

Environmental and Health Aspects of ChemCycling[®]:

A Measurement Program

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Advanced Recycling Conference
Cologne, 29 November 2023

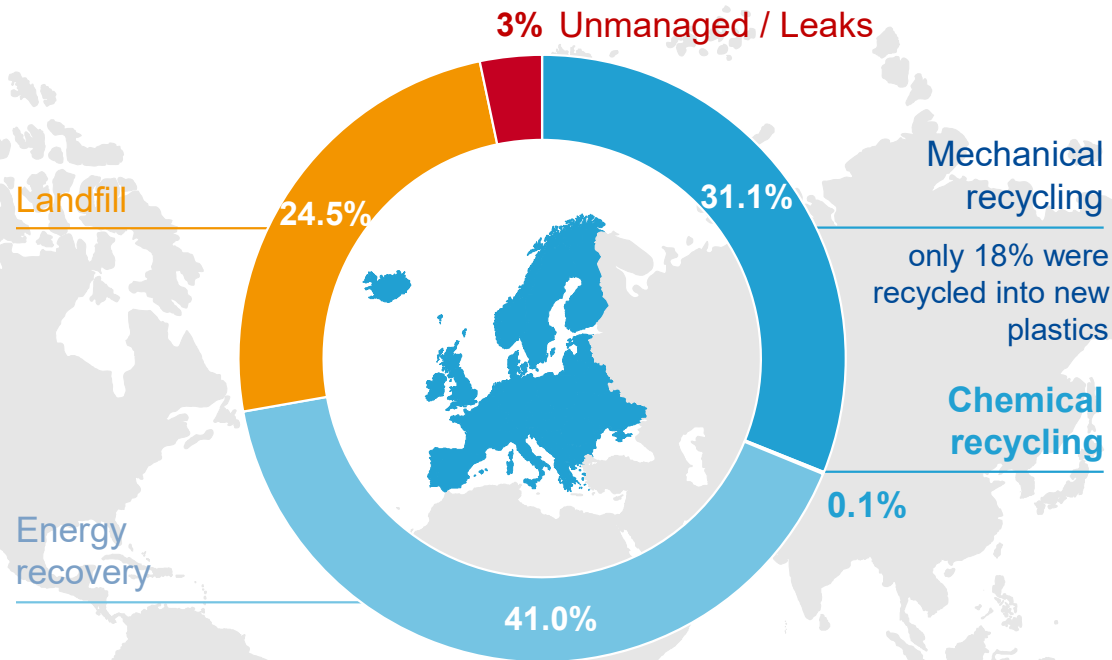
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Today's recycling landscape for plastic waste

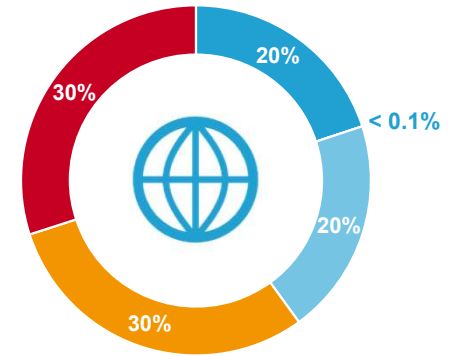
Fate of 30 million metric tons of plastic waste generated in EU28+2 in 2018



Mechanical recycling
only 18% were recycled into new plastics

Chemical recycling

Globally: 250 million metric tons



Opportunities for chemical recycling

- Recycle waste streams currently incinerated, landfilled or unmanaged following the complementarity principle
- Use rejects from mechanical recycling

Source: Conversio, "Circular Economy of Plastics 2018 EU28+2", September 2019 // Conversio, "Global Plastics Flow 2018", February 2020

Only less than 20% of all plastic waste is kept in the materials cycle in EU28+2.

Partnerships to develop ChemCycling® as Business Success

- Pyrolysis of mixed plastic waste (MPW)
- Pyrolysis of end-of-life tires (ELT)
 - ▶ Chemical recycling is complementary to other recycling methods
 - ▶ Our focus is on waste streams that are not recycled mechanically for technological, economic or ecological reasons
 - ▶ The pyrolysis oils are used as alternative feedstocks for the manufacture of plastics and chemicals in BASF's Verbund

A contribution to increased overall recycling rates and a more circular economy in BASF's production Verbund.



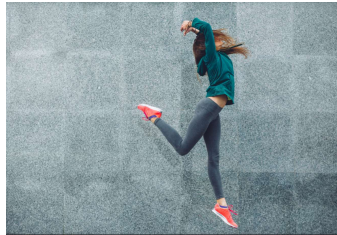
Benefits of ChemCycling® - Overview

Supporting evidence from external sources

Benefits	References	
Reduced CO2 emissions + Saving fossil resources	Garcia-Gutierrez et al. 2023 Gracida-Alvarez et al. 2023 Maga et al. 2023	Sphera et al. 2023
Complementarity + Increased total recycling rates	Volk et al. 2021 Zero Waste Europe 2022 Lase et al. 2023	
Same quality as conventional products for demanding applications (e. g. food contact)	Commission Regulation (EU) No 10/2011* Commission Regulation (EU) 2022/1616**	
BASF's experience in different industry segments	Successful launch of >200 certified Cycled® commercial products for (food) packaging, textiles, transportation, etc.	

* Commission Regulation (EU) No 10/2011 of 14 January 2011 on plastic materials and articles intended to come into contact with food.

** Commission Regulation (EU) 2022/1616 of 15 September 2022 on recycled plastic materials and articles intended to come into contact with foods, and repealing Regulation (EC) No 282/2008.



Background of and Motivation for Measurement Program

We need reliable facts

Frequent questions

- Are toxic substances introduced into and created in chemical recycling processes, released into the environment and/or can they be found in corresponding end-consumer products?
- Is reliable information on toxic substances available?

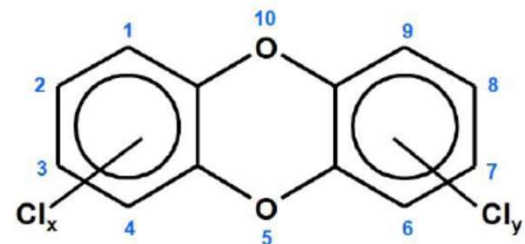
Robust facts are needed

- In-depth knowledge of critical substances introduced into and remaining, created, converted and separated in chemical recycling processes and corresponding concentrations in streams leaving the plants.
- Profound evaluation of results.

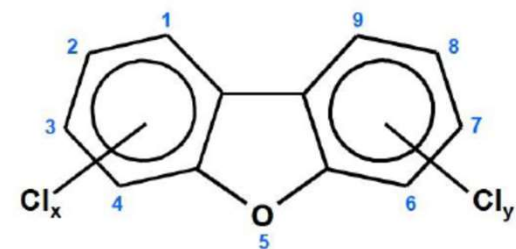


Facts on Polychlorinated Dioxins, Furans and Biphenyls

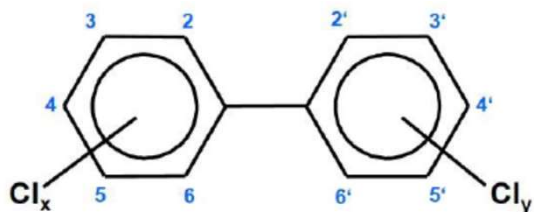
Substances deserving their bad image!



Polychlorinated Dioxins



Polychlorinated Furans



Polychlorinated Biphenyls (PCB)

- **Key features**

- Become widely distributed
- Remain intact for long time in the environment
- Accumulate in fatty tissue of living organisms
- Some are highly toxic to humans and wildlife
- Toxicity strongly dependent on number and position of chlorine atoms
- Several congeners exist: 75 dioxins, 135 furans, and 209 biphenyls

- **Consequences**

- Significant analytical effort required
- Individual toxic equivalent factors to be considered

Our Measurement Program

85 Dioxins, Furans, PCB, PAH and Metals in outgoing streams of commercial plants

Substance class	Substances	Legal reference(s)*
Polychlorinated Dioxins and Furans	17 Congeners with <u>Chlorine</u> at Position 2, 3, 7, 8	ChemVerbotsV, 17. BlmschV, POPV
Polybrominated Dioxins and Furans	17 Congeners with <u>Bromine</u> at Position 2, 3, 7, 8	ChemVerbotsV
Polychlorinated Biphenyles (PCB)	12 dioxin-like PCB 6 non-dioxin-like PCB	17. BlmschV, POPV
Polycyclic Aromatic Hydrocarbons (PAH)	16 PAH from US EPA list PLUS Benzo[e]pyrene, Benzo[j]fluoranthene**	17. BlmschV, POPV
(Heavy) metals	Aluminium, Arsenic, Cadmium, Cobalt, Chromium, Copper, Mercury, Manganese, Nickel, Lead, Antimony, Tin, Thallium, Vanadium, Zinc and Components.	17. BlmschV
In total	85 individual measurements	

* Examples. ChemVerbotsV=Chemikalien-Verbotsverordnung; 17. BlmschV=17. Verordnung zur Durchführung des Bundes-Immissionschutzgesetzes; POPV= Regulation (EU) 2019/1021 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 June 2019 on persistent organic pollutants.

** Benzo[e]pyrene (CAS 192-97-2) and Benzo[j]fluoranthene (CAS 205-82-3) are not included in 16 EPA PAH but REACH Annex XVII listed.

Dioxins, Furans and PCB are analyzed via GC/HRMS, PAH via GC/MS.

Metals are analyzed via ICP-OES or ICP-MS, respectively.

Our Measurement Program

Results obtained & Conclusion so far

- Until now **>10 samples of pyrolysis oils** from mixed plastic waste and end-of-life tires from different partners taken at different times **were analyzed**.
- **All values for polychlorinated and polybrominated dioxins and furans were far below the limit values of the ChemVerbotsV** – even after applying a very conservative evaluation approach.
- In addition, **no other European or German legislation on chemicals** was identified **resulting in the ban or restriction of pyrolysis oils** as feedstock for Chemical Recycling.



Our Measurement Program

Summary

- We have set up an **extensive measurement program targeting at 85 Dioxins, Furans, PCB, PAH and Metals** in all streams leaving the pyrolysis plants.
- It is **voluntary and performed on top** of all required and mandatory measurements.
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Our Measurement Program

Next Steps



Further measurements are in preparation **covering all outgoing streams from commercial scale pyrolysis plants** which are operated in a representative way.

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