Introduction to Recycled Plastics

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Outline

Introduction to recycled plastics (main types, formulation, uses, characteristics)

Market for recycled plastics (main drivers)

Special risk assessment considerations for recycled plastics used in food packaging

Recycled Plastics – WHY?

- Plastics production has increased over the past 50 years, from 15 M tonnes in 1964 to 311 M tonnes in 2014; expected to double again over the next 20 years

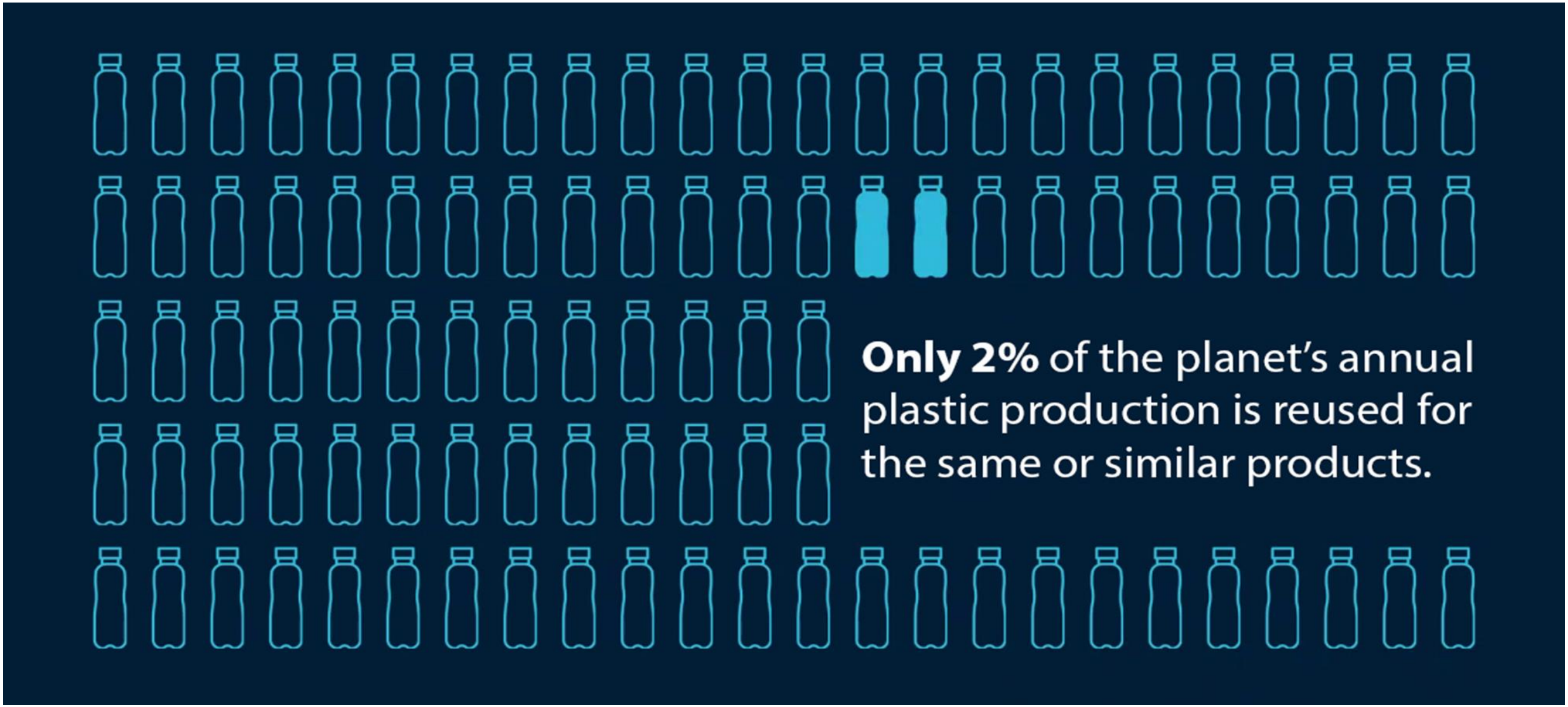
- Only 14% of plastic packaging is collected for recycling with another 14% directed to energy recovery. 72% of plastics not recovered – 40% landfilled + 32% escapes collection system. In comparison, paper and steel recycling is at 58-90%.

- 8 M tonnes of plastics "leak" into the ocean every year – equivalent to dumping the contents of one garbage truck into the ocean every minute. If no action is taken, this is expected to increase to two per minute by 2030 and four per minute by 2050. Packaging represents the majority.

Recycled Plastics – WHY?

- Globally, **less than 10 percent of plastics are recycled**, about **12 percent** are incinerated, with the majority disposed of in landfills or littered in the natural environment:
  - Low rate of recycling due to:
    - **low cost of feedstocks (monomers) derived from oil**
    - **Inexpensive landfill space;**
    - **Some plastics, such as poly(vinyl chloride), low-density polyethylene, polypropylene, and polystyrene have chemical properties that make them difficult to recycle.**
- As of 2015, the world has produced some 6.3 billion tonnes of plastic waste, only 9% of which has been recycled, and only ~1% has been recycled more than once.
- In 2017, the recycled plastics market worldwide was 55% PET and 33% HDPE, with < 8% for PP + LDPE.

Recycled Plastics – WHY?



TOMRA, 2020

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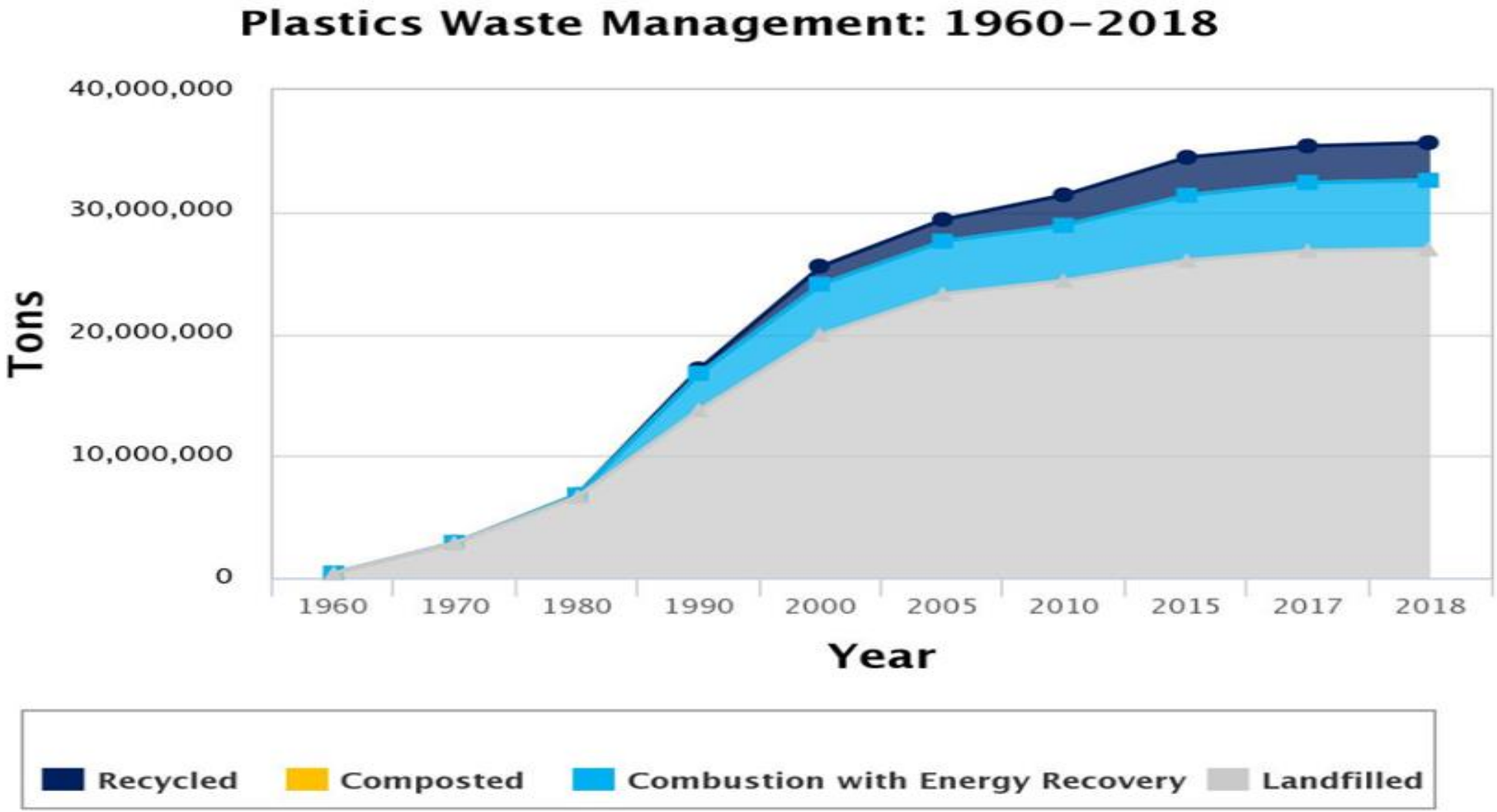
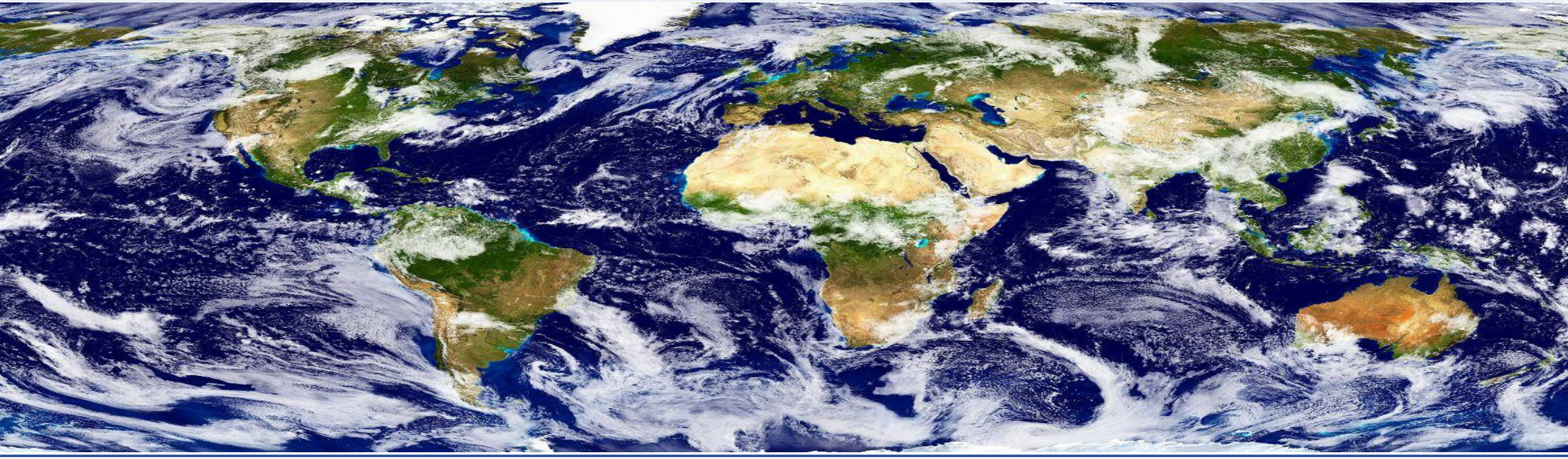
Plastic Waste Generation



Plastic Waste Generation (2)

Country	Plastic waste per year (Mt)*	Waste per person per day (Kg)	Recycled	Incinerated	Landfill
United States	37.83	0.34	8%	14%	78%
EU total	24.70	0.15	24%	34%	42%
Germany	14.48	0.48	33%	65%	2%
World total	245.00	0.10	16%	22%	62%



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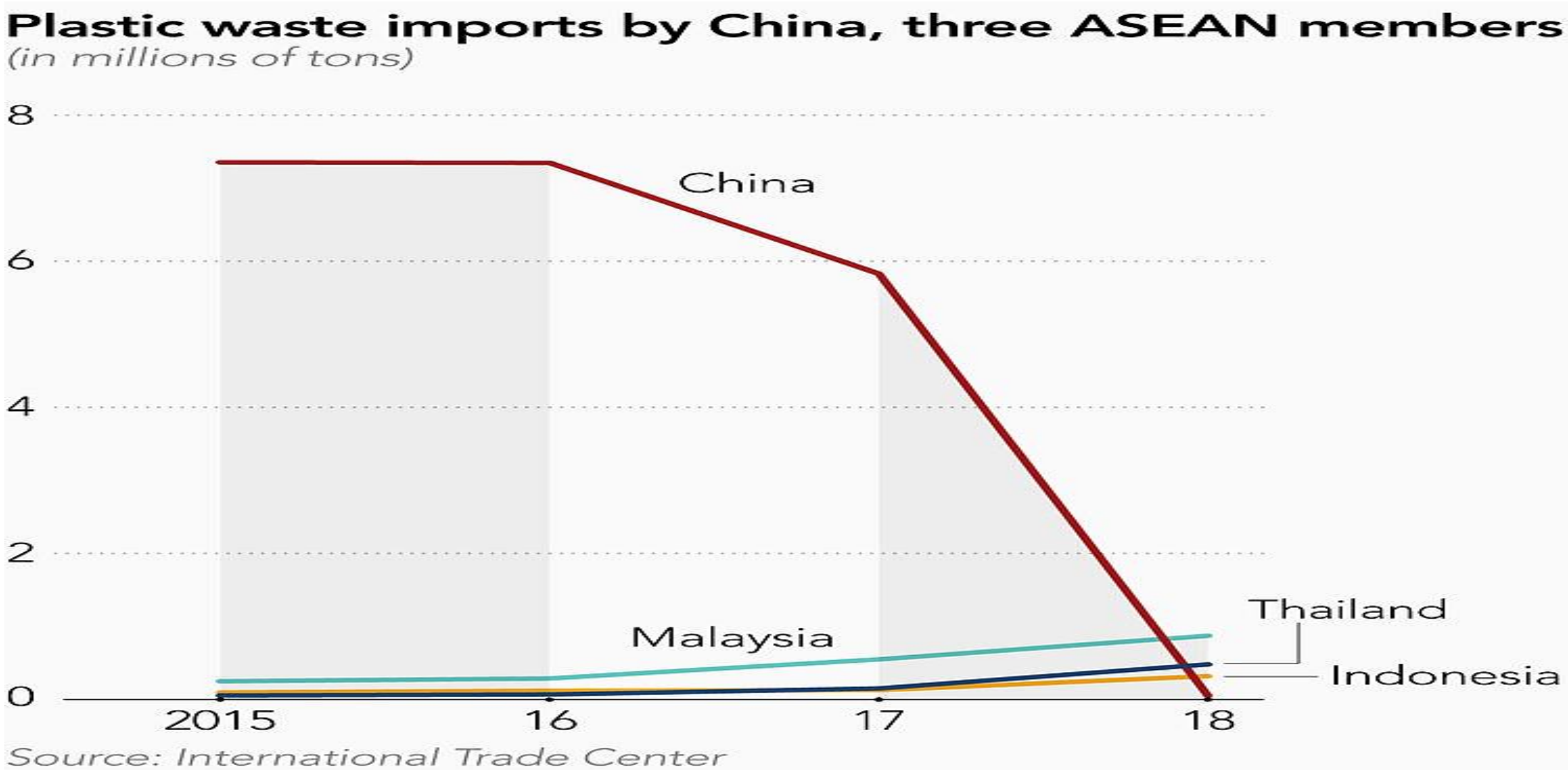
Plastic Waste Generation (3)



Plastic Resin Identification Codes

Polyethylene Terephthalate	High-Density Polyethylene	Polyvinyl Chloride	Low-Density Polyethylene	Polypropylene	Polystyrene	Other Plastic
01 PET	2 HDPE	03 PVC	4 LDPE	5 PP	6 PS	7 OTHER
Drink bottles, polyester fabrics, food packaging	Chemical containers, toys, milk bottles	Pipes, window frames, disposable gloves	Plastic bags, shrink wrap, pallet wrap	Food containers, rugs, medical items	Packaging, car parts, appliance parts	Car parts, bottles, safety equipment, food containers
Usually Recycled	Generally Recycled	Occasionally Recycled	Sometimes Recycled	Generally Recycled	Occasionally Recycled	Rarely Recycled
Light, clear	Solvent resistant, UV resistant	Electric insulator, durable, flame retardant	Impact resistant, chemical resistant	Hinges, heat resistant	Heat resistant	Impact resistant, soluble, UV resistant

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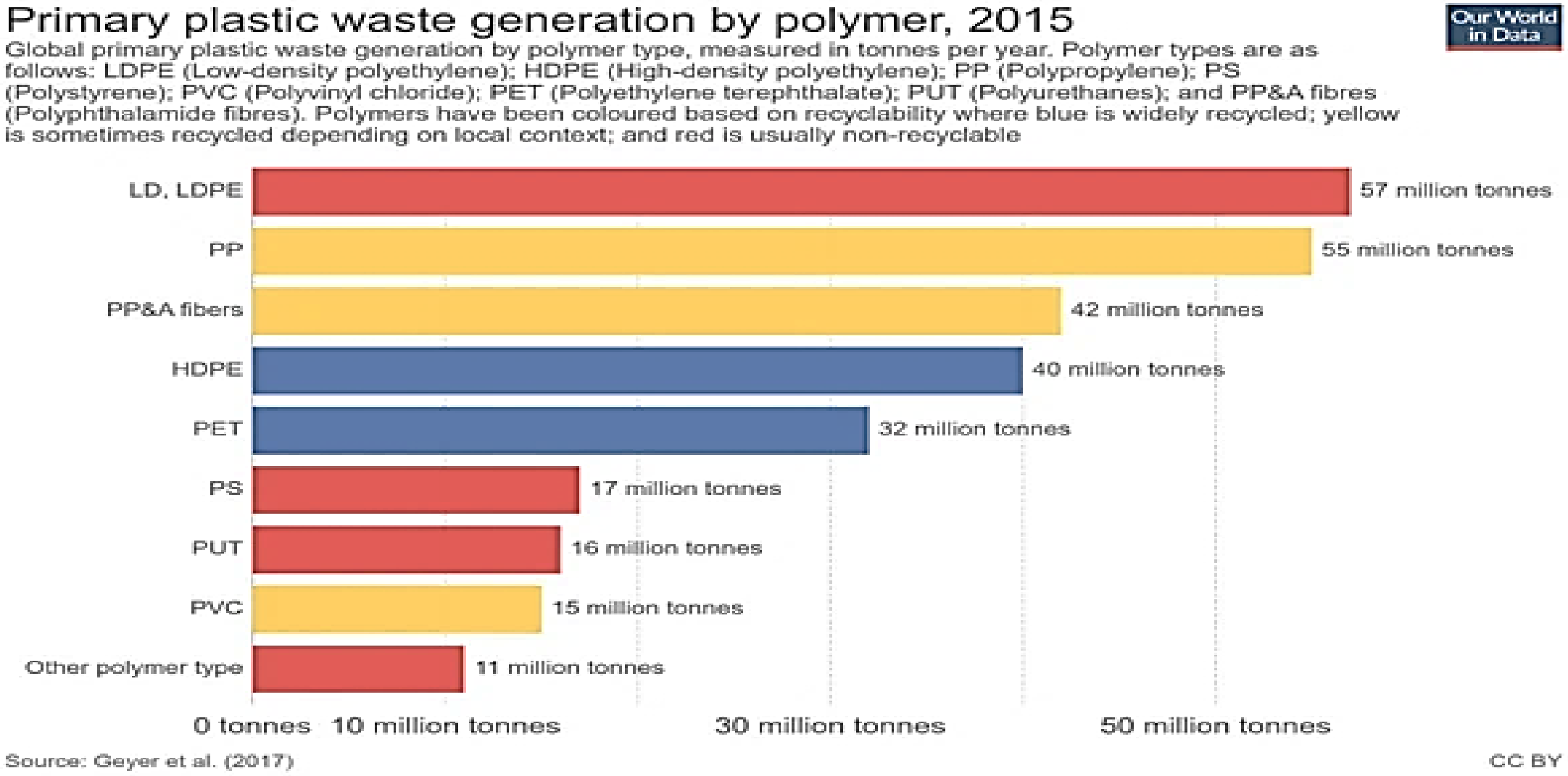
Recycled Plastics

- The recycling symbol found on plastic products is a resin identification code that tells you what kind of plastic that material is made of.
  - Some plastics can be reused but not all recycled.
  - Plastics that have #1 (PETE or PET) or #2 (HDPE) are the most commonly recycled plastics.
- Plastics #3 , #4, #5, #6 and #7 are generally more difficult and expensive to recycle and are not universally collected in local recycling programs.

Plastic Waste Generation



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PET (Polyethylene Terephthalate)

- PET is one of the most commonly used plastics in consumer products and is typically used in most water and soft drink bottles and some food packaging. **It is intended for single use applications.**
- PET is made up of ethylene glycol and terephthalic acid, which are combined to form a polymer chain. Resulting pellets are then heated to a molten liquid that can be easily extruded or molded into items **of practically any shape.**
- More than **half of the world's synthetic fiber is made from PET,** referred to as "polyester" when used for fiber or fabric applications. **When used for food packaging, it's called PET or PET resin.**
- **PET is completely recyclable, and is the most recycled plastic worldwide.** The current recycling rate for PET is 31% in the US and 52% in Europe.
- Approximately **40% of PET's energy use** is attributable to "resource energy" - the energy inherently trapped in its raw materials that can be recaptured and reused through recycling.

HDPE – High Density PolyEthylene

- Typically used for **food and beverage containers** and for consumer products (personal care products). HDPE plastic has a high-impact resistance and melting point.
- HDPE is manufactured from **ethylene produced** either by heating petroleum products or natural gas under pressure.
- HDPE is one of the easiest polymers to recycle and is typically mixed with new HDPE to improve the strength. **HDPE can be recycled up to 10x before the quality is compromised.**
- In the United States, up to **31% of HDPE bottles were recycled in 2017**.
- Stability results in a relatively long environmental half life (up to 50 years for HDPE bottles).

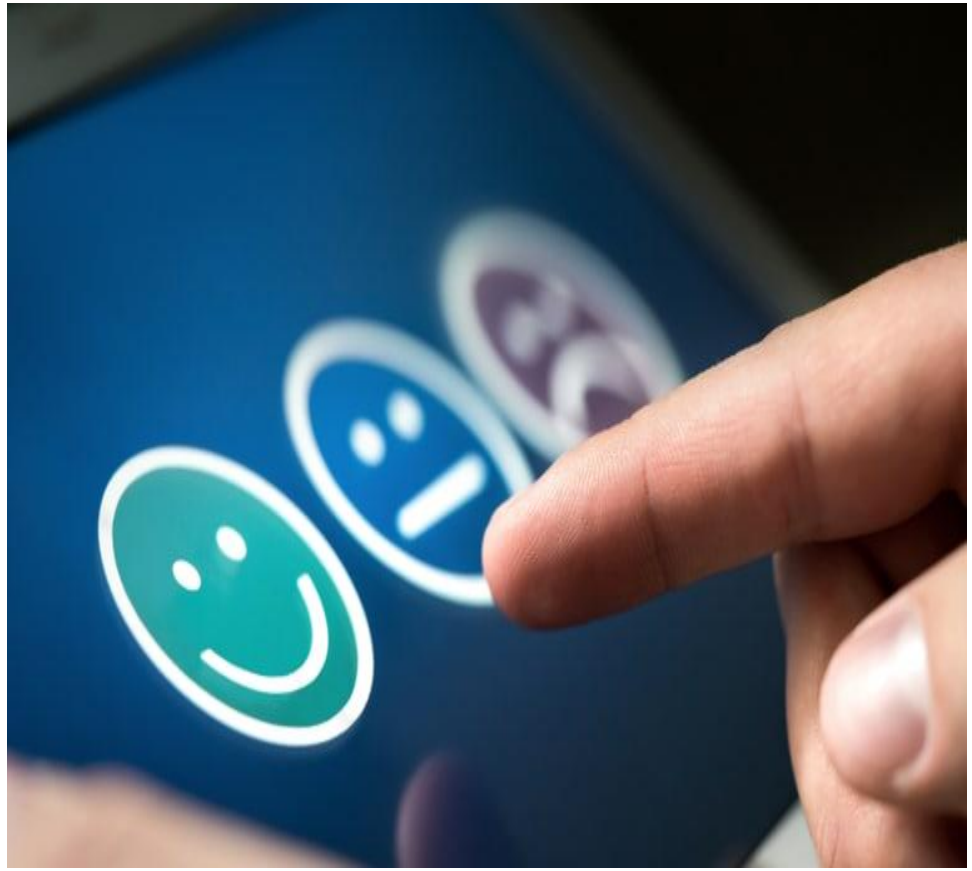
Why Recycle Plastics?

Main reasons:

- Conserves natural resources
- Saves energy
- Reduces landfill use
  - 60-75% of landfill material can be recycled
- Reduces carbon emissions and green house gases (climate change)
- Reduces environmental contamination
  - Approximately 8 million tons of waste plastic enter the Earth's oceans every year
- Increasing demand
  - Global recycled plastic market size was valued at USD 45.1 billion in 2019 and is expected to grow at 5.0%/year from 2020 to 2027
- Human health effects due to micro/nano plastics

Survey of 6000 consumers in 11 countries (Accenture, 2019)

- 83% of consumers believe it's important or extremely important for companies to design products that are meant to be reused or recycled.
- 72% of respondents said they currently buy more environmentally friendly products than they did five years ago, and 81% said they expect to buy more over the next five years.
- Price was important to 84% of respondents while environmental concerns were identified by only 37%.



Accenture Chemicals Global Consumer Sustainability Survey 2019

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Recycling Process

- Mechanical recycling is the **main method** for recycling plastics. Waste plastics are melted and formed into new products that are often of lower quality than the original products. Subject to polymer degradation.
- Chemical recycling of plastics is **increasing in use**. The two main techniques for chemically recycling waste plastics are depolymerization and pyrolysis.
  - Depolymerization - waste plastics are broken down to starting materials (monomers) to make plastics equal in quality to virgin plastics produced from petroleum-derived feedstocks. Polyester and polystyrene are examples of “depolymerizable” plastics.
  - Pyrolysis - breaks down long-chain polymers into shorter-chain hydrocarbons (preferably naphtha) at high temperatures (400 to 500 degrees Celsius). Naphtha can be further broken down into smaller hydrocarbons such as ethylene and propylene which can then be used as starting monomers. Pyrolysis is particularly useful for handling mixed-waste plastics, such as mixtures of polyethylene and polypropylene.
- Chemical recycling **reduces plastic waste pollution**, avoids incineration, reduces production of virgin plastics from petroleum, and prevents landfilling.

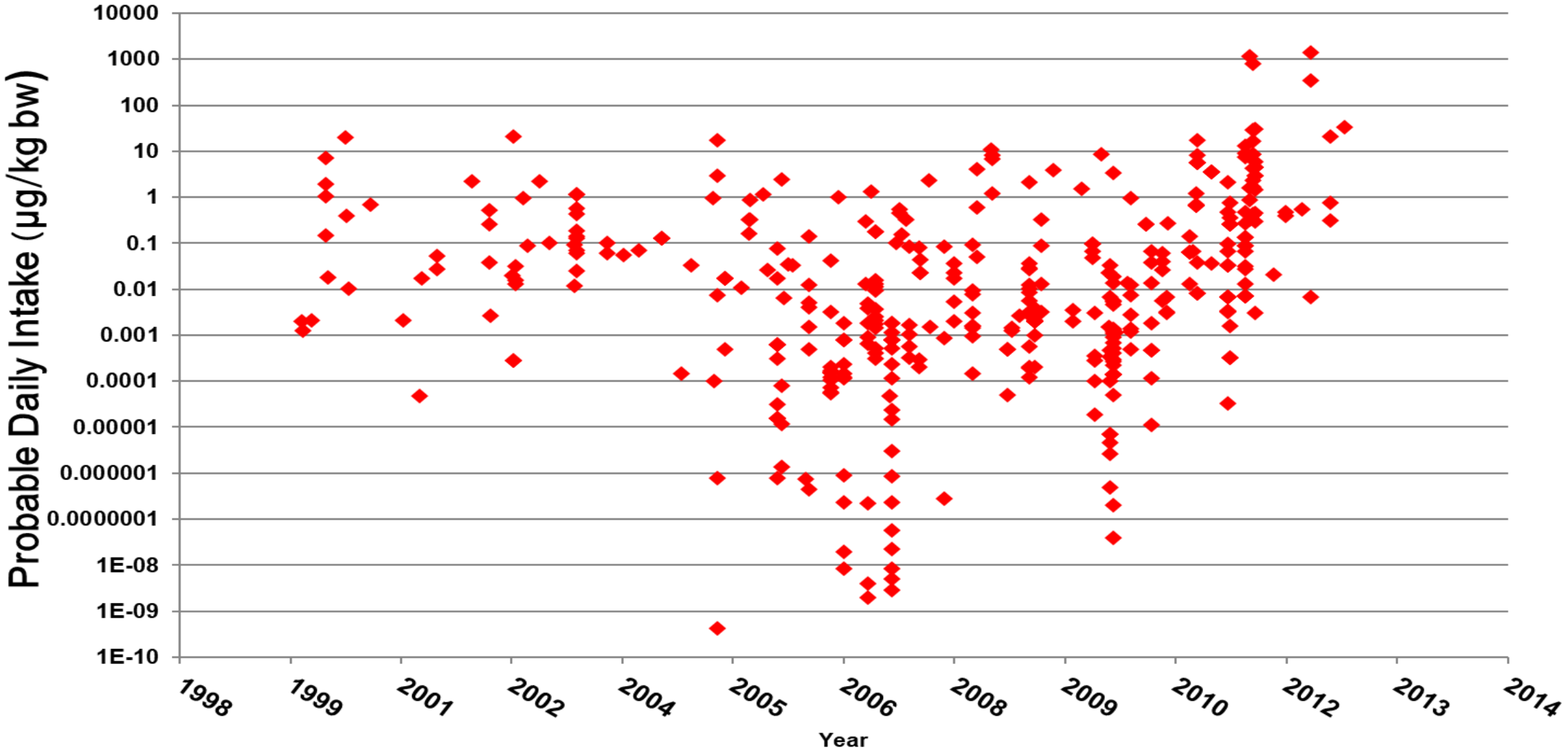
General Concept for Safety Assessment of Plastics

- All plastics contain some residual(s) of the chemicals used in their manufacture.
- These can include one or more catalysts that assist the polymerization reaction, as well as traces of unreacted raw material (monomers).

- A number of additives are typically included with polymer resins prior to forming the final product to enhance both processing and performance characteristics of the final product.
  - E.g.: stabilizers, UV-blockers, plasticizers, antioxidants, colorants, etc.
- Migration of chemicals (> 10000*) used in food packaging into food can occur under typical conditions of storage and use; rate and extent is dependent on temperature, pH, and chemical properties of both the food and FPM.

*Weisinger et al., 2021

Potential Chemical Migrants from Food Packaging



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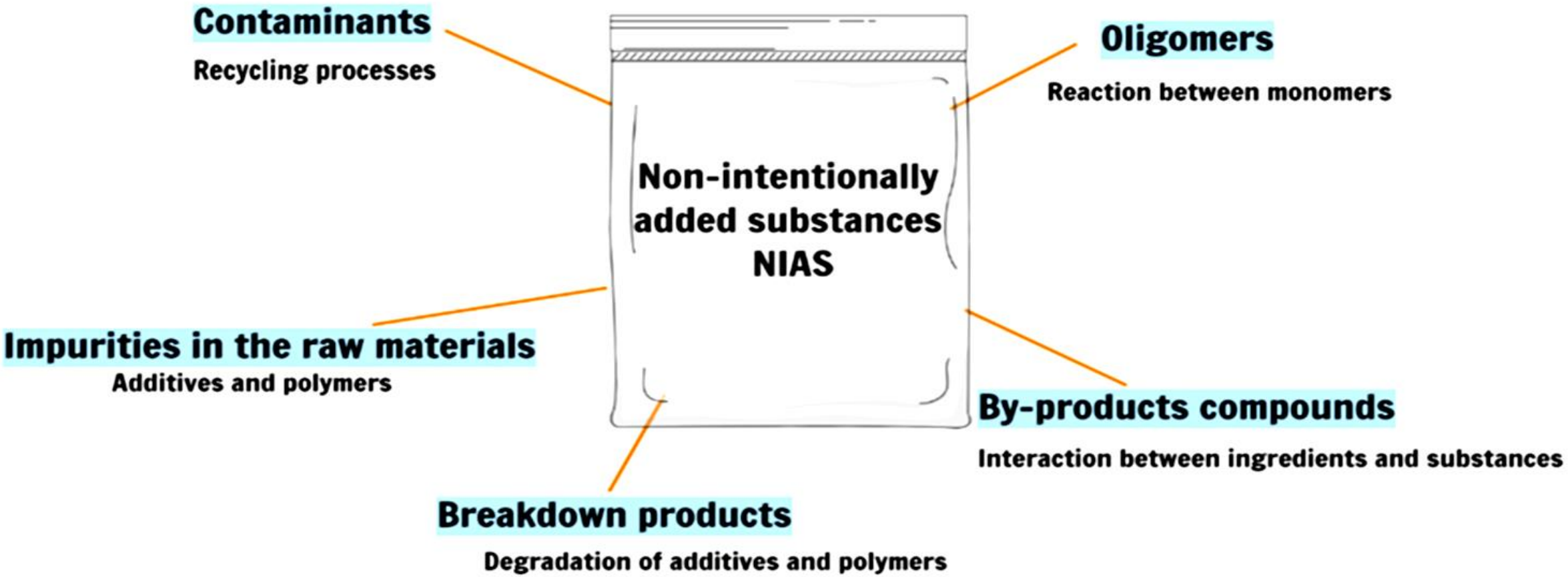
Issues Specific to Recycled Plastics

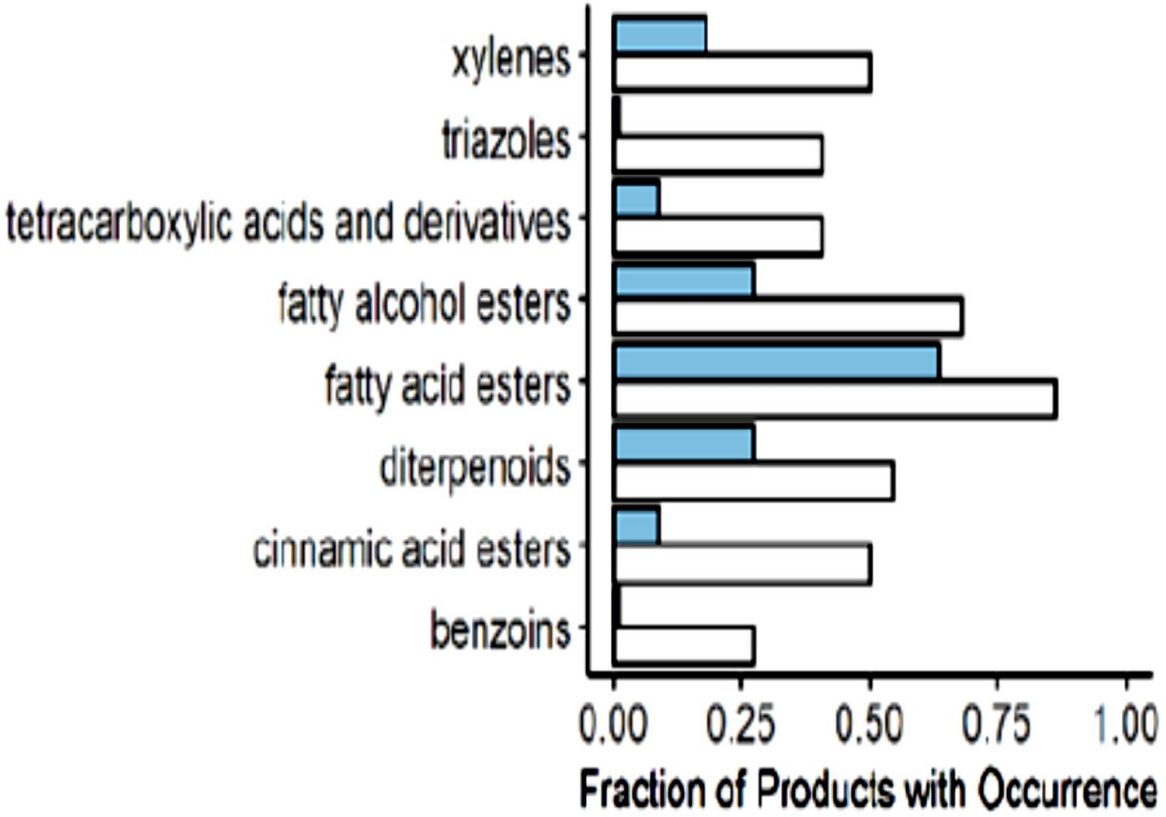
- **Studies on recycled and virgin polystyrene, HDPE and polypropylene (PP) food contact materials have shown a higher volume of chemical migration, including additives, using recycled materials compared to new.**
- **Previous use and misuse of plastic packaging may contribute to the presence of unexpected contaminants and non-food grade materials entering the recycling stream (inadequate sorting).**
- **Chemicals used in the recycling process may not be completely eliminated from the recycled plastic.**
- **Degradation products of the polymer or of plastic additives may be formed during thermal treatments.**
- **Safe Food Advocacy Europe (SAFE) considers that the increasing use of recycled plastics in FCMs as a high-risk issue.**

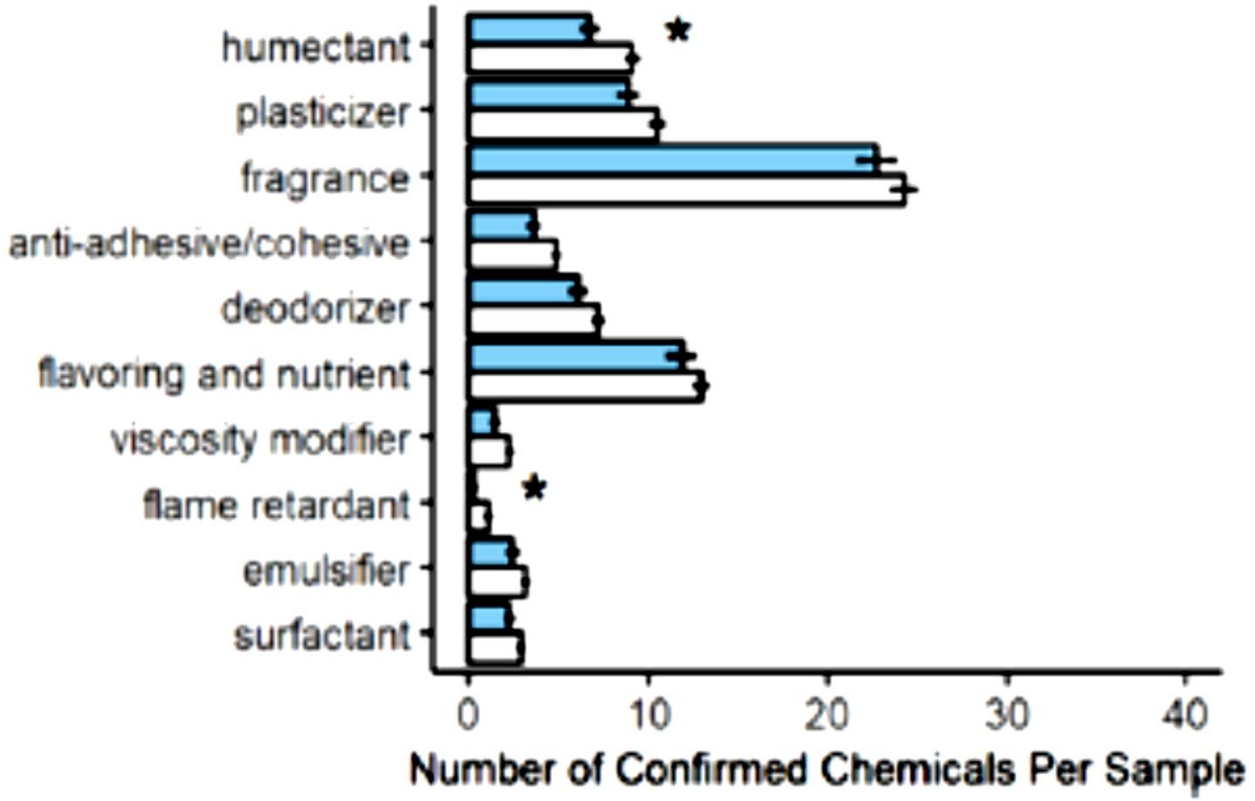
Issues Specific to Recycled Plastics (2)



Kato and Conte-Junior, 2021

Issues Specific to Recycled Plastics (4)





Lowe et al., ES&T, 2021

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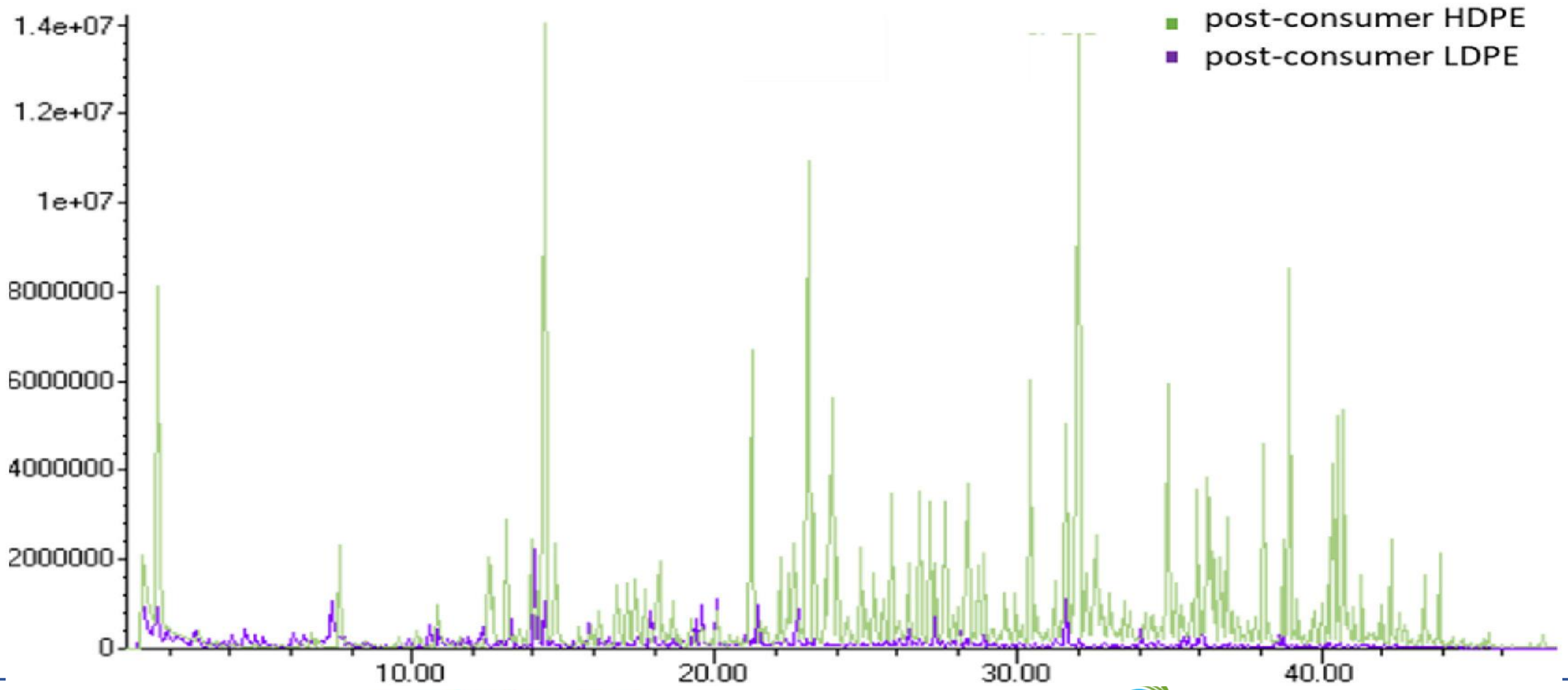
Issues Specific to Recycled Plastics (5a)



Horodytska et al., 2020

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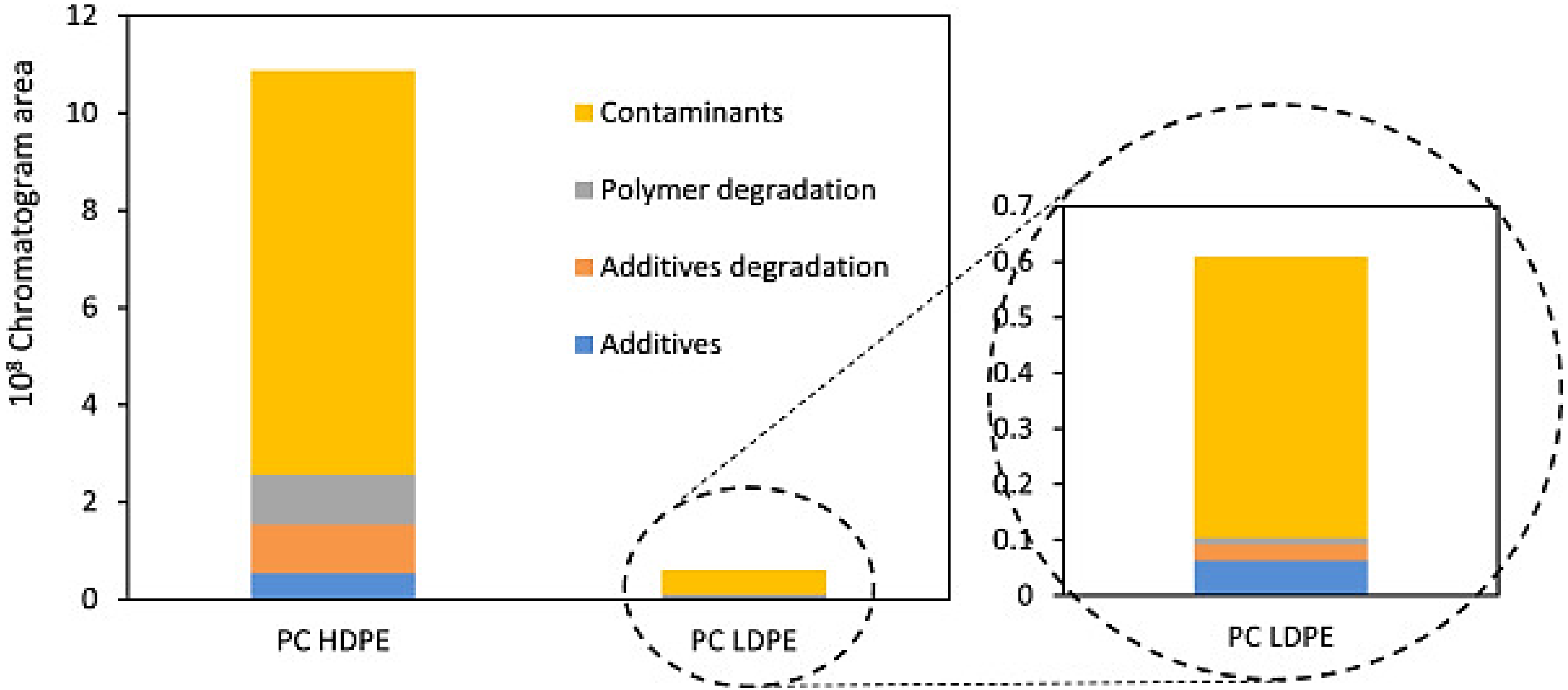
Issues Specific to Recycled Plastics (5b)



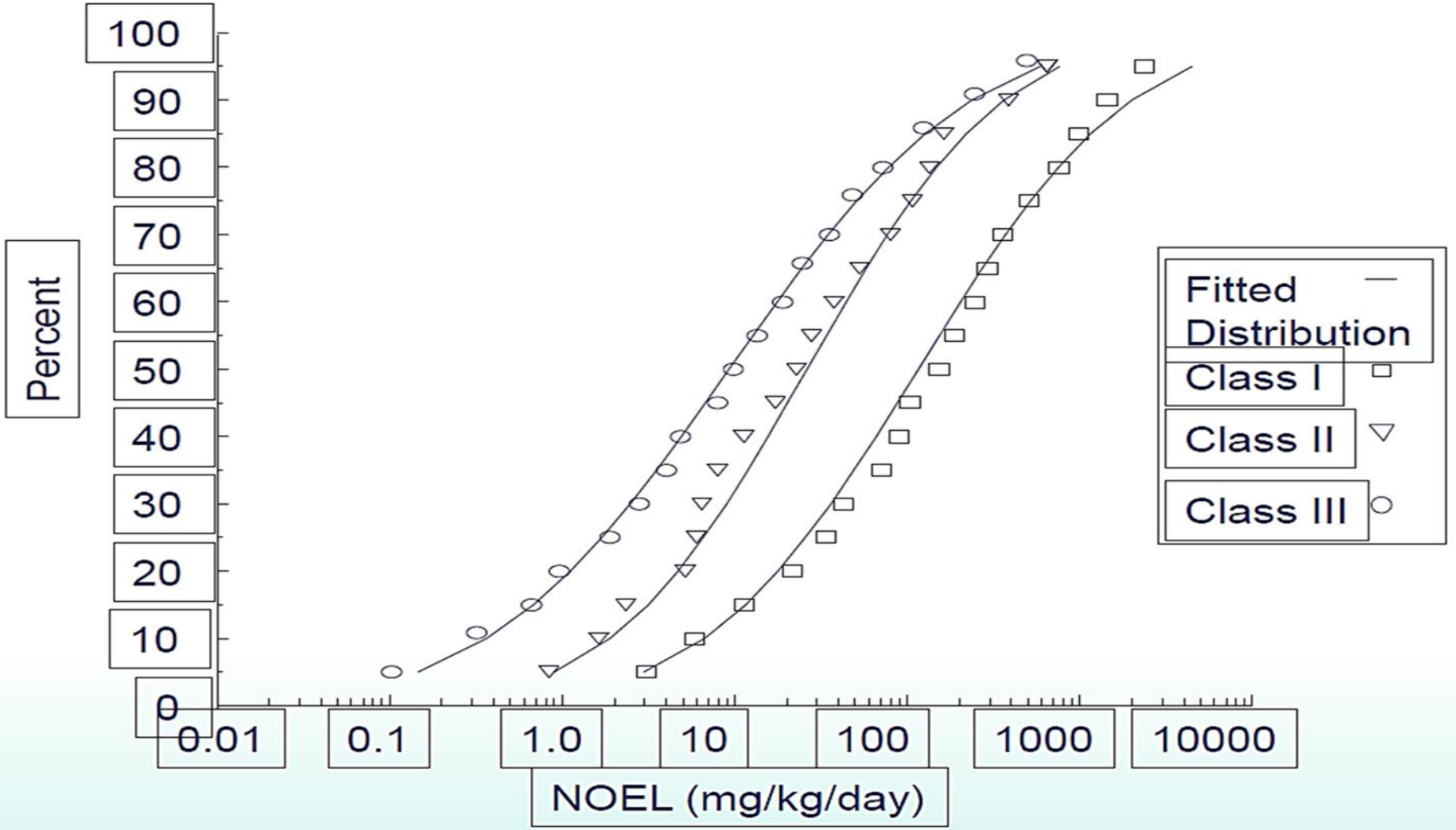
Horodytska et al., 2020

Issues Specific to Recycled Plastics (6)

- Any application for the **approval of use of a recycled plastic in food packaging must contain sufficient information (dossier) to demonstrate all human health considerations have been addressed.**
- Challenge tests have been designed using chemical contaminant surrogates which create a worse case scenario for migration.
- Contaminant surrogates are substances with different molecular weight and polarity representative of all possible contaminants of concern.
- FDA recommends the following:
  - Volatile Polar – Chloroform, Chlorobenzene, 1,1,1-Trichloroethane, Diethyl ketone
  - Volatile Non-Polar – Toluene
  - Heavy Metal - Copper(II) 2-ethylhexanoate
  - Non-Volatile Polar – Benzophenone, Methyl salicylate
  - Non-Volatile Non-Polar – Tetracosane, Lindane, Methyl stearate, Phenylcyclohexane, 1-Phenyldecane, 2,4,6-Trichloroanisole

- **Surrogate migration < 0.5 ppb** would generally be considered to be of negligible risk for a contaminant migrating from recycled plastic. (FDA limit)

Threshold of Toxicological Concern



Issues Specific to Recycled Plastics (7)

- Provide a complete description of the recycling process, starting from initial collection of the recycled feedstock from post-consumer use to the final fabrication of the product
- Effective sorting allows for food use and food type controls
- A complete description of the quality control program that demonstrates elimination and neutralization of chemical and microbial contaminants in the recycled materials

Conclusions

- Plastic waste created by the production and use for FPMs has created a market for the increased use of recycled plastics.

- A number of countries have introduced legislation **mandating the phase-out of single-use plastics and encouraging increased recycling of plastics (circular economy).**

- Vision **is that by 2030**, most/all plastic packaging placed on the EU market should be reusable or recyclable.

- Creating recycled plastics for food use **must recognize unique specific safety issues that are addressed through a fulsome risk assessment process**.


thank you
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danke
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teşekkür ederim
gracias
obrigado
dziękuję
bedankt
go raibh maith agat
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