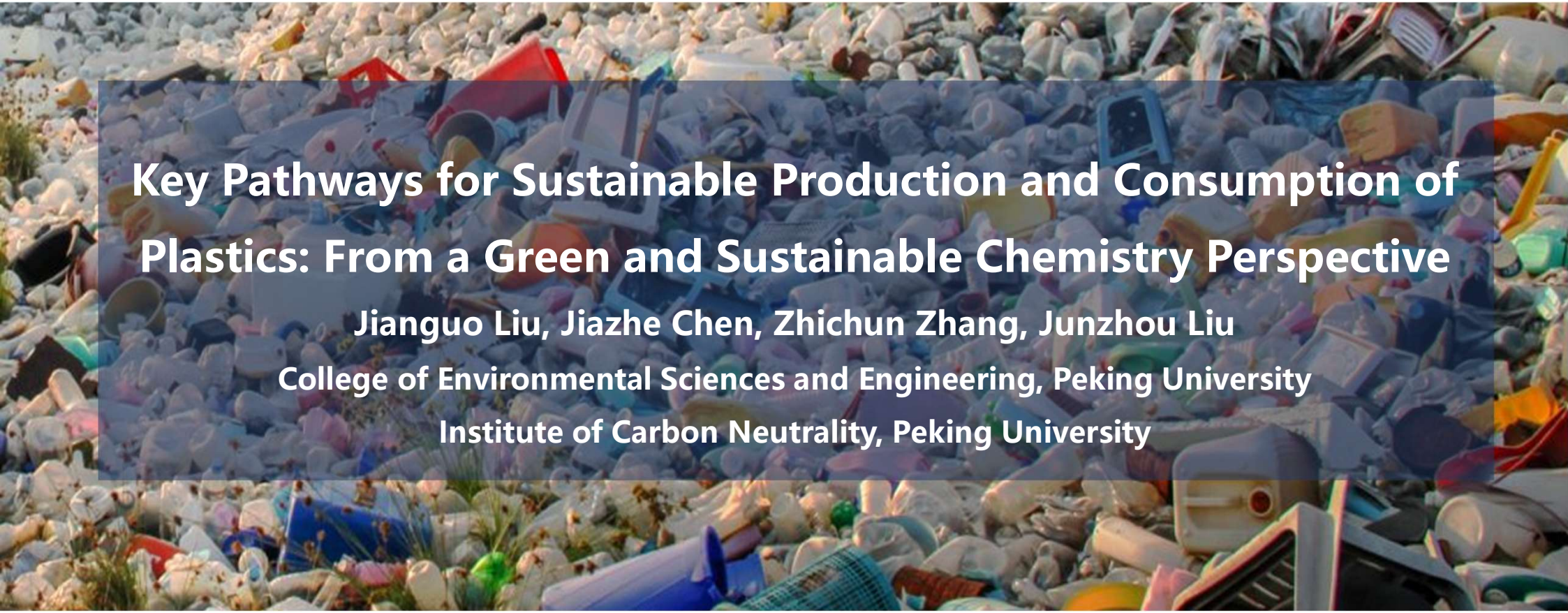

Key Pathways for Sustainable Production and Consumption of Plastics: From a Green and Sustainable Chemistry Perspective

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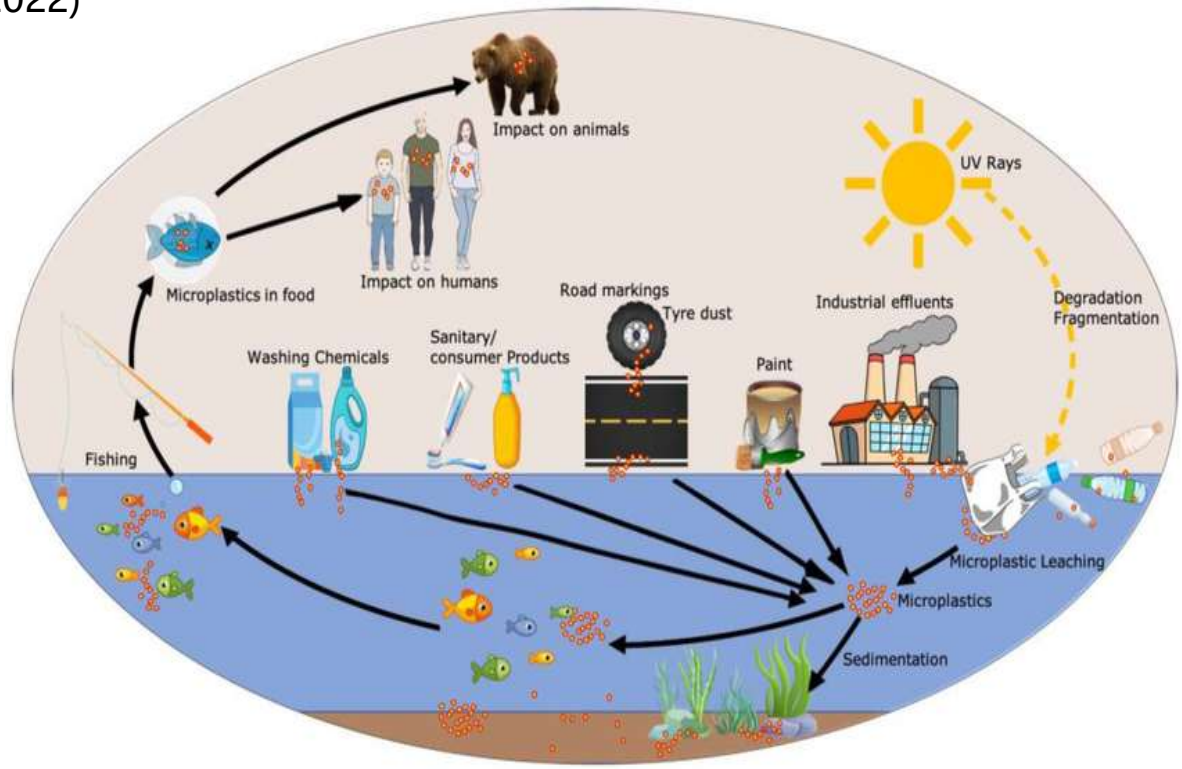
2026 China Petroleum & Chemical International Conference, 2026.10.28-31, Zhanjiang, Guangdong

Global plastic pollution: beyond the planetary boundary

Global plastics: ~460 Mt/y production, only ~9% recycled, ~22Mt/y leakage, ~1.7Mt/y flow into the ocean (OECD 2022)



(Image: Timur Matahari/AFP/Getty Images)



Sources and impacts of microplastics (Ghosh et al., 2023)

Global Plastics Treaty:

addresses the full life cycle of plastics to promote their sustainable production and consumption

Tough intergovernmental negotiations on the treaty:

Originally scheduled time for agreement, but delayed repeatedly

2022.03	2022.12	2023.05	2023.11	2024.04	2024.11-12	2025.08	2026.02	2027
Kenya	Uruguay	France	Kenya	Canada	South Korea	Switzerland	Switzerland	...?
UNEP-5.2	INC-1	INC-2	INC-3	INC-4	INC-5.1	INC-5.2	INC-5.3	INC-5.4

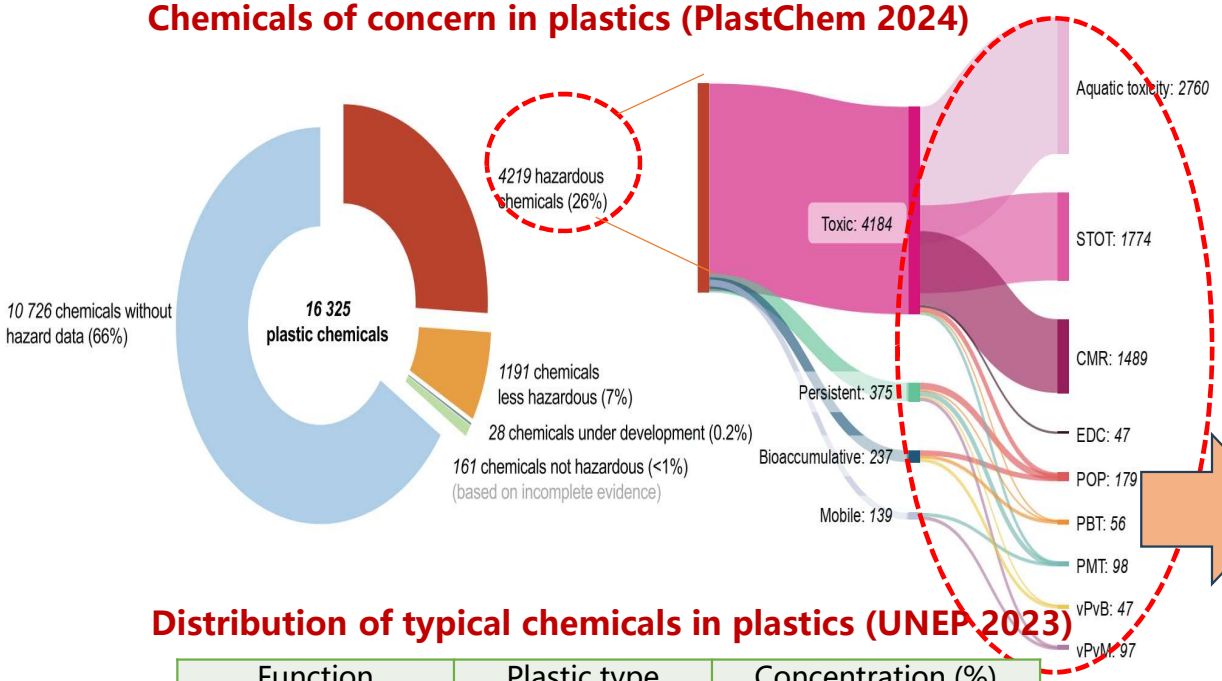


Main Focus:

- ✓ Environmentally sound management of the entire plastics value chain/life cycle
- ✓ Risk management of hazardous chemicals (plastic additives) in plastics

Plastic additives: thousands of hazardous chemicals

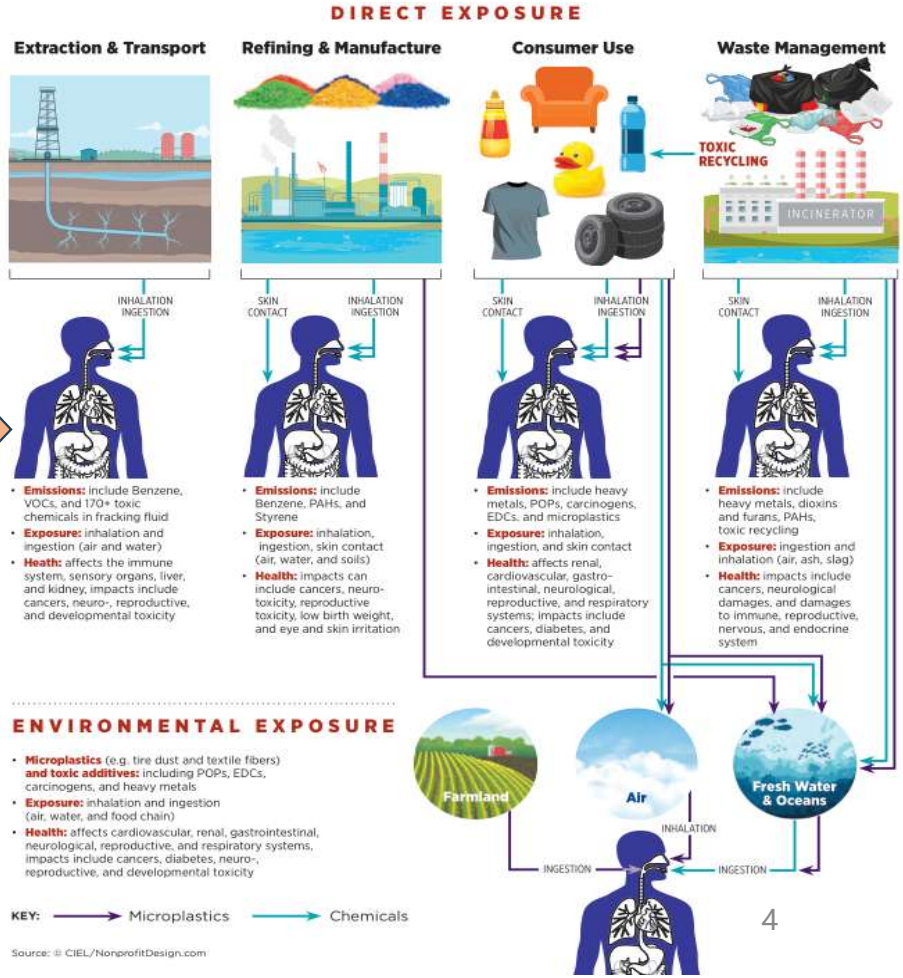
Chemicals of concern in plastics (PlastChem 2024)



Distribution of typical chemicals in plastics (UNEP 2023)

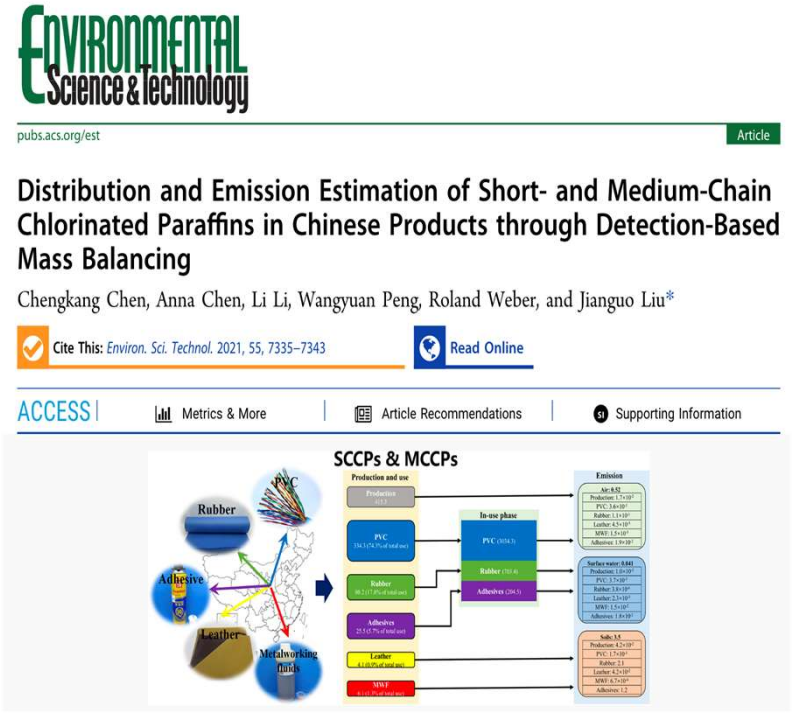
Function	Plastic type	Concentration (%)
Light stabilizers	PE, PP, PVC	0.1-10
Heat stabilizers	PVC	0.1-3
Antistatic agents	PE, PP, PVC	0-1
Antioxidants	PE, ABS	0.05-3
Flame retardants	All	2-28
Plasticizers	PVC	10-70
…		

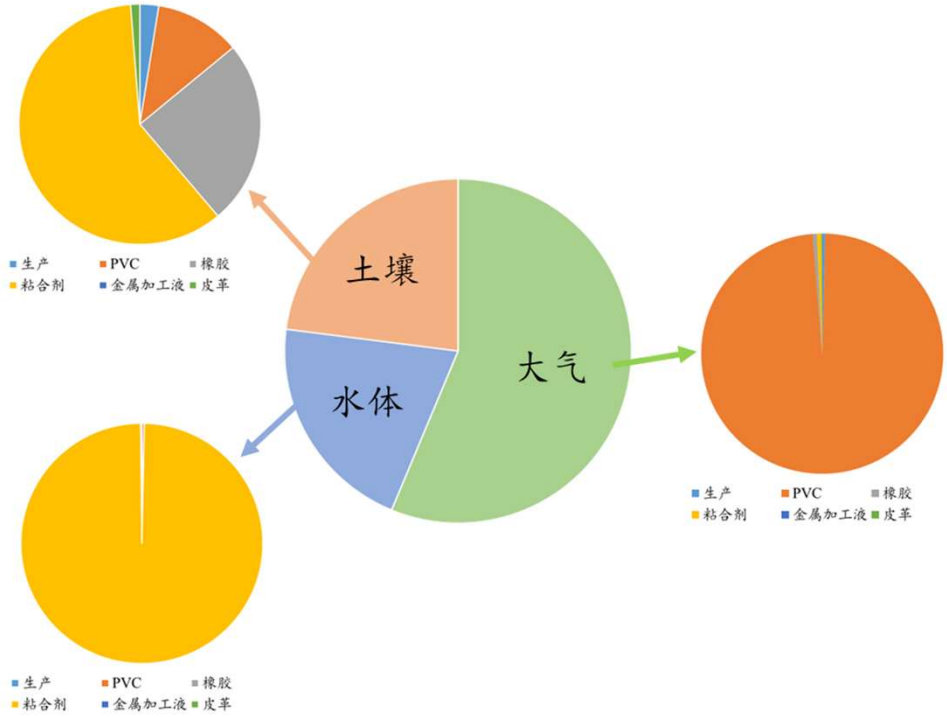
Human exposure to hazardous chemicals in plastics and associated health risks (CIEL 2019)



Case 1: Short-chain and Medium-chain Chlorinated Paraffins (SCCPs & MCCPs)

- **SCCPs & MCCPs——Persistent organic pollutants (POPs),** cause a range of potential toxic effects on the liver, kidneys, thyroid, endocrine system, nervous system, immune system, …

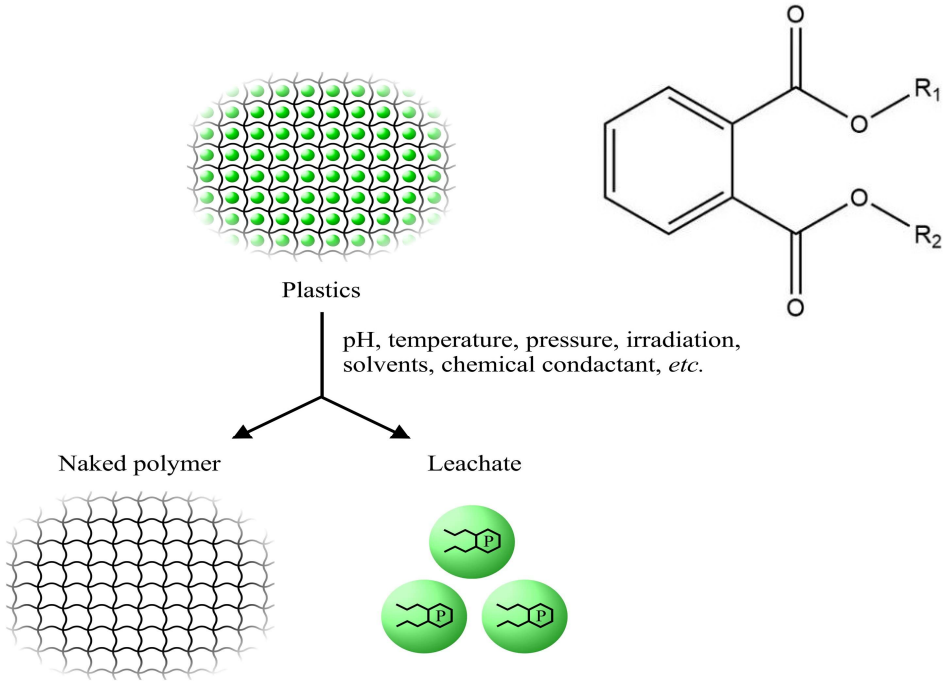




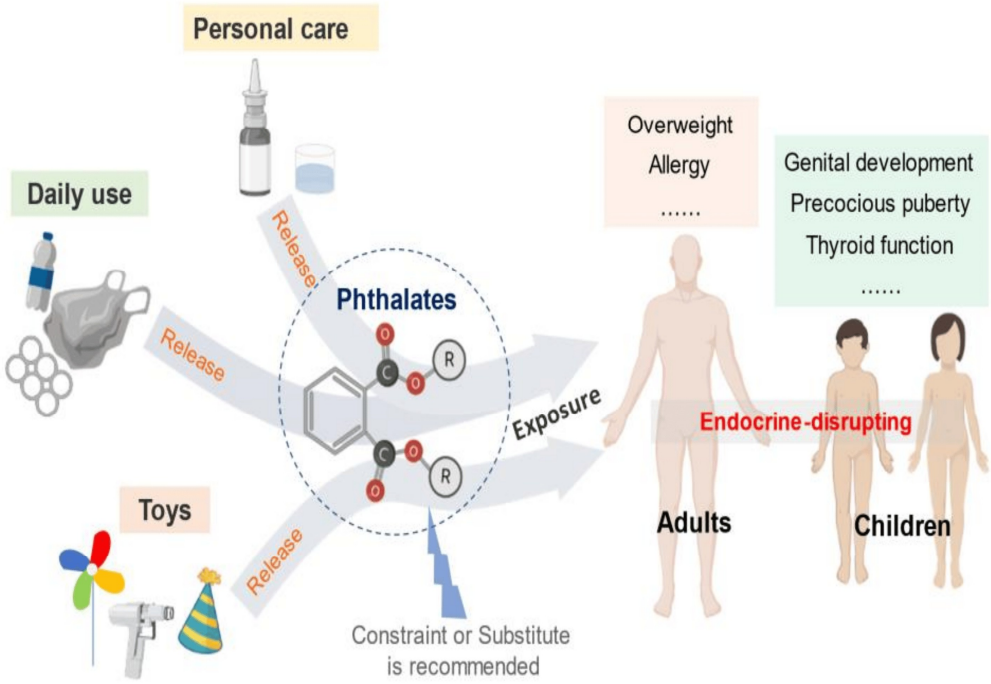
- **Environmental release of SCCPs & MCCPs from products, mainly PVC plastics: ~8,000 tonnes/year**
  - **(C Chen, J Liu* et al., ES&T, 2021)**

Case 2: phthalates, PAEs

- **PAEs——Endocrine-disrupting substances (EDCs)**, ~75% of the global plasticizer market, ~90% used in plastics, induce a range of endocrine-disrupting effects, including obesity, diabetes, precocious puberty, male infertility…

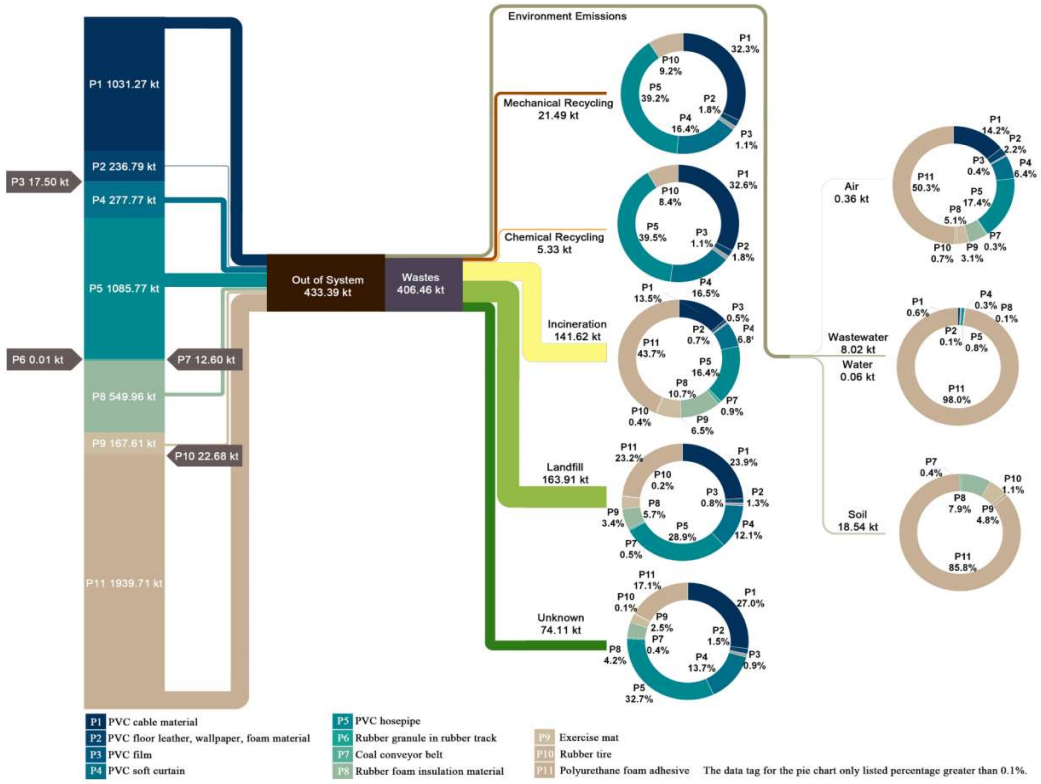


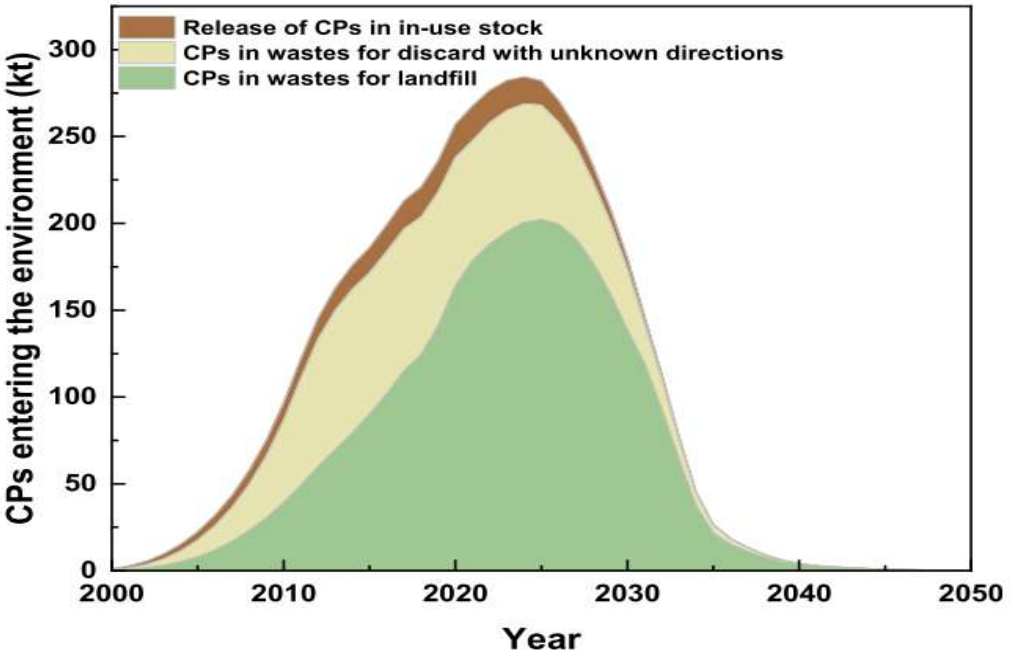
Environmental release of PAEs (Benjamin et al., 2017)



Risks of PAEs on human health (Wang et al., 2021)

>90% plastic additives end up in wastes, and are continuously released into the environment over the long term





➢ **In products including PVC plastics, ~95% of SCCPs & MCCPs end up in waste, with ~58% released into the environment over the long term** (J Chen, J Liu* et al., Environment International, 2024)

Atmospheric pollution by hazardous chemicals in plastics is increasing

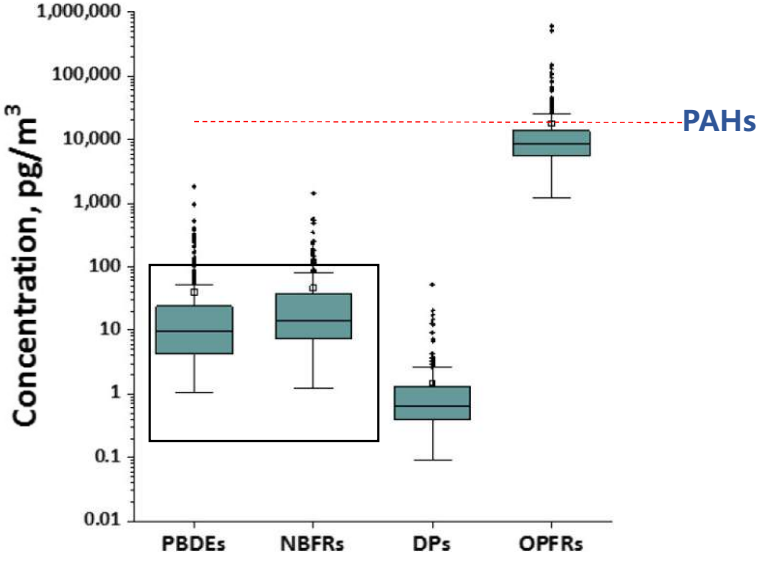
➢ **Atmospheric concentrations of hazardous chemicals in plastics are comparable to or even higher than those of conventional organic pollutants such as PAHs**

PAHs: 10^4 pg·m^{-3} domain

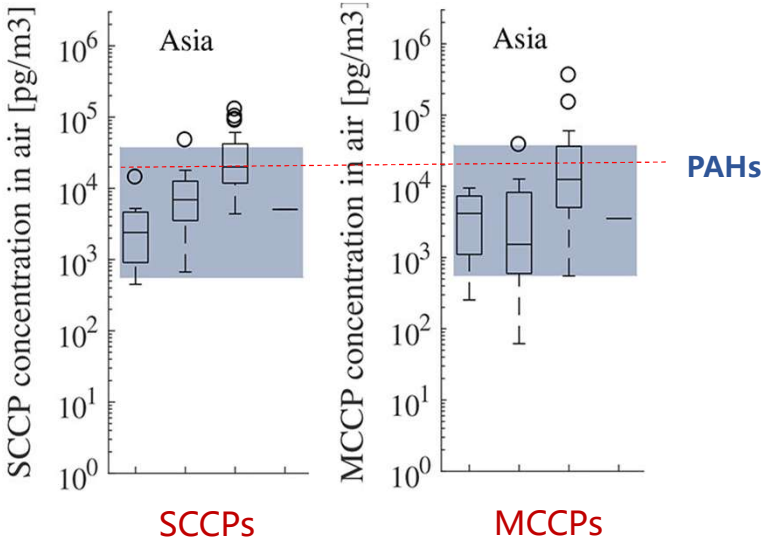
OPFRs: 10^4 pg ·m^{-3} domain

CPs: 10^3~10^4 pg ·m^{-3} domain

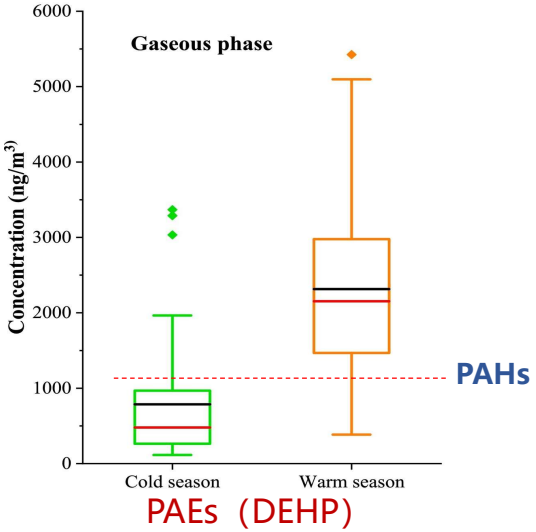
DEHP: 10^3 pg ·m^{-3} domain



(Zhao et al., 2021)

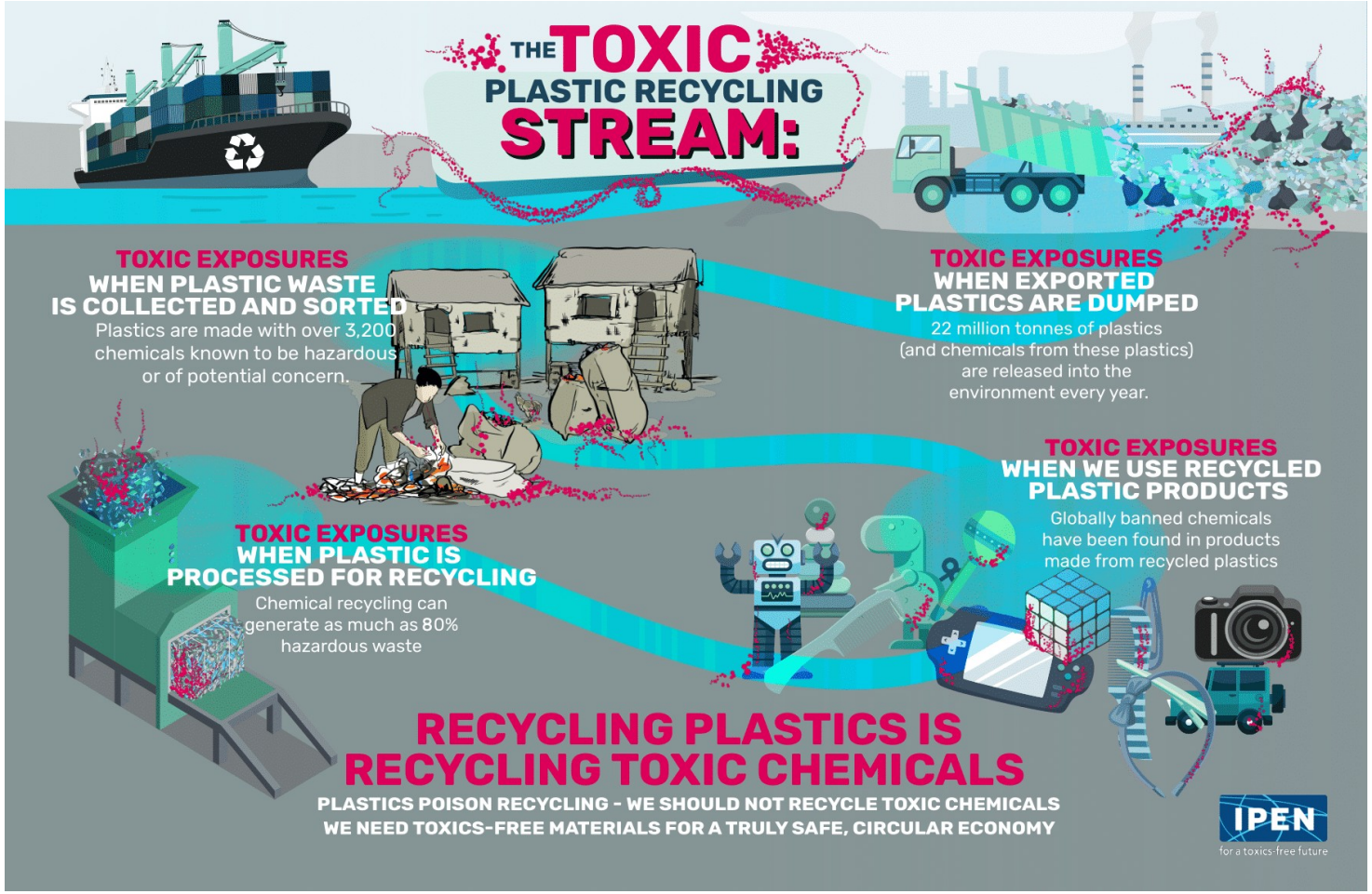


(Juliane et al., 2018)



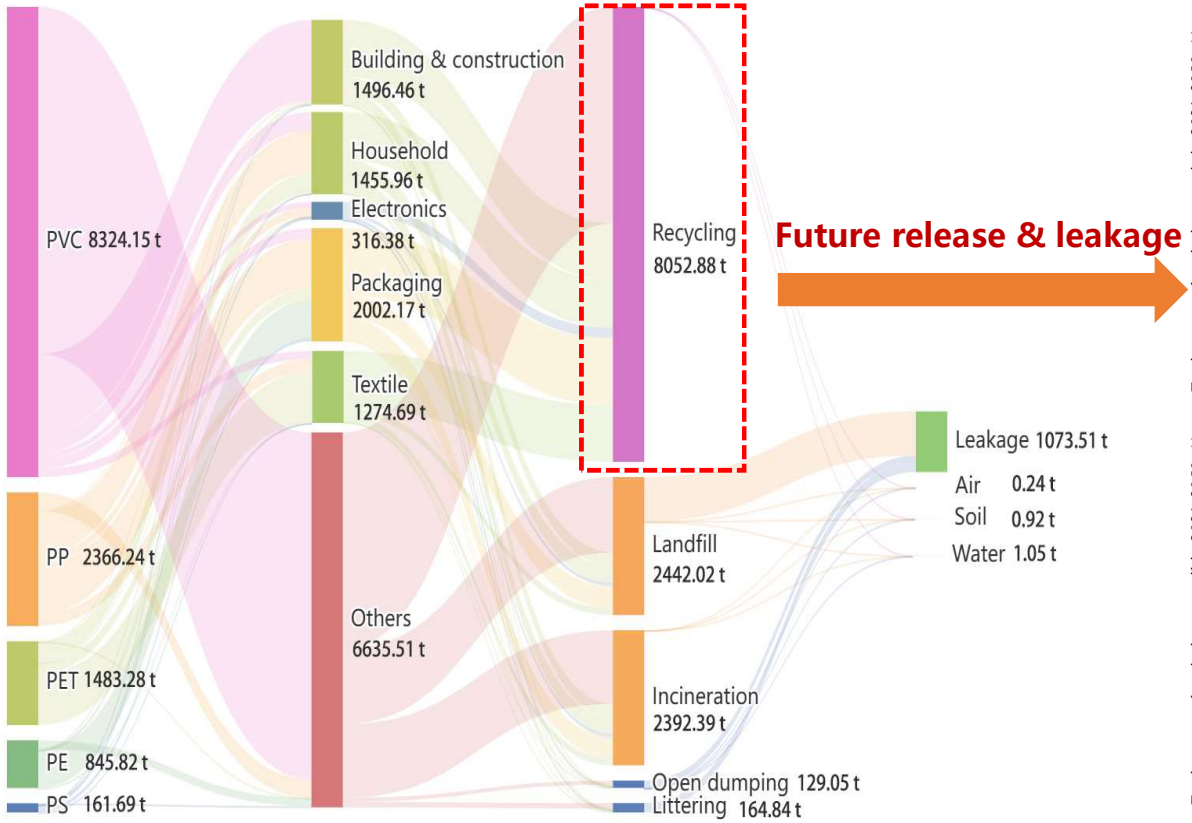
(Lu et al., 2023)

Long-term environmental and health impacts of hazardous chemicals in plastic circulation



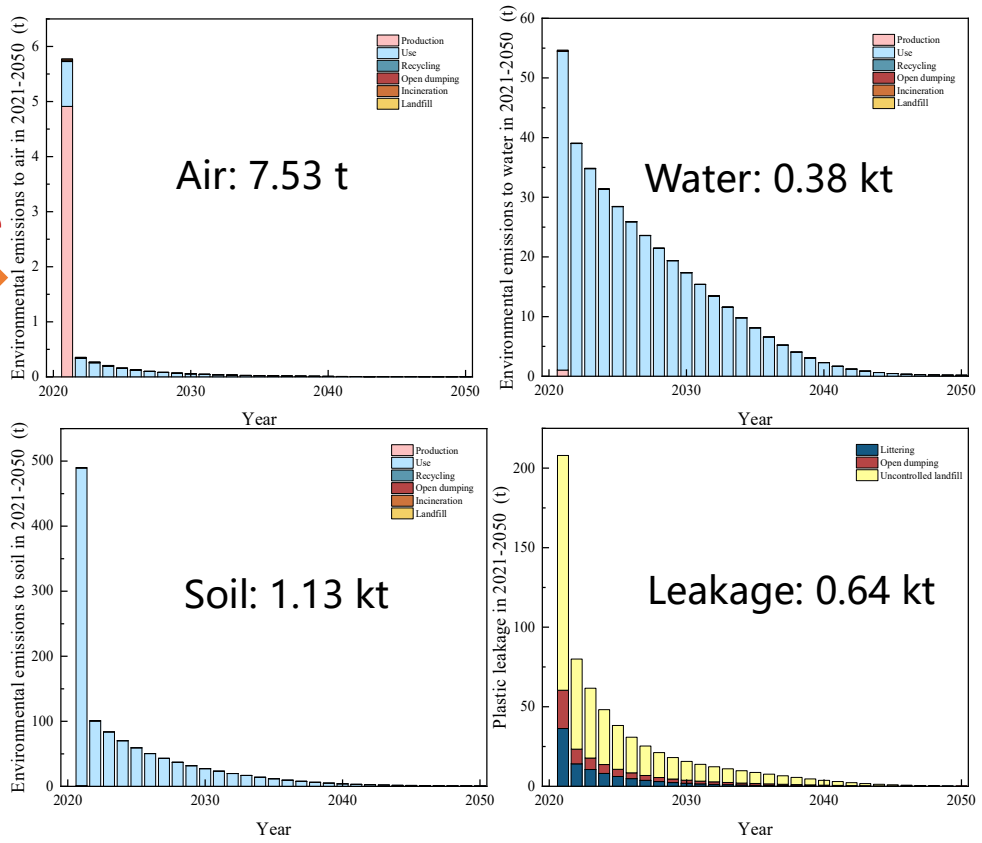
(IPEN, 2024)

Long-term environmental impacts of hazardous chemicals in plastic circulation: a case study on PAEs



Substance flow analysis on PAEs in Chinese plastic products in 2020 (unpublished data)

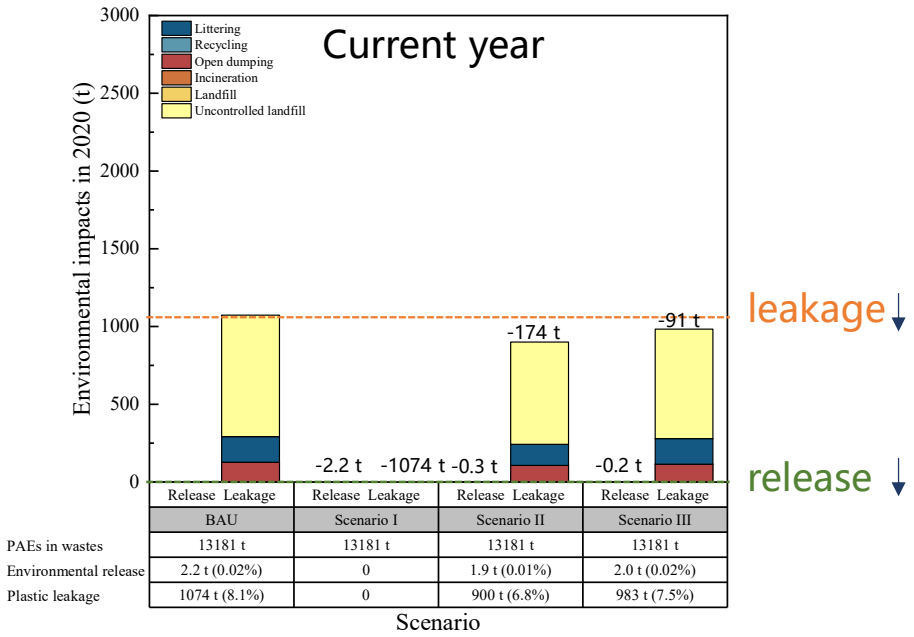
Future release & leakage

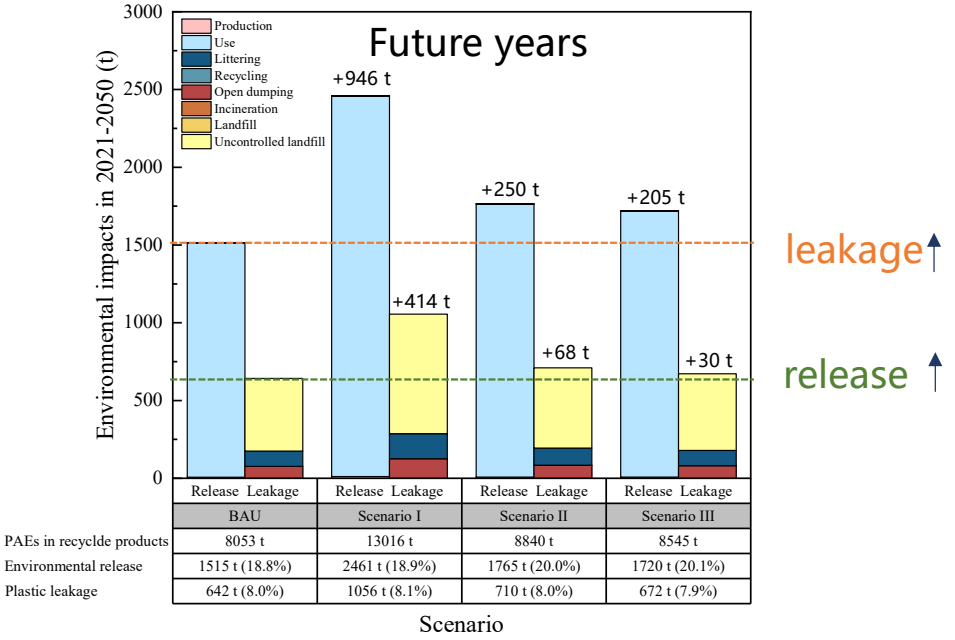


Future environmental release and leakage of PAEs in recycled plastics during 2021-2050 (unpublished data)

- **PAEs in plastic circulation will cause environmental impacts for decades: lasting environmental release and leakage from recycled plastics**

Long-term environmental impacts of hazardous chemicals in plastic circulation: a case study on PAEs





Environmental release and leakage of PAEs in plastic circulation

(2020-2050, unpublished data)

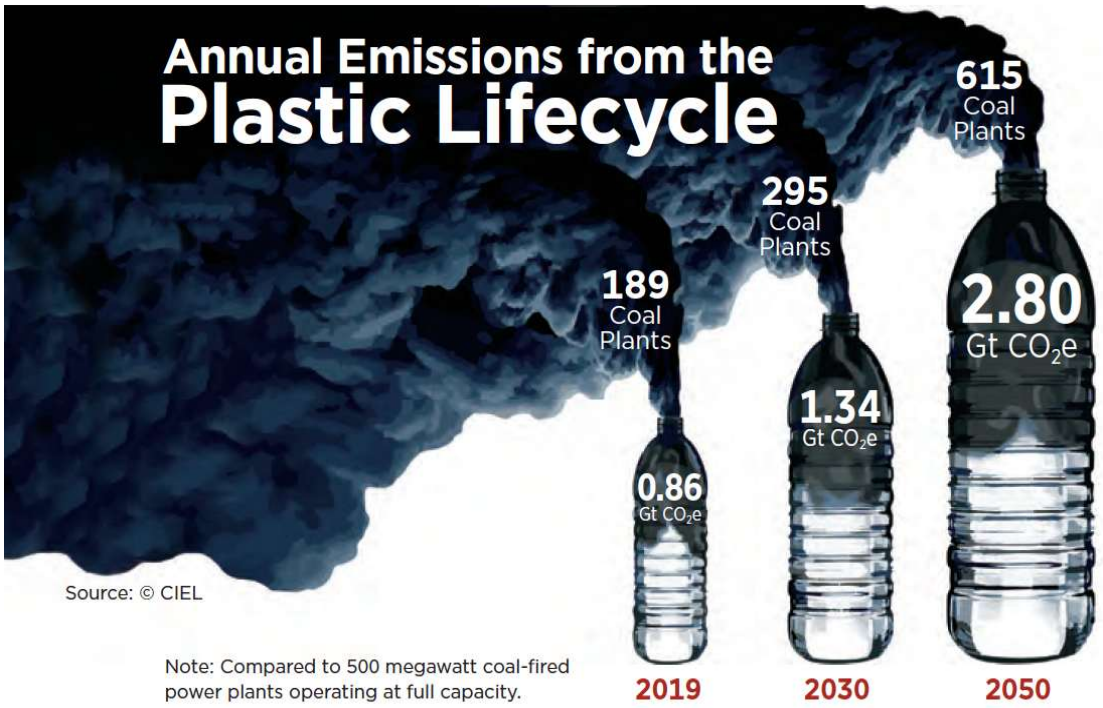
- **While plastic recycling can reduce the environmental release of PAEs in the current year, it will cause lasting accumulation of PAEs in products, increasing their environmental impacts in future years**

Climate impact of the plastics industry

➢**By 2050, the cumulative greenhouse gas emissions will be over 56 gigatons CO_2 e, or between 10%-13% of the total remaining carbon budget** (CIEL 2019)

FIGURE 1

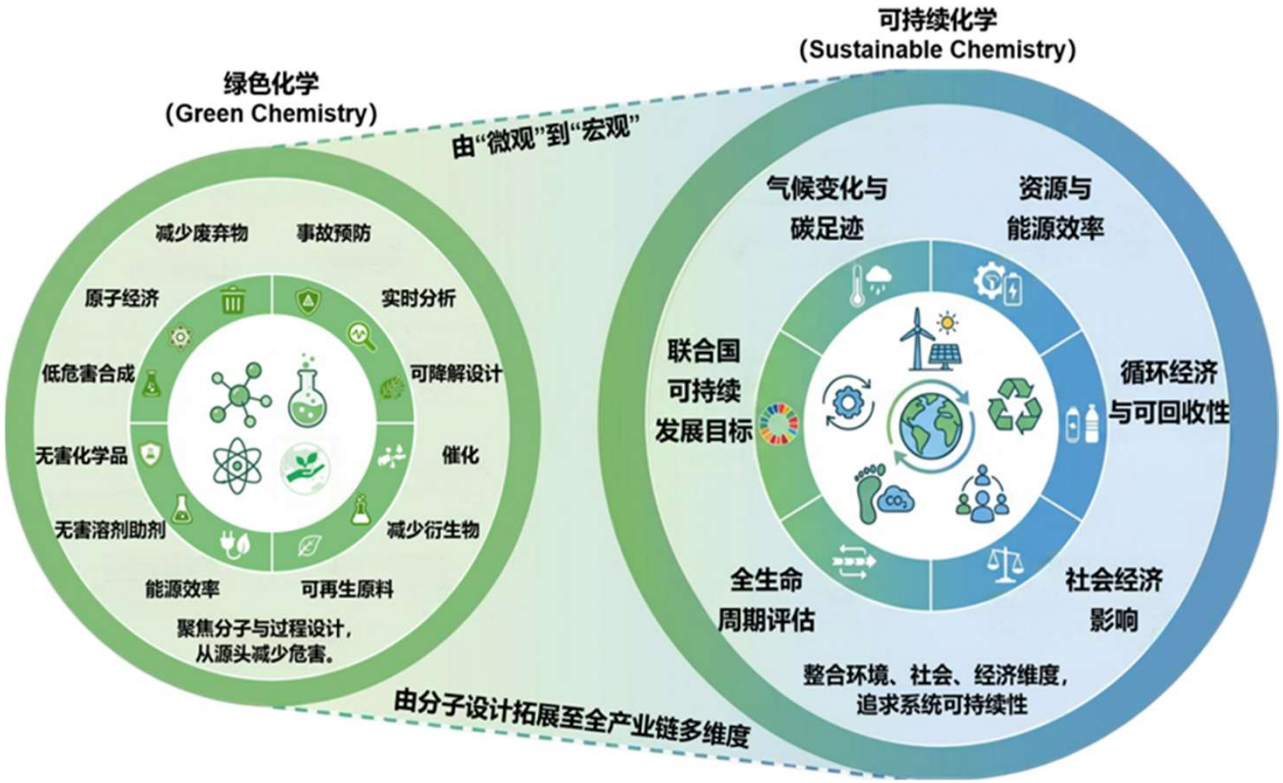
Emissions from the Plastic Lifecycle



Sources of Greenhouse Gas Emissions

- Extraction and transport
- Refining and manufacture
- Waste management
- Plastic in the environment

Green and sustainable chemistry (GSC)



(Z Zhang, J Liu* et al., Chinese Science Bulletin. 2026)

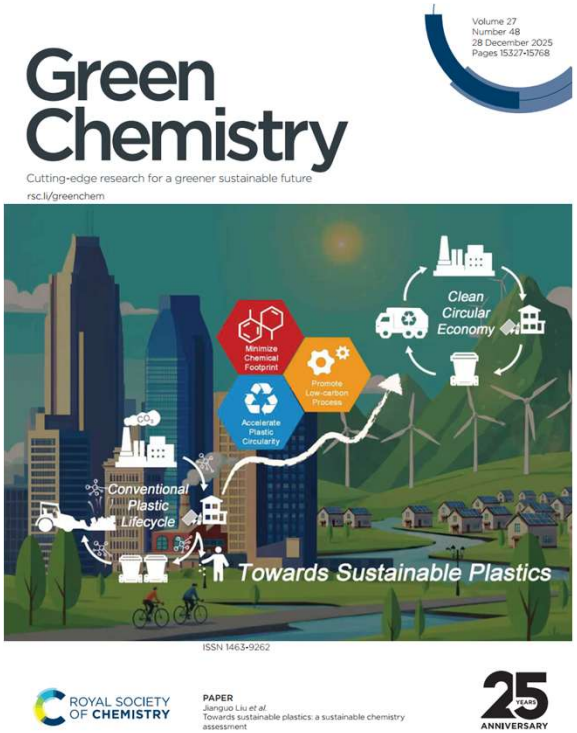
Ten objectives in GSC

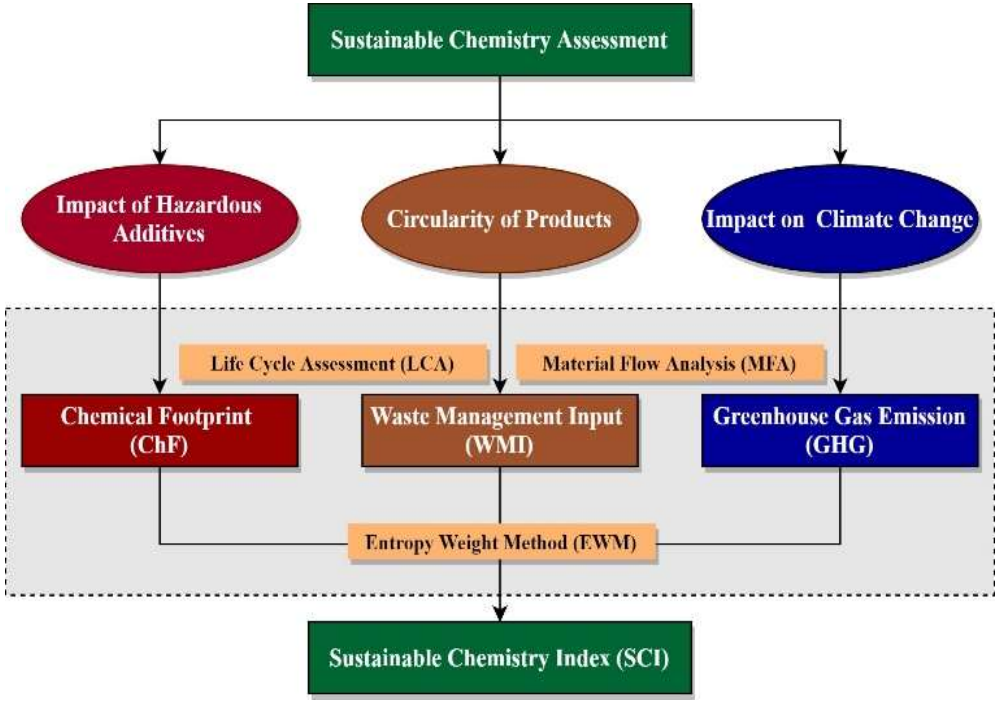
(UNEP, 2021)

- ✓ Minimize chemical hazards
- ✓ Avoid regrettable substitutions and alternatives
- ✓ Sustainable sourcing of resources and feedstocks
- ✓ Advancing sustainability of production processes
- ✓ Advancing sustainability of products
- ✓ Minimizing chemical releases and pollution
- ✓ **Enabling non-toxic circularity**
- ✓ ……

Sustainable chemistry assessment on the plastics industry

- **Develop a "Sustainable Chemistry Index" by integrating metrics including chemical footprint, plastic circularity, and greenhouse gas emissions**





Chen J, Liu J*, et al. Towards Sustainable Plastics: A Sustainable Chemistry Assessment. ***Green Chemistry***. 2025 **(Front Cover)**

Chemical footprint: a new metric for future evaluation on sustainability in the plastics industry



安全替代与可持续化学方案（5 项）

Safer Alternatives and Sustainable Solutions — Including Safety and Sustainability by Design (SSbD)

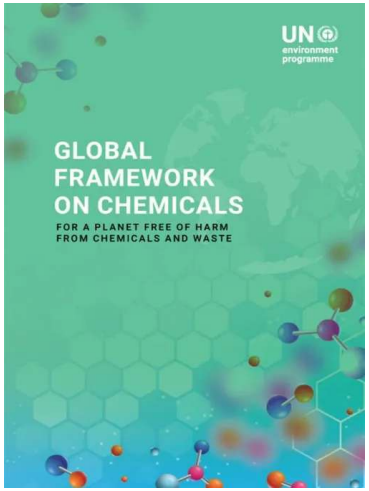
D1 到 2030：企业投入开发并采用更安全的化学品与材料替代方案
By 2030: Industry investment in development and adoption of safer alternatives

D2 到 2030：推广安全与可持续设计（SSbD），从源头降低化学品风险
By 2030: Promoting Safety and Sustainability by Design (SSbD) to reduce risks at source

D3 到 2030：产品价值链减少危险化学品使用，促进循环经济与减量
By 2030: Reducing hazardous chemicals in value chains; promoting circularity and minimization

D4 到 2030：市场增加安全可持续化学品与材料的供给
By 2030: Increased availability of safe and sustainable chemicals

D5 到 2030：推广化学品全生命周期足迹评估方法
By 2030: Methods for life-cycle footprint assessment



Implementation Programme 2

"Industry Engagement and Action along Value Chains"

Workstream on Chemical Footprint approaches

Chemical Footprint - Terminology and Methodological Framework

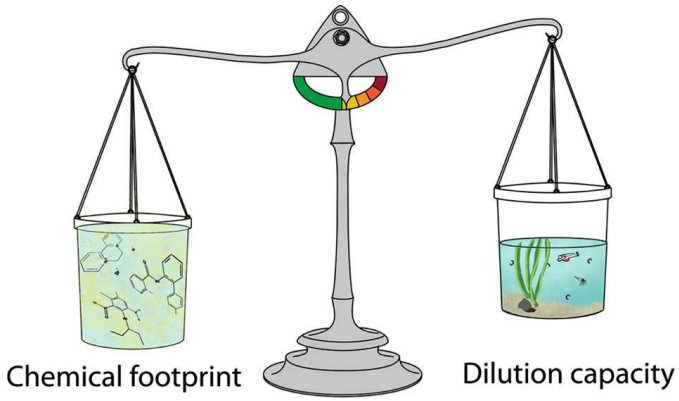
Convenor: United Nations Environment Programme (UNEP), Llorenç Milà i Canals

About this document:

This document was developed under the Workstream on Chemical Footprint approaches within Implementation Programme 2 of the Global Framework on Chemicals, through an inclusive multi-stakeholder process combining contributions from working-group members, a systematic literature review, iterative drafting and review, coordination with other working groups, and a wide stakeholder consultation. It responds to the absence of broadly agreed terminology and a standardized methodology for chemical footprint assessments, which currently limits the consistency, comparability and practical uptake of chemical footprint approaches, and is intended to inform the first GFC International Conference in November 2026, while laying the foundation for a future international standard.

Key messages:

1. **a chemical footprint should quantify potential toxicity-related impacts** on human health and ecosystem quality from chemical use and emissions across the life cycle of products, processes or organizational activities;
2. assessments **should follow an ISO-aligned, life-cycle-based, and iterative framework** covering goal and scope definition, inventory analysis, impact assessment, and results interpretation;
3. **partial assessments must use clear qualifiers**, such as "chemical usage" or "chemical emission" assessments, rather than being presented as complete chemical footprint assessments;
4. and results should support **transparency, hotspot identification, prioritization, substitution** and **performance improvement**, while being interpreted with disclosed boundaries, data gaps and uncertainties, and not as measures of chemical safety or risk.



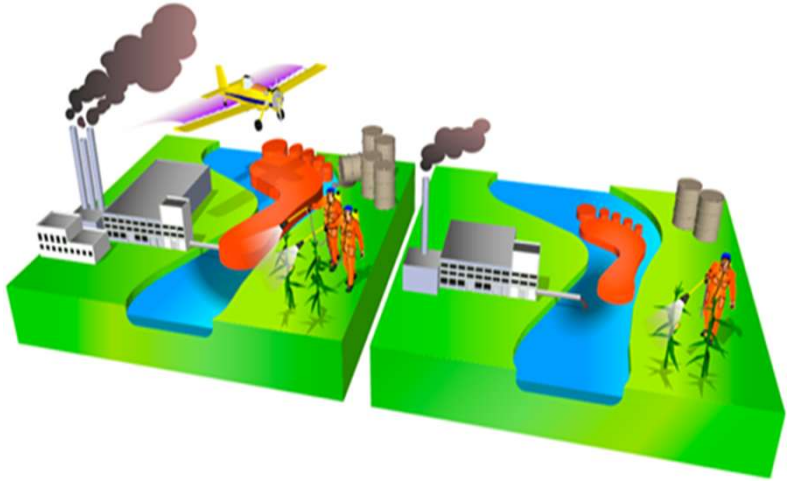
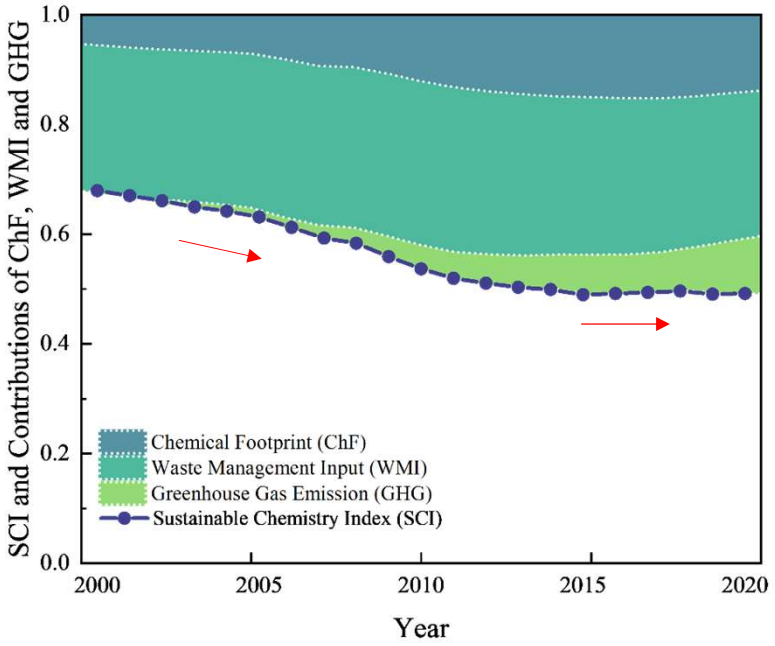


Illustration of chemical footprint

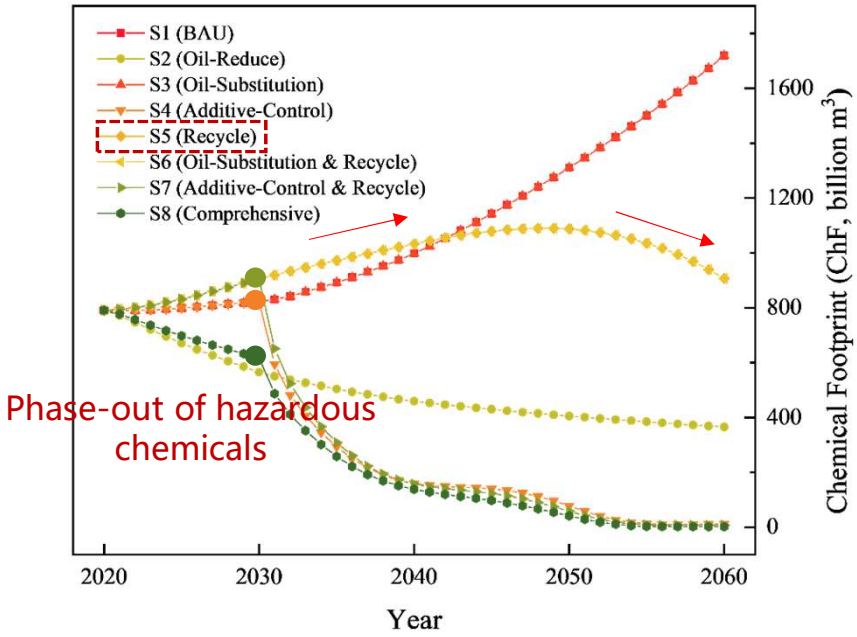
(Bjørn et al., 2014. Zijp et al., 2014)

Sustainable chemistry assessment on the plastics industry

Opposite temporal trends in ChF and SCI



A seesaw effect of ChF in the recycling scenario



Chen J, Liu J*, et al. Towards Sustainable Plastics: A Sustainable Chemistry Assessment. ***Green Chemistry***. 2025 **(Front Cover)**

➢ **Chemicals in plastics are a key factor in the sustainable transition of the plastics industry**

THANKS FOR YOUR ATTENTION

Research Group on Environmental & Health Risk of Chemicals and Global Governance, Peking University
http://scholar.pku.edu.cn/jgliu