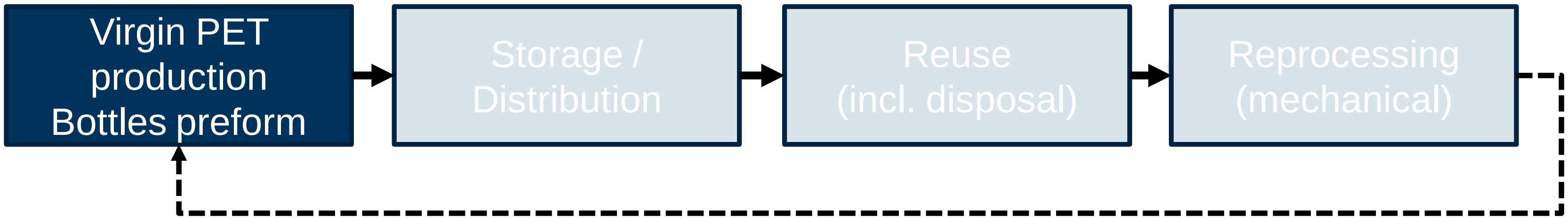


PET beverage bottles lifecycle stages

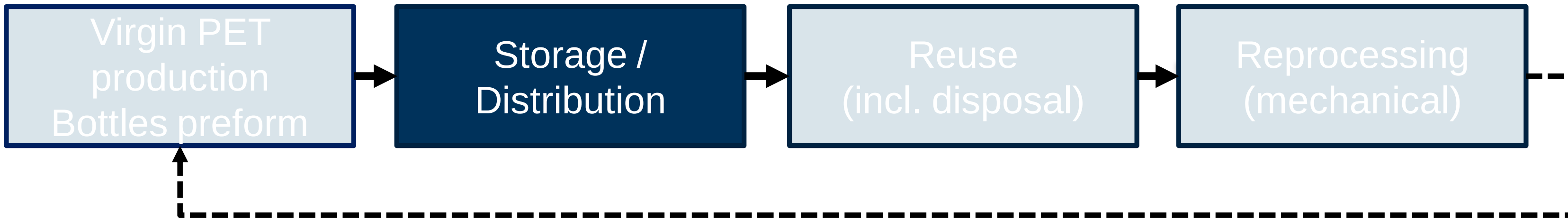
- ❑ Catalysts & co-catalysts
- ❑ Monomers & co-monomers
- ❑ Additives
- ❑ Oligomers
- ❑ Degradation products
- ❑ Residual contaminants

Research attention / number of studies:

0: None	11-15: Moderate
1-5: Very limited	16-20: High
6-10: Limited	>20: Very high

- **Place of production**: differences in quality assurance of (re-)processing, physical properties, trading, and manufacturing process (polymerisation and thermal degradation)
- **Bottle capacity** (Surface area: volume): higher FCCs migration in small bottles
- **Wall thickness**: positive correlation with FCCs migration
- **Colour** (controversial): potentially higher migration in coloured bottles

Unpacking the evidence



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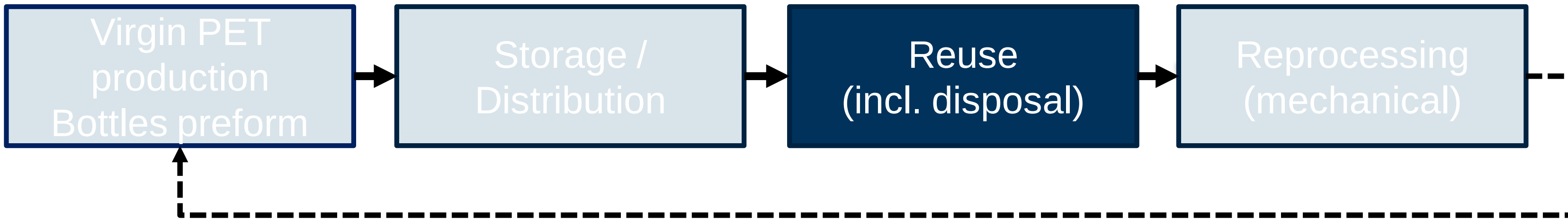
- **Storage temperature**
- **Storage time**
- **UV exposure**

- Positive correlation with FCCs migration;
- Extent of influence depends on FCC;
- Extreme storage conditions should be avoided

Unpacking the evidence



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- **Frequency of reuse:** could be more influential than storage conditions
- **Extent of misuse by consumers:** filling bottles with highly acidic or fatty foodstuff under uncontrolled storage conditions – can be even more influential than frequency of reuse

Unpacking the evidence

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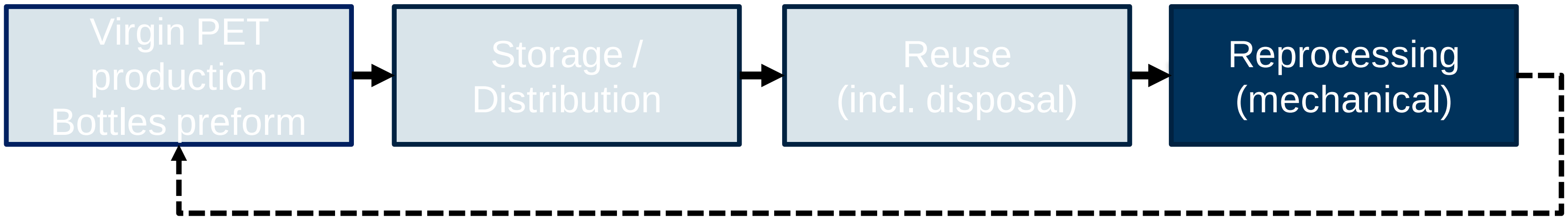

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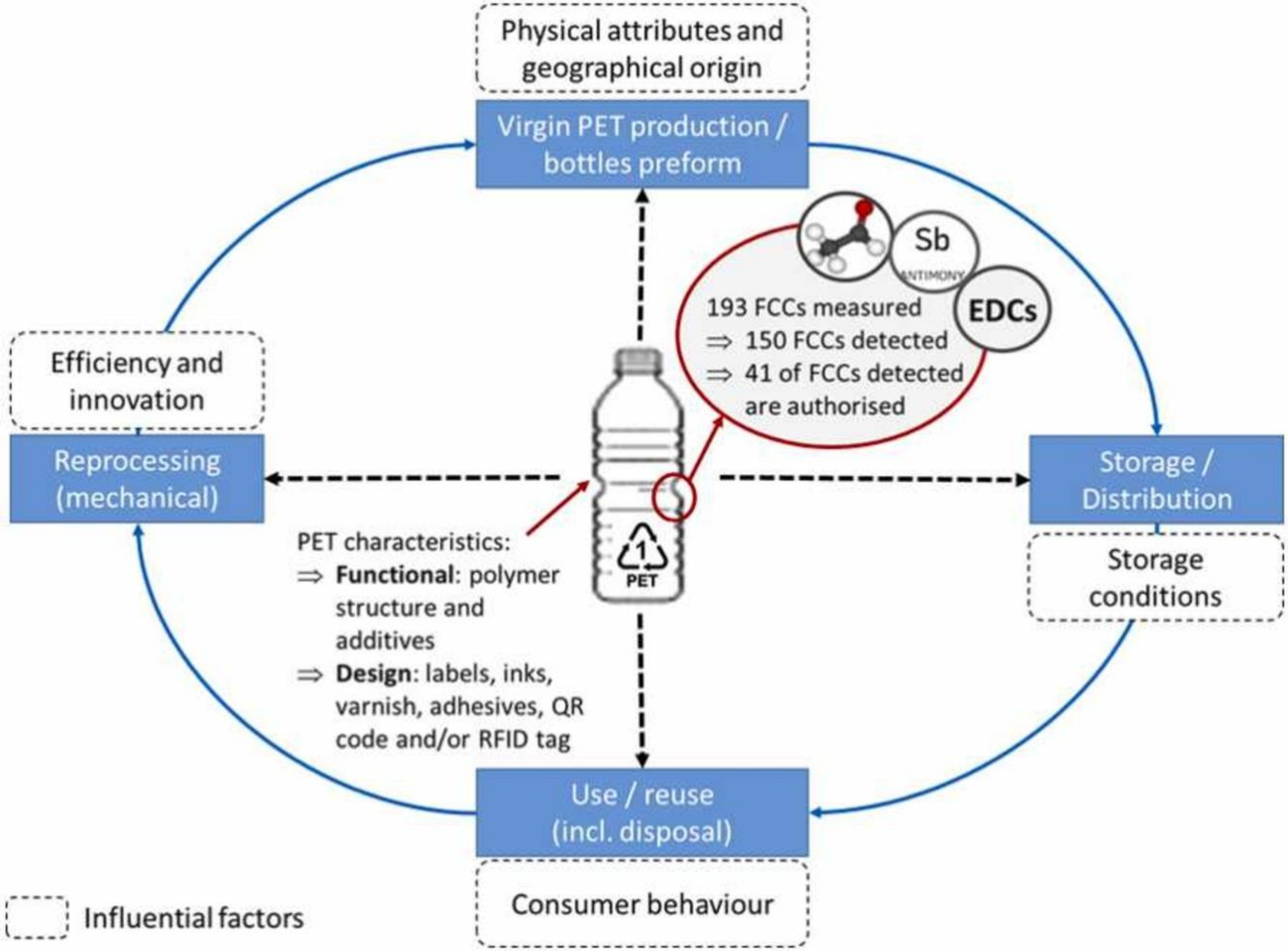
- **Cross-contamination:** by collection system (e.g., kerbside collection vs DRS), waste stream (e.g., non-food PET), design components (e.g., inks and adhesives)
- **Cleaning process:** e.g., conventional vs super cleaning
- **Thermal degradation:** formation of degradation products and oligomers

Key findings in a glance



Conclusions

- The safety and quality implications arising from reprocessing of PET bottles are underexplored.

- The FCCs found to be migrating from PET bottles originate from several geographical regions and time periods and can be linked to the lack of official guidance on risk assessment of NIAS, safety and quality standards at the reprocessing stage and how these are implemented and monitored.

- Emphasis has been placed on chemicals of interest to the manufacturing industry (Sb, aldehydes, phthalates and BPA) hinting to the fact that there is a bias that might be influenced by the ‘politics’ of bottled drinks manufacturing.

Key actions

- Adoption of design-for-recycling and traceability principles at the production stage;
- Monitoring the presence of chemicals at the PET bottles production/filling stage;
- Controlling the storage conditions that bottled drinks are subjected to;
- Promoting consumer behaviour change;
- Improving the collection, sorting and reprocessing infrastructure of PET drink bottles and introducing a traceability mechanism;
- A compliance mechanism arising from a bilateral agreement on what constitutes good quality rPET between the industry and the regulator;
- Revising the chemical risk assessment approaches used as a basis for setting the current regulatory limits.

Transparency and improved communication among all stakeholders in the PET beverage bottles value chain is truly a key prerequisite.

REFERENCES

Gerassimidou et al (2022) J. Haz. Mat. 430: 128410 https://doi.org/10.1016/j.jhazmat.2022.128410