

## Submission

### Impact of microplastics and other toxics on human health<sup>1</sup>

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## Background and Statement

This Submission is in relation to an online submission opportunity via the “Community Affairs References Committee”. It relates to the “Impact of microplastics and other toxics on human health” and terms of reference (noted below).

This submission is made on behalf of COPAR Pty Ltd<sup>2</sup>.

COPAR is an Australian owned company, manufacturing recyclable / compostable fibre based and bioplastic products.

### **Terms of Reference**

*The impact of microplastics, toxics and forever chemicals on human health, with particular reference to:*

- *the impact of microplastics, toxics and forever chemicals on reproductive health, including: women's fertility, hormonal disorders, endometriosis, polycystic ovary syndrome and premature menopause, in utero transmission of microplastics and the impact on placental function and foetal development, maternal health, including impacts on pregnancy outcomes like miscarriage, preterm birth and still birth, and fertility impacts across all populations, including men's fertility;*
- *disruption of key developmental pathways in the first 1,000 days of life that significantly impact later-life health outcomes like obesity, heart disease, diabetes and cognitive function;*
- *cardiovascular impacts, including links between microplastic accumulation in arterial plaque and increased risks of heart attack, stroke and cardiovascular mortality;*
- *links between endocrine disrupters and increased rates of cancer in young people, fertility issues, hormone dysregulation, respiratory diseases, inflammatory conditions and immune system dysfunction;*
- *the effectiveness of any education or informative efforts to notify the public of potential harms and prevention opportunities;*
- *the potential benefits of a national standard for consumer products;*
- *protocols and policies of other countries which have proven to be effective;*
- *the adequacy of current research, monitoring and measurement standards for microplastic contamination in Australia; and*
- *any other related matter.*

Whilst reference in the submission process notes that a submission of around four pages is best (“*concise, generally no longer than four to five pages*”) it would be a disservice to the amount and importance of research available on this subject not to list each with a summary.

The impact of plastics and chemicals upon human health is highly researched. Whilst some may say there is a lack of causal link and more research is required to act, there is a “weight of evidence<sup>3</sup>” that cannot be denied, possibly to the point of legal obligation.

Weight of evidence is also a concern around the Basel Convention<sup>4</sup>, where the committee needs to consider its requirements to human rights, both within Australia and internationally. Inaction in areas related to evident plastic issues, could place Australia in contravention of the convention it is a signatory to.

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<sup>2</sup> <https://copar.eco/pages/about-us>

<sup>3</sup> [https://www.law.cornell.edu/wex/weight\\_of\\_the\\_evidence](https://www.law.cornell.edu/wex/weight_of_the_evidence)

<sup>4</sup> <https://www.basel.int/>

Whilst most international cases are brought against petroleum companies, there is a heightened focus on government action and a “duty of care” where there may be a legal requirement to protect citizens and the environment from foreseeable harm caused by plastic.

Additionally, a case involving administrative law that could challenge a failure to perform a duty, or a decision that ignores environmental / health risks. This is noted in part within “*The Paradox Test in Climate Litigation*” (noted below).

As such, this submission will list each piece of research and provide a selective summary, that will enable the committee to ensure they make informed recommendations.

In regard at least to recycled plastic, the DCCEEW has stated<sup>5</sup> :

### *2.3 Principles to support the framework - 6.*

*Precautionary principle: If there are threats of serious or irreversible environmental or human harm arising from use of recycled content, lack of full scientific certainty should not be used as a reason for postponing measures to prevent such harm.*

**Weight of the evidence**<sup>6</sup> - Weight of the evidence refers to the believability or persuasiveness of evidence in terms of its probative value, not the quantity or amount. In *State v. Thomas*, weight of the evidence involved the tendency of credible evidence in the trial to support one side over the other.

It represents the degree to which evidence convinces triers of fact to either accept or reject a factual assertion.

This can apply to both a single piece of evidence and the cumulative effect of the entire collection of evidence presented on an issue, indicating its overall strength and reliability in proving or disproving a particular fact.

This evaluation helps in making legal or factual determinations in judicial or administrative proceedings.

**The Paradox Test in Climate Litigation**<sup>7</sup> - The courts are already being asked to declare as unlawful governmental decisions that breach human rights and statutory or constitutional protection of the environment.

This perspective article proposes that when presented with scientific evidence of habitat destruction in judicial review cases, the courts could examine whether a decision is unlawful and/or irrational.

This ‘Paradox Test’ would ask: (1) will the decision contribute to the destruction of the human habitat and (2) if so, is it justified on the ground of necessity?

It is proposed that a decision that failed such a test would be unlawful and irrational as contrary to what is arguably the most fundamental law of nature: species survival.

The weight of evidence seems to say that current worldwide plastic strategy and production processes are placing future generations at risk, with consequences too significant for the committee to ignore and allow Government to continue along the same path.

The risk of action by citizens and/or Governments themselves needs to be considered where continued research appears likely to show absolute proof of the damage of plastics (recycled or not) and where inaction following reasonable knowledge / evidence could carry legal liability.

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<sup>5</sup> <https://www.dceew.gov.au/sites/default/files/documents/national-framework-recycled-content-traceability.pdf>

<sup>6</sup> [https://www.law.cornell.edu/wex/weight\\_of\\_the\\_evidence](https://www.law.cornell.edu/wex/weight_of_the_evidence)

<sup>7</sup> <https://academic.oup.com/oacc/article/3/1/kgad005/7223729>

Whilst one or two pieces of research can be contested, a summary of more than one hundred is more difficult to ignore.

The following suggestions are made with the intention of seeking better transparency upon products, more circular outcomes (in part for the packaging industry) and better outcomes for the environment and human health.

- Mandate the Australian Recycling Logo (ARL) for all plastic products. This will assist consumers to better dispose of them and help keep waste out of the environment, that could break down into damaging microplastics.
- Make illegal any other symbols upon packaging that could confuse the consumer as to the product being recyclable.
- Regulate claims around sustainability upon plastic products (green label laws) that could confuse the consumer into making poor choices that could increase waste and landfill.
- More testing and auditing of migration of toxins (particularly for food contact products).
- The ARL declaration system (PREP) for plastic products needs a PFAS statement. Increase auditing/testing for PFAS in plastic content.
- Responsibly sourced PCR (pre and post-consumer recycled plastic content) should be preferred over PCR with no supply chain information. Look to SEDEX 4 pillars as increased volumes of recycled plastics just leads to more pickers etc in poor countries being exploited.
- A Government owned recycled content symbol or applied TM would reduce non-regulated imports, where imports are more likely to be problematic for toxins and general non-compliance.
- Increased research on the impact of recycled plastic on human health and the environment.
- Random test audits of products paid for from EPR gains on plastic products
- Tax incentives for companies who submit all products to testing and supply chains to review (as with responsibly sourced content).

## Health and Human Rights

- **Hazardous chemicals in recycled and reusable plastic food packaging**<sup>8</sup> - Food Packaging Forum Foundation, Zurich, Switzerland - Independent Consultant, Raleigh, NC, USA - May 2023

*reusing and recycling plastics can also lead to unintended negative impacts because hazardous chemicals, like endocrine disruptors and carcinogens, can be released during reuse and accumulate during recycling. In this way, plastic reuse and recycling become vectors for spreading chemicals of concern. This is especially concerning when plastics are reused for food packaging, or when food packaging is made with recycled plastics.*

*The data presented in this review are obtained from the Database on Migrating and Extractable Food Contact Chemicals (FCCmigex), which is based on over 800 scientific publications on plastic FCMs.*

***We provide systematic evidence for migrating and extractable food contact chemicals (FCCs) in plastic polymers that are typically reused, such as polyamide (PA), melamine resin, polycarbonate and polypropylene, or that contain recycled content, such as polyethylene terephthalate (PET).***

***These concerns about migration of hazardous chemicals and their impacts on human health are especially relevant for plastic food contact materials (FCMs) made from recycled plastics (Geueke et al., Reference Geueke, Groh and Muncke<sup>2018</sup>; Cook et al., Reference Cook, Derks and Velis<sup>2023</sup>) because unknown and/or hazardous chemicals can accumulate in recycled material and then migrate into foodstuffs, leading to chronic human exposure, as has been shown in the case of beverage bottles made from polyethylene terephthalate (PET) plastics (Gerassimidou et al., Reference Gerassimidou, Lanska, Hahladakis, Lovat, Vanzetto, Geueke, Groh, Muncke, Maffini, Martin and Iacovidou<sup>2022</sup>; Steimel et al., Reference Steimel, Hwang, Dinh, Donnell, More and Fung<sup>2022</sup>; Tsochatzis et al., Reference Tsochatzis, Lopes and Corredig<sup>2022</sup>).***

*Illicit plastic recycling, where non-food grade plastics containing hazardous brominated flame retardants are used to make FCMs, is prevalent, as data from the European, U.S. and Korean markets reveal (Samsonok and Puype, Reference Samsonok and Puype<sup>2013</sup>; Rani et al., Reference Rani, Shim, Han, Jang, Song and Hong<sup>2014</sup>; Turner, Reference Turner<sup>2018</sup>; Paseiro-Cerrato et al., Reference Paseiro-Cerrato, Ackerman, de Jager and Begley<sup>2021</sup>).*

*Additionally, technical limitations exist with respect to the recyclability of commonly used plastic food packaging into chemically safe recycled food packaging because of the inherent physico-chemical properties of the materials that hamper the efficient removal of chemical contaminants (Palkopoulou et al., Reference Palkopoulou, Joly, Feigenbaum, Papaspyrides and Dole<sup>2016</sup>). Especially concerning is the use of recovered plastic waste, for example, from ocean clean ups, for food contact applications, as persistent organic pollutants may be present (Gallo et al., Reference Gallo, Fossi, Weber, Santillo, Sousa, Ingram, Nadal and Romano<sup>2018</sup>).*

<sup>8</sup> <https://www.cambridge.org/core/journals/cambridge-prisms-plastics/article/hazardous-chemicals-in-recycled-and-reusable-plastic-food-packaging/BBDE514AAFE9F1ABB3D677927B343342>

***The information on chemical migration that is available in the FCCmigex database and summarised in this review shows that recycling and reuse of plastic FCAs implies that human exposure to hazardous chemicals increases if this aspect is not carefully managed.*** However, there is experimental evidence that recycled PET contains chemical contaminants that are introduced during use, waste handling and recycling and that can migrate into the packaged beverages.

***Associations have been found between the presence of recycled content and the migration of, for example, benzene and styrene (two carcinogenic chemicals) as well as the EDC BPA (Dreolin et al., Reference Dreolin, Aznar, Moret and Nerin<sup>2019</sup>; Thoden van Velzen et al., Reference Thoden van Velzen, Brouwer, Stärker and Welle<sup>2020</sup>).***

***Plastic recycling can introduce unknown or known hazardous chemicals originating from all stages of the life cycle as well as from illicit sources into food packaging and other plastic FCAs. Further concern stems from the observation that it is very difficult to discriminate virgin and recycled materials.***

- **Evaluation of chemicals leached from PET and recycled PET containers into beverages<sup>9</sup>** – US National Library of Medicine – unable to access in full - December 2022

*The use of recycled polyethylene terephthalate (rPET) containers, a recent shift in the beverage industry, poses new potential human health concerns including contamination from the original container; use of additives, detergents, and catalysts during recycling; and improper recycling practices.*

***The purpose of this analysis was to evaluate available data regarding: (1) chemicals leached from PET and rPET in bottle form; (2) concentration of these chemicals; and (3) trends between rPET percent and concentration of chemicals leached.***

***This analysis identified 211 scientific articles related to recycled plastic and leachables. Three articles met the inclusion criteria: (1) plastic was in bottle form; (2) plastic was made of PET or rPET; and (3) the study analyzed both PET and rPET using the same methods.*** This evaluation demonstrated that only nine compounds - benzene, styrene, acetaldehyde, 2-methyl-1,3-dioxolane, furan, bisphenol A (BPA), 2-buta-none, acetone, and limonene - have been studied.

***Notably, the leachable concentration of benzene, styrene, and BPA increased as the percent of recycled content increased from 0 to 100%.***

***Evidently, recycling PET can lead to changes in the leachables profile.***

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<sup>9</sup> <https://pubmed.ncbi.nlm.nih.gov/36521108/>

**Minderoo-Monaco Commission on Plastics and Human Health<sup>10</sup>** - March 2023

**Human Health Findings:** *Coal miners, oil workers and gas field workers who extract fossil carbon feedstocks for plastic production suffer increased mortality from traumatic injury, coal workers' pneumoconiosis, silicosis, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer.*

**Plastic production workers are at increased risk** *of leukemia, lymphoma, hepatic angiosarcoma, brain cancer, breast cancer, mesothelioma, neurotoxic injury, and decreased fertility.*

**Residents of "fenceline" communities adjacent to plastic production and waste disposal sites** *experience increased risks of premature birth, low birth weight, asthma, childhood leukemia, cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer.*

**Infants in the womb and young children** *are two populations at particularly high risk of plastic-related health effects. Because of the exquisite sensitivity of early development to hazardous chemicals and children's unique patterns of exposure, plastic-associated exposures are linked to increased risks of prematurity, stillbirth, low birth weight, birth defects of the reproductive organs, neurodevelopmental impairment, impaired lung growth, and childhood cancer.*

- **Risk assessment of recycled plastic products<sup>11</sup>** – University of Newcastle, Australia - May 2025

*Nonetheless, reports detailing the chemicals present in recycled plastic products raise concerns for human and environmental health. This is exacerbated by the lack of regulation governing recycled plastic applications, and the potential for leachates to be released from recycled plastic products.*

*To address this gap, comprehensive sequential investigations were conducted to investigate the properties, chemical fingerprints and environmental fate of recycled plastic products to better understand their potential risk to human and environmental health.*

*This thesis explores the interplay between recycling, chemical toxicity, effects on human health and terrestrial organisms, as well as the fate and behaviour of recycled plastic during ageing and weathering in aquatic environments.*

**This research has shown that levels of chemicals are higher in recycled plastics compared to virgin plastic products. Recycled microplastic particles revealed distinct effects on terrestrial organisms, including adverse effects on reproduction, alteration of the gut microbiome, and impacts on DNA and metabolites.**

**The leaching of PFAs is also observed in biological matrices (saliva, gastric and intestine juices) and the recycled plastic tends to leach more than virgin plastic which causes risk to human life.** *Consequently, we highlight a significant knowledge gap regarding recycled plastic and its toxicity, emphasizing the need to safeguard human health and environmental well-being in the recycling process.*

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<sup>10</sup> <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10038118/>

<sup>11</sup> [https://openresearch.newcastle.edu.au/articles/thesis/Risk\\_assessment\\_of\\_recycled\\_plastic\\_products/29038547](https://openresearch.newcastle.edu.au/articles/thesis/Risk_assessment_of_recycled_plastic_products/29038547)

- **Toxicity evaluation and prioritization of recycled plastic food contact materials using in silico tools<sup>12</sup>**

Journal of Hazardous Materials – May 2025 –

***This study assessed the toxicity of virgin and recycled plastic food contact materials (FCMs) at various recycling stages, migrated in four food simulants (water, 20 % ethanol, 4 % acetic acid, and n-heptane), using cytotoxicity and high-content screening (HCS) bioassays.***

*Toxicity was correlated with migrating substances identified through chemical analyses, and samples were ranked by toxicity priority.*

*Nonetheless, the negative effects on cell viability and HCS parameters were mostly mitigated at the final pellet stage. In HepaRG cells exposed to 4 % acetic acid, antimony negatively correlated with cell viability and positively with cellular area, indicating its role in rPET-induced necrosis. ToxPi ranking identified vPET migration in n-heptane and water as top priorities given the nephrotoxic risks. This study emphasizes refining recycling methods and testing plastics to minimize FCM cytotoxicity.*

#### 4. Discussion

***Despite strict regulations regarding chemicals intended for use in FCMs, concerns remain about their safety because of the potential migration of unknown chemicals [16].*** Compared with the solvent control, exposure to the FCM migration solutions resulted in even lower cell viability. This indicates that the cytotoxic effect on BALB/c 3T3 cells might be attributed to the migrating chemical substances in the migration solutions, with 20 % ethanol causing the most severe reduction in cell viability.

***This indicates that alcoholic foods might cause a more significant release of harmful substances from recycled plastic FCMs than in other types of foods. In plastic materials, exposure to migration solutions of rPET, regardless of the food simulant, led to the highest percentage of reduced cell viability.***

*Summarizing the HCS results, the particular toxicity of rPET bales and flakes to HepaRG and HK-2 cells was observed after exposure to 4 % acetic acid and 20 % ethanol.*

***These results propose that migrating substances from plastic materials could induce specific toxic effects on the kidney or liver depending on the food substances and type of plastic involved.***

***These observations indicate that packaging acidic foods in rPET may lead to Sb release, which could contribute to liver cell necrosis.***

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<sup>12</sup> <https://www.sciencedirect.com/science/article/pii/S0304389425003796>

- **Recycled plastic can affect hormone systems<sup>13</sup>** - University of Gothenburg & Leipzig – June 2025

*A single pellet of recycled plastic can contain over 80 different chemicals.*

***A new study with researchers from University of Gothenburg and Leipzig shows that recycled polyethylene plastic can leach chemicals into water causing impacts in the hormone systems and lipid metabolism of zebrafish larvae.***

**Recycled plastic is a toxic cocktail: Over 80 chemicals found in a single pellet<sup>14</sup>** – Science Daily (citing University of Gothenburg - above) - June 25

**Summary:**

*Recycled plastic pellets can release a hidden mix of over 80 chemicals into water, disrupting hormones and fat metabolism in zebrafish larvae.*

***Researchers warn that unknown and toxic additives make current recycling practices dangerously unpredictable.***

**Story Content:**

*A single pellet of recycled plastic can contain over 80 different chemicals. A new study with researchers from University of Gothenburg and Leipzig shows that recycled polyethylene plastic can leach chemicals into water causing impacts in the hormone systems and lipid metabolism of zebrafish larvae.*

***Increasing gene expressions***

*In a new study, researchers bought plastic pellets recycled from polyethylene plastic from different parts of the world and let the pellets soak in water for 48 hours.*

***After which zebrafish larvae were exposed to the water for five days. The experimental results show increases in gene expression relating to lipid metabolism, adipogenesis, and endocrine regulation in the larvae.***

***"These short leaching times and exposure times are yet another indicator of the risks that chemicals in plastics pose to living organisms.***

*The impacts that we measured show that these exposures have the potential to change the physiology and health of the fish," says Azora König Kardgar, lead author and researcher in ecotoxicology at the University of Gothenburg.*

***"Never full knowledge"***

***Previous research has shown similar effects to humans, including threats to reproductive health and obesity, from exposure to toxic chemicals in plastics.***

***Some chemicals used as additives in plastics and substances that contaminate plastics are known to disturb hormones, with potential impacts on fertility, child development, links to certain cancers, and metabolic disorders including obesity and diabetes.***

***"This is the main obstacle with the idea of recycling plastic. We never have full knowledge of what chemicals will end up in an item made of recycled plastic.***

***And there is also a significant risk of chemical mixing events occurring, which render the recycled plastic toxic,"*** says Bethanie Carney Almroth, professor at the University of Gothenburg and principal investigator on the project.

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<sup>13</sup> <https://www.gu.se/en/news/recycled-plastic-can-affect-hormone-systems>

<sup>14</sup> <https://www.sciencedaily.com/releases/2025/06/250623072802.htm>

### **Different chemicals**

*Apart from the study on the impact that recycled plastics have on zebra fish larvae, the researcher also conducted a chemical analysis of the chemicals leaching from the plastic pellets to the water. And they found a lot of different chemical compounds, but the mixture altered between different samples of pellets.*

**"We identified common plastics chemicals, including UV-stabilizers and plasticizers, as well as chemicals that are not used as plastics additives, including pesticides, pharmaceuticals and biocides.**

*These may have contaminated the plastics during their first use phase, prior to becoming waste and being recycled. This is further evidence of the complicated issue of plastics waste flows, and of toxic chemicals contaminating recycled plastics," says Eric Carmona, researcher at Department of Exposure Science, Helmholtz Centre for Environmental Research in Leipzig.*

### **"Ban hazardous chemicals"**

*Representatives from the nations of the world are preparing to head to Geneva, Switzerland, in August, for what is planned to be the final negotiating meeting for a Global Plastics Treaty at the Intergovernmental Negotiating Committee under the United Nations Environmental Program. The authors of the work stress that negotiators and decision-makers must include provisions to ban or reduce hazardous chemicals in plastics, and to increase transparency and reporting along plastics value chains.*

**Plastics cannot be recycled in a safe and sustainable manner if hazardous chemicals are not addressed.**

*"This work clearly demonstrates the need to address toxic chemicals in plastics materials and products, across their life cycle," says Professor Bethanie Carney Almroth.*

**"We cannot safely produce and use recycled plastics if we cannot trace chemicals throughout production, use and waste phases."**

- **Recycling warning! Reconfiguring the toxic politics of a circular economy<sup>15</sup>** - KTH Royal Institute of Technology, Stockholm, Sweden – September 2022

### **Introduction**

**The dispersion of hazardous substances<sup>Footnote1</sup> in a circular economy has previously been highlighted as an anomaly, as a consequence of inferior, uncontrolled, and immoral recycling.**

*For example, when electrical waste is exported from the global north to the south where plastic and rubber are burned to quickly access the precious metals, with risk to human health and the environment (Man et al. [2013](#)).*

**However, it is less noticed that also formal, or to be more precise, industrial recycling and reuse can increase the distribution, dilution and accumulation of hazardous substances (Johansson et al. [2020](#)).**

*Researchers and NGOs have uncovered the unintentional recycling of hazardous substances into new articles.*

**Elevated levels of hazardous substances from recycling have been identified in, for example, consumer articles such as toys (Chen et al. [2009](#); DiGangi and Strakova [2015](#); Guzzonato et al. [2017](#)), kitchen utensils (Samsonek and Puype [2013](#); Turner and Filella [2017](#); Kuang et al. [2018](#)), **food packaging** (Jurek and Leitner [2017](#); Abdallah et al. [2018](#); Geueke et al. [2018](#)), and industrial products such as fertilizers (Johansson and Krook [2021](#)).**

<sup>15</sup> <https://link.springer.com/article/10.1007/s11625-022-01220-0>

### **Hazardous substances in a circular economy**

*In addition, different types of materials and substances are usually mixed during waste collection. For example, even in the separate collection of plastic waste, different types of polymers from different products and time-periods are typically mixed. Modern recycling plants can separate some polymers from each other.*

*However, depending on the use, different additives are added to the plastic such as plasticizers and flame retardants that make even products made of the same polymers substantially different.*

***As a result, secondary plastics tend to be significantly more contaminated than their virgin counterpart (Groh et al. 2019).***

### **The non-regulation of hazardous substances**

*The European Union has arguably the strictest legislation of hazardous substances in the world (EU 2020b).*

*Approximately 26,000 substances have been registered in the region (ECHA 2022d).*

*However, given that more than 200,000 substances are estimated to be present in the European economy (ECHA 2022e), only about 15% of all substances are registered.*

***Many substances remain unregistered since EU's chemical legislation, REACH, requires registration only when more than 1 tonne per year of a specific substance is manufactured or imported (EU 2006:6(1)). Thereby, direct imports for personal use are generally exempted from REACH.***

***Hence, elevated levels of hazardous substances have repeatedly been identified in waste-based plastic products with a risk of exposure such as toys and food contact articles (Abdallah et al. 2018; Geueke et al. 2018; Chen et al. 2009), with the consequence of increased risk of leaching (Greassimidou et al. 2022).***

*Elevated levels of SVHC are, therefore, partially permitted in circulated products.*

***For example, according to annex XVII in REACH (EU 2006), the threshold limit for cadmium in new plastics is 0.01% cd, while the limit for recycled plastic is 0.1%, and thus 10 times higher.***

*In the Stockholm Convention (2001:4(3)) there are also stated possibilities for countries to exempt products from the regulation of POPs based on recycled material.*

- **Towards clean material cycles: Is there a policy conflict between circular economy & non-toxic**

**environment?**<sup>16</sup> – KTH Royal Institute of Technology, Stockholm, Sweden / University of Leeds, UK / Lund University, Sweden - July 2020

***This means that the outputs from recycling processes (e.g. secondary plastic, paper and metal scrap) may contain higher levels of non-intentionally added substances than their virgin counterparts.***

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<sup>16</sup> <https://journals.sagepub.com/doi/10.1177/0734242X20934251>

*These substances might not have been exhaustively tested for toxicity before being added in the first place, and may be classified today as hazardous. Furthermore, prohibited ‘legacy substances’ may remain in the material economy for a long time, through products with a long designed-in lifetime, bringing a false belief of ‘problem solved’.*

***However, how much is the allowable risk of contamination (and split into relevant risk considerations: eco- and human; cancer and non-cancer)?***

***How much of this risk is exacerbated by the aspired re-circulation of after-use resources? How can one exclude that a combination of chemicals creates a cocktail effect?***

*Whereas there can be no generalized answers to these questions, we may as well admit that we generally do not know enough yet to develop evidence-based policies.*

*Despite stunning advances of toxicology, epidemiology and wider public health, there is no exact science for how the limit values shall be calculated, which means that they can differ greatly between different countries and evolve in time.*

*A ‘Garden of Eden’ fantasy (Skene, 2018) based on non-toxic material cycles will not be of much help to the actors who will be left to deal with the myriad of hazards that will be too important to ban, and, at the same time, they will feel the pressure to increase the level of circulation.*

*Therefore, the continued development of a circular economy needs strategies based on the scientifically sound assessment of where hazardous substances actually exist in products to be circulated, enhancing the capacity to successfully deal with risk mitigation.*

***Otherwise, there is a risk that we will have a circular economy laden with hazardous substances or a society without optimal resource circulation.***

- **Overview of known plastic packaging-associated chemicals and their hazards<sup>17</sup>** – Food Packaging Forum

Foundation, Zurich, Switzerland - University of Gothenburg, Gothenburg, Sweden - International Chemical Secretariat (ChemSec), Gothenburg, Sweden - Vrije Universiteit Amsterdam, the Netherlands - Independent Consultant, Germantown, MD, USA - Centre for Sustainable Development (GMV), University of Gothenburg, Gothenburg, Sweden - School of Medicine, New York University, New York, USA - CHEM Trust, London, United Kingdom – September 2018

For example, PAHs are often found in the PS polymer or in some additives, e.g., carbon black (Li et al., 2017), and **‘legacy’ chemicals such as flame retardants have been detected in recycled plastics** (Andra et al., 2012; Filella and Turner, 2018; Leslie et al., 2016; Pivnenko et al., 2017; Rani et al., 2014; Samsonek and Puype, 2013).

**Many of these chemicals are classified as carcinogenic or have other highly hazardous properties, while others have never been tested.**

Though it can be difficult to control these impurities in the first place, their presence in plastics should not be simply disregarded but rather seen as an additional aspect to be considered when making decisions on the (future) use of a particular polymer for a specific application.

**Paying attention to impurities and contaminants is also important when evaluating the potential health effects of increasing levels of recycled content in products** (Geueke et al., 2018).

<sup>17</sup> <https://www.sciencedirect.com/science/article/pii/S0048969718338828?via%3Dihub>

- **Plastic recycling: A panacea or environmental pollution problem<sup>18</sup>** – Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Kanagawa, Japan - Dalhousie University, Halifax, Canada – August 2024

#### **Environmental impacts of recycling**

*However, a notable limitation in several standard LCA methodologies lies in omitting a crucial factor—the long-term fate of chemicals and particulates released during EoL plastic<sup>1,45</sup>.*

***The disadvantage of existing short-term LCAs in disregarding the consequences of chemical and particulate releases raises concerns about the overall efficacy of plastics and recycling as a solution to plastic pollution. This gap in evaluating the true ecological footprint of virgin and recycle plastics (i.e., raw materials transported to a waste recycling facility for processing into a new materials or products) may result in unintended environmental and health costs.***

***Recycling facilities have been identified as potential hotspots and contributors of toxic and hazardous waste, however, there is limited attention to chemical or particle release from plastic recycling facilities.***

*Despite the current and emerging technologies to recycle plastic waste, non-recoverable tiny plastic particles (microplastics) cannot be addressed with existing collection methods due to their exceptionally small size. Further, the size reduction and washing during mechanical recycling facilities tend to release significant microplastics into the environment<sup>46</sup>.*

*About 13% of plastics infiltrate water or air as microplastics from recycling facilities in the UK<sup>47</sup>.*

*A study on PET recycling facilities reveals microplastic releases range from approximately 23–1836 mg/L in wastewater that is distributed in the effluent (8–83 mg/L) and the sludge (52,166–68,866 mg/L) as it leaves the facility<sup>48</sup>. Microplastics generated during the recycling process are governed by the properties of plastics (polymer type or hardness) and environmental exposure<sup>46</sup>.*

*Ideally, plastic recycling facilities are equipped with filters to prevent and mitigate environmental contamination, but it partially mitigates microplastic release and is not a comprehensive solution<sup>47</sup>.*

***Additionally, the leaching of harmful plastic chemicals during and after recycling also poses a significant threat<sup>29</sup>. Recycled plastics exhibit higher levels of hazardous chemicals such as brominated flame retardants as legacy contaminants.***

***The contamination not only hinders the wide application, it also poses health risks for workers and end-users<sup>12</sup>.***

*With this, it is imperative to produce toxic chemical-free material through controls over what is being recycled and standards for recycled plastics and their usability in different sectors.*

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<sup>18</sup> <https://www.nature.com/articles/s44296-024-00024-w>

- **Plastic's toxic additives and the circular economy**<sup>19</sup> – Regional Activity Centre (for Sustainable Consumption and Production) – United Nations Environment Program – Mediterranean Action Plan Barcelona Convention - BRS Conventions - IPEN - September 2020

*It is almost impossible for families and children to avoid exposure to chemical additives:*

*Children's toys. **"Recycled plastics" – plastics from a variety of sources that have been melted down and re-formed – are used to make children's toys and have been shown to contain many banned, restricted, or otherwise hazardous chemicals.***

***A lack of manufacturer transparency, inadequate recycling regulation, and poor labelling allows this practice to continue.***

*There is no doubt that there is an urgent need to address the sources of plastic pollution, and in particular the additives used in plastics, to allow a proper implementation of circular economy strategies, to avoid the presence of banned toxic chemicals in products made from recycled materials, and to reduce the risk to human health and the environment.*

*Recyclers and promoters of a circular economy approach are currently facing multiple environmental and technological challenges in dealing with plastic streams.*

***The presence of POPs and other toxic or potentially toxic substances in plastic products has a negative impact on the environment and human health, and impacts on all phases of the life cycle of plastic products.***

***Toxic additives need to be substituted with non-chemical alternatives or non-toxic substances to make recycling easier and to avoid contaminating recycled materials with toxic chemicals, including those which are already banned under the existing chemical agreements, and to reduce the consumption of virgin materials (2).***

*In large part, industry's efforts have been focused only on addressing waste and/or increasing the use of recycled content with the intention of keeping materials in the value chain longer (10). But in practice industry is currently cycling materials that were never optimised for human and environmental health. For example, polymeric materials such as foam, plastic food packaging, paper, rubber and textiles can contain flame retardants, softeners, plasticisers, coatings, modifiers, catalysts, other performance enhancing additives and residuals.*

*When they are recycled into new products, the output tends to be highly contaminated, non-homogeneous, and impure even for toys and food contact materials (11) (12) (13) (14) (15).*

*The output is complex to assess thoroughly for toxicological impacts; hence inadvertently humans and the environment are increasingly exposed to risk through a number of recycled products and materials.*

***In Asia, customs officers have had to impound imports registered as "recyclable plastics" because they contained an undefined mixture of plastic types and other municipal and industrial waste.***

***Many countries have now banned, or are proposing to ban, plastic waste imports.***

***During the recycling process, other plastic is also impacted by toxic substances where they were originally not used even in food contact materials (77) (78) (79) (80).***

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<sup>19</sup> [https://ipen.org/sites/default/files/documents/plastics\\_and\\_additives\\_final-low-o-en.pdf](https://ipen.org/sites/default/files/documents/plastics_and_additives_final-low-o-en.pdf)

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact**

**during their use, disposal and recycling**<sup>20</sup>. - University of Leeds, Woodhouse Lane, Leeds, United Kingdom - POPs Environmental Consulting, Schwäbisch Gmünd, Germany – February 2018

***Despite how useful these additives are in the functionality of polymer products, their potential to contaminate soil, air, water and food is widely documented in literature and described herein.***

*These additives can potentially migrate and undesirably lead to human exposure via e.g. food contact materials, such as packaging.*

***They can, also, be released from plastics during the various recycling and recovery processes and from the products produced from recyclates.***

***Whereas in the Global North plastics production, use and recycling is regulated to varying degrees, in many developing countries plastic recycling is often not controlled by an appropriate regulatory framework, and environmental protection is poorly enforced, resulting in significant contamination of the ambient environment in areas where plastic is recycled [19].***

*Uncontrolled recycling can also result in the transfer of potentially harmful substances or PoTSs into plastics for sensitive uses, such as children's toys and food contact materials [20], [21], [22], [23].*

*Some processes for cascading involve innovative uses for plastic waste, with untested potential for dispersion into the environment and associated unknown pollution.*

*For instance, brominated flame retardants including POPs, phosphorous flame retardants and phthalates have been found in children toys from recycling [20], [177], [178]. BFRs have also been detected in food contact materials and household products [22], [179].*

*Pivnenko et al. [180] studied a number of selected phthalates in samples of virgin, waste and recycled plastics, and concluded that DBP, DiBP and DEHP had the highest frequency of detection in the samples analysed, with 360  $\mu\text{g g}^{-1}$ , 460  $\mu\text{g g}^{-1}$  and 2700  $\mu\text{g g}^{-1}$  being the maximum concentrations measured, respectively [180].*

***Huang et al. [183] demonstrated that the exhaust gases emitted from plastic waste recycling granulation have an effect on the ambient environment in Xingtian, Guangdong, China [183].*** *Also PAHs were detected inside and outside of the recycling granulation plants in the area.*

### **Conclusion**

***Given the current situation on what can be placed on the market, while in compliance with all legal requirements that ensure the safety of plastic food contact materials, it can be concluded that only a limited part of the plastic waste stream might not be suitable for recycling purposes.***

<sup>20</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X>

- **The role of safe chemistry and healthy materials in unlocking the circular economy**<sup>21</sup>- Ellen MacArthur Foundation – Google – 2018

*While it's necessary to eliminate and avoid certain problematic chemistries in the supply chain and in our products, we also know that a restricted substance list approach is fundamentally inadequate because it doesn't designate what is safe or preferred for use.*

*We need a strategy that proactively assesses and screens material chemistry to avoid regrettable substitutions and reduces the toxicity of the materials circulating in commerce.*

*This continues to present a fundamental dilemma—how can a chemist or a product designer optimize material chemistry for human and environmental health when we lack transparency into chemical ingredient data and their impacts?*

***Toxicity data still isn't available for many human and environmental health endpoints.***

***Animal testing has been significantly reduced over the last three decades due, in part, to voluntary or government bans, ethical issues and cost.***

***If companies do engage in animal testing, they often don't make those studies available to the public or scientific community.***

***More importantly, this means that we are currently cycling materials that were never optimized for human and environmental health.***

*For example, polymeric materials such as foam, plastic food packaging, paper, rubber and textiles contain a range of coatings, modifiers, catalysts, residuals, and other performance enhancing additives.*

***When we recycle them into the current system, the output tends to be highly contaminated, non-homogeneous, and impure.***

*It is very difficult to assess them thoroughly for toxicological impacts.*

*It's certainly not feasible to obtain full formulation information of mixed streams since there is no molecular chain of custody, and it would be impractical to attempt to reverse engineer a contaminated lot of material to identify all chemical constituents.*

***The chemical variability of these recycled material feedstreams begs the question: If we close the loop on materials and include recycled content in products, does that create the unintended consequence of simply moving our toxic legacy from a landfill into our homes and offices?***

*We believe the two must not be mutually exclusive.*

*However, the reality is that if recycling technology maintains its current path, we will undermine all of our efforts in designing and implementing safer materials when those optimized materials are recycled and co-mingled in a dirty system.*

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<sup>21</sup> <https://content.ellenmacarthurfoundation.org/m/1a270dba9b937bb/original/The-role-of-safe-chemistry-and-healthy-materials-in-unlocking-the-circular-economy.pdf>

- **Occurrence of brominated flame retardants in black thermo cups and selected kitchen utensils purchased on the European market<sup>22</sup>** - InSite pro testovani a certifikaci, a.s., Trida Tomase Bati 299, Zlin, Czech Republic – July 2013

*In order to screen for the presence of a recycled polymer waste stream from waste electric and electronic equipment (WEEE), a market survey was conducted on black plastic food-contact articles (FCA).*

*Newer types of BFRs such as tetrabromobisphenol A (TBBPA), tetrabromobisphenol A bis(2,3-dibromopropyl), ether (TBBPA-BDBPE) and decabromodiphenylethane (DBDPE), replacing the polybrominated diphenylethers (PBDEs) and polybrominated diphenyls (PBBs), were also identified. In none of the tested samples were PBBs or hexabromocyclododecane (HBCD) found.*

*Polymer identification was carried out using Fourier-transformed infrared spectroscopy measurement (FTIR) on all samples.*

*The results indicate that polypropylene-polyethylene copolymers (PP-PE) and mainly styrene-based food-contact materials, such as acrylonitrile-butadiene-styrene (ABS) have the highest risk of containing BFRs.*

- **“Chemical Recycling” Is a Toxic Trap<sup>23</sup>** – National Resources Defence Council – March 2025

*NRDC’s new issue brief “More Recycling Lies” confirms and expands on our previous findings: So-called “chemical recycling” is mostly plastic incineration.*

*The term “chemical recycling” is used by the plastic industry to refer to a number of different technologies that include pyrolysis, gasification, solvolysis, and solvent-based purification. The plastic industry, however, is pushing one of these technologies above all others: pyrolysis.*

*Pyrolysis (along with gasification) is a form of incineration with serious toxic impacts and is regulated as such under the federal Clean Air Act.*

*Yet pyrolysis can’t actually recycle much—if any—plastic. A 2023 study by scientists from the Department of Energy’s National Renewable Energy Lab (NREL) found that when pyrolysis is used to process plastic waste, only 0.1 to 6 percent of this plastic waste can become new plastic.*

*NREL scientists also concluded that “the economic and environmental metrics of pyrolysis and gasification are currently 10 to 100 times higher than virgin polymers.” In other words, it would be cheaper and environmentally preferable to make plastic from virgin fossil fuels than to try to use pyrolysis or gasification to turn plastic waste into new plastic products.*

*What pyrolysis mostly produces is fuels, yet fuel production and use do not constitute “recycling.”*

*What’s more, these fuels can be highly toxic. In 2023, the U.S. Environmental Protection Agency (EPA) approved 18 new chemical mixtures derived from plastic waste for use as fuels, even though EPA scientists had also determined that some of these chemicals posed astoundingly high cancer risks.*

<sup>22</sup> <https://pubmed.ncbi.nlm.nih.gov/24040839/>

<sup>23</sup> <https://www.nrdc.org/resources/chemical-recycling>

***One of the chemical mixtures, intended to be used as jet fuel, was estimated to pose a one in four cancer risk (meaning that one in every four people regularly exposed to it throughout their life would likely develop cancer). The EPA later rescinded the approvals and is reassessing the chemicals.***

*At the same time, the pyrolysis process creates large amounts of hazardous waste. EPA reporting data shows that between 2021 and 2024, just three pyrolysis facilities that were processing plastic waste generated more than 2 million pounds of hazardous waste and shipped it off-site for disposal.*

**Read the full issue briefs:**

More Recycling Lies: What the Plastics Industry Isn't Telling You About "Chemical Recycling" - Issue Brief (PDF)<sup>24</sup>

Recycling Lies: "Chemical Recycling" of Plastic Is Just Greenwashing Incineration - Issue Brief (PDF)<sup>25</sup>

"Chemical Recycling" Is Not Recycling: The Plastic Industry Is Greenwashing Incineration - Fact Sheet (PDF)<sup>26</sup>

- **Evidence of waste electrical and electronic equipment (WEEE) relevant substances in polymeric food-contact articles sold on the European market<sup>27</sup>** - Institute for Testing & Certification, Zlin , Czech Republic – Feb 2017  
*In order to confirm the possibility that recycled fractions from the waste electrical and electronic equipment (WEEE) stream were illegally entering the European market in black polymeric food-contact articles (FCAs), bromine quantification, brominated flame retardant (BFR) identification combined with WEEE-relevant elemental analysis and polymer impurity analysis were performed.*

*From the 10 selected FCAs, seven samples contained a bromine level ranging from 57 to 5975 mg kg<sup>-1</sup>(1), which is lower than expected to achieve flame retardancy.*

***The BFRs that were present were tetrabromobisphenol A (TBBPA), decabromodiphenylether (decaBDE), decabromodiphenylethane (DBDPE) and 1,2-bis(2,4,6-tribromophenoxy)ethane (BTBPE).***

***Typical elements used in electronic equipment and present in WEEE were detected either at trace level or at elevated concentrations.***

<sup>24</sup> [https://www.nrdc.org/sites/default/files/2025-03/More\\_Recycling\\_Lies\\_IB\\_25-02-A\\_07\\_locked.pdf](https://www.nrdc.org/sites/default/files/2025-03/More_Recycling_Lies_IB_25-02-A_07_locked.pdf)

<sup>25</sup> <https://www.nrdc.org/sites/default/files/chemical-recycling-greenwashing-incineration-ib.pdf>

<sup>26</sup> <https://www.nrdc.org/sites/default/files/chemical-recycling-plastic-greenwashing-incineration-fs.pdf>

<sup>27</sup> <https://pubmed.ncbi.nlm.nih.gov/25599136/>

- **Evidence of bad recycling practices: BFRs in children's toys and food-contact articles<sup>28</sup>** –

University of Birmingham, Birmingham – July 2017

***Brominated flame retardants (BFRs) have been used intentionally in a wide range of plastics, but are now found in an even wider range of such materials (including children's toys and food contact articles) as a result of recycling practices that mix BFR-containing waste plastics with "virgin" materials.***

*In this study Br was quantified in toy and food contact samples on the assumption that its concentration can be used as a metric for BFR contamination.*

***61% of all samples were Br positive: of these samples, 45% had decaBDE concentrations exceeding the concentration limits for PBDEs and their main constituent polymer was - according to the REE signature of such samples - Acrylonitrile Butadiene Styrene (ABS), uses of which include copying equipment, laptops and computers.***

- **Brominated flame retardants in black plastic kitchen utensils: Concentrations and human exposure implications<sup>29</sup>** - University of Birmingham, Birmingham, UK – January 2018

***Concerns exist that restricted brominated flame retardants (BFRs) present in waste polymers may have, as a result of recycling, inadvertently contaminated items not required to meet flame retardancy regulations (e.g. plastic kitchen utensils).***

*To investigate the extent to which kitchen utensils are contaminated with BFRs and the potential for resultant human exposure, we collected 96 plastic kitchen utensils and screened for Br content using a hand-held X-ray fluorescence (XRF) spectrometer.*

***Of our target BFRs, BDE-209 was the most abundant one in most samples, but an extremely high concentration (1000µg/g) of BTBPE was found in one utensil. Simulated cooking experiments were conducted to investigate BFR transfer from selected utensils (n=10) to hot cooking oil, with considerable transfer (20% on average) observed.***

- **Navigating the Challenges of Using Recycled Plastics in Food Contact Materials<sup>30</sup>** – SGS – July 2025

*The idea of 'use, recycle, re-use' is appealing, but there are several risks associated with the recycling of plastics, particularly for food contact materials.*

*While monitoring supply chains from raw material to finished product is feasible with virgin plastic, traceability and contamination control become significantly more complex when using recycled materials.*

***Using recycled plastic in food contact materials introduces the risk of contamination, such as:***

***Non-food-grade plastics entering the recycling system***

***Residual chemicals from previous uses (e.g. solvents, inks, adhesives)***

<sup>28</sup> <https://pubmed.ncbi.nlm.nih.gov/28636053/>

<sup>29</sup> <https://pubmed.ncbi.nlm.nih.gov/28847134/>

<sup>30</sup> <https://www.sgs.com/en-au/news/2025/07/cc-2025-q2-navigating-the-challenges-of-using-recycled-plastics-in-food-contact-materials>

***Microbiological contamination due to inadequate cleaning***

***Heat-induced degradation of plastic products***

***Recycling can amplify contamination risks as, each time the plastic is recycled and reused, pollutants can accumulate in the material.***

***Harmful substances, such as endocrine disruptors and carcinogens, could migrate into food or beverages, potentially posing long-term health risks.***

- **Characterization of Composition and Structure–Property Relationships of Commercial Post-Consumer**

**Polyethylene and Polypropylene Recyclates**<sup>31</sup> Institute of Polymeric Materials & Testing, Johannes Kepler University Linz Linz, Austria – May 2021

***Five recycling companies from the Austrian and German markets were asked to supply their purest high-quality rPE and rPP grades.***

*These were characterized by differential scanning calorimetry (DSC), thermo-gravimetric analysis (TGA), and Fourier-transform infrared (FTIR) spectroscopy, and micro-imaging. Technological characterization included density measurements, determination of the melt flow rate (MFR), and Charpy impact testing.*

***All recyclates contained diverse contaminants and inclusions ranging from legacy fillers like calcium carbonate to polymeric contaminants like polyamides or polyolefin cross-contamination.***

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact**

**during their use, disposal and recycling**<sup>32</sup> - School of Civil Engineering, University of Leeds, UK - POPs Environmental Consulting, Schwäbisch Gmünd, Germany – October 2017

*Despite how useful these additives are in the functionality of polymer products, their potential to contaminate soil, air, water and food is widely documented in literature and described herein.*

*These additives can potentially migrate and undesirably lead to human exposure via e.g. food contact materials, such as packaging. They can, also, be released from plastics during the various recycling and recovery processes and from the products produced from recyclates.*

***Whereas in the Global North plastics production, use and recycling is regulated to varying degrees, in many developing countries plastic recycling is often not controlled by an appropriate regulatory framework, and environmental protection is poorly enforced, resulting in significant contamination of the ambient environment in areas where plastic is recycled [19].***

<sup>31</sup> <https://www.mdpi.com/2073-4360/13/10/1574>

<sup>32</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X>

Uncontrolled recycling can also result in the transfer of potentially harmful substances or PoTSSs into plastics for sensitive uses, such as children's toys and food contact materials [20], [21], [22], [23].

**Some processes for cascading involve innovative uses for plastic waste, with untested potential for dispersion into the environment and associated unknown pollution.**

For instance, brominated flame retardants including POPs, phosphorous flame retardants and phthalates have been found in children toys from recycling [20], [177], [178]. BFRs have also been detected in food contact materials and household products [22], [179].

Pivnenko et al. [180] studied a number of selected phthalates in samples of virgin, waste and recycled plastics, and concluded that DBP, DiBP and DEHP had the highest frequency of detection in the samples analysed, with  $360 \mu\text{g g}^{-1}$ ,  $460 \mu\text{g g}^{-1}$  and  $2700 \mu\text{g g}^{-1}$  being the maximum concentrations measured, respectively [180].

**Huang et al. [183] demonstrated that the exhaust gases emitted from plastic waste recycling granulation have an effect on the ambient environment in Xingtian, Guangdong, China [183]. Also PAHs were detected inside and outside of the recycling granulation plants in the area.**

#### Conclusion

Given the current situation on what can be placed on the market, while in compliance with all legal requirements that ensure the safety of plastic food contact materials, **it can be concluded that only a limited part of the plastic waste stream might not be suitable for recycling purposes.**

- **Plastic Recycling Practices in Vietnam and Related Hazards for Health and the Environment**<sup>33</sup> – University of Natural Resources and Life Sciences, Vienna, Austria - Vietnam Cleaner Production Centre Co. Ltd, Hanoi, Vietnam - Hanoi University of Science and Technology, Hanoi, - Vietnam - Vietnam National University, Hanoi, Vietnam – April 2021

*This paper analyzes how plastic waste is handled in Vietnam, a country with a fast-growing industry and growing consumption.*

***A number of craft villages have focused on recycling activities.***

***However, due to a lack of state-of-the-art technology for recycling and a low degree of organization, the typical processes for plastic recycling in craft villages come along with health risks for workers and neighbours and a high potential of environmental pollution.***

***This includes dust from sorting and shredding, wastewater from washing steps, and the uncontrolled disposal of residuals including uncontrolled burning.***

***A major source of contamination is the emissions of VOC from the extrusion process.***

*To improve this situation, several measures can be taken, beginning with a more selective material intake to the recycling facilities and improvement in the sorting step in terms of sorting equipment and personal protection equipment.*

*Wastewater from washing and shredding should undergo wastewater treatment before being released to the environment.*

<sup>33</sup> <https://www.mdpi.com/1660-4601/18/8/4203>

*For extrusion and granulation, the gaseous emissions should be reduced and at least collected and filtered. Finally, the disposal of residues should be organised in a better way; with partly hazardous materials open dumping is not an appropriate technology.*

#### 4.1. Environmental Impacts

***Waste plastics contain a wide range of different additives, which are mixed up with the polymer substrate in order to improve plastic characteristics such as durability, colour, and flammability.***

***The most commonly used additives can be classified into the following categories with descending average concentration in the polymer substrate: plasticisers, flame retardants, stabilizers and antioxidants, slip agents, curing agents, biocides, colorants and pigments, and fillers [30].***

***During the informal recycling activities, waste plastics are exposed to mechanical, thermal, and chemical stresses, and a combination of these in uncontrolled conditions. For this reason, plastic additives tend to be released during the recycling process with the potential to cause adverse effects on health and the environment [29].***

*However, the plastic emissions during recycling activities are not inherently hazardous, but they should be regarded as potentially toxic substances (PoTSs) as defined by Hahladakis et al. [31]. Their toxicity arises from environmental conditions and stresses, exposure pathways, concentration, exposure duration, and other social-economic factors.*

#### 3.1.5. Management of Plastic Waste in Vietnam

***The awareness of the majority of people of the sorting, collection, transportation, and treatment of MSW, especially plastic waste and plastic bags, is still limited. People are usually not aware of the harmful effects of plastic waste disposal to the environment and the ecosystem.***

***The collection and sorting of recyclable plastic waste from households is done by informal collectors. The collection rate for plastic waste is low, specifically for plastic bags, which are made of thin films and difficult to recycle. Producers of plastic packaging and other plastic products do not have a responsibility for the management of plastic waste.***

***Regarding the plastic recycling industry, most of the actors in the market are in the informal sector.***

***The recycling of plastic waste still faces many difficulties, the reuse of waste is done through collection and transportation. It is then sent to the craft villages for recycling [25].***

***The recycling materials are mainly paper and plastics, which are processed manually and with outdated technology causing high emissions rates.***

*Minh Khai village has a processing capacity of between 550–600 t/day of input material, which mostly consists of waste PE, PP, PVC, PS, HDPE, and LDPE plastics.*

***It originates both from domestic and from international markets such as China, South Korea, Australia, and European countries.***

*About 85–90% of input material is used for waste plastic recycling, 5–10% consists of other recyclables, and approx. 3–5% is disposed of in the proximity of the village in dumpsites and roadsides [29].*

*The main production outputs from Minh Khai village are PE and PP granules (90% purity), while the remaining outputs consist of other plastic products, such as plastic bags, trays, ropes, and buckets, and other recycling services, such as plastic shredding and trading in waste materials. The main recycling processes at Minh Khai village are sorting, cutting, shredding, washing and drying, extruding, and granulating [29]. The overview of the recycling processes in Minh Khai village is shown in [Figure 2](#).*

## 4.2. Health Risks Arising from Informal Recycling

*At the current stage, there is no health risk assessment of the plastic recycling activities for the workers and people who are living in the craft village, as there is no standard measurement for assessing the health risk potential. **However, the exceeding of parameters and the contamination of the air and surface water can lead to health problems.***

*Informal recycling sites are known hotspots of dioxins and dioxin-related compounds (DRC), since they are formed during incomplete combustion at temperatures between 200 and 800 °C under the presence of BFRs and other halogenated FR as their chemical catalysts [58]. Such conditions are abundantly present during the open burning of waste plastics [59,60].*

*Dioxins are highly lipophilic compounds and insoluble in water, which triggers an easy transition from the environment to living organisms and subsequently humans [61]. Tue et al. [62] investigated the accumulation levels and profiles of DRC in breast milk samples from women living in the proximity of separate informal recycling sites.*

*The results showed that women who are living in the proximity of informal recycling sites but are not directly involved, do not have significantly higher concentrations of World Health Organization toxicity equivalents (WHO-TEQ) compared to the control group of the Vietnamese background range (0.22–7.4 vs. 1.1–3.0 pg/g lipid).*

*However, women directly involved in the informal recycling activities did have significantly higher concentrations of polychlorinated dibenzofurans PCDFs (13–15 pg/g lipid) and polybrominated dibenzofurans PBDFs (1.1–1.5 pg/g lipid) compared to the background range of 2.3–8.8 pg/g lipid and <1.1 pg/g lipid for PCDFs and PBDFs, respectively.*

*Cao et al. [63] assessed bioaccessibility and human health risk of Cu, As, Cd, Sb, and Pb in the soil near e-waste and waste plastic burning sites in Accra, Ghana using in vitro assay.*

*The results of this study show elevated total concentrations of 211–20,400 mg/kg for Cu, 10–29 mg/kg for As, 7–29 mg/kg for Cd, 24–9450 mg/kg for Sb, and 24–10,800 mg/kg for Pb.*

*The results for bioaccessibility-corrected human health risk assessment revealed noncarcinogenic risk for local inhabitants in half of the analyzed sites, while the carcinogenic risk was within an acceptable range.*

*Sb together with Cu and Pb were identified to be one of the major metals of concern that contributed the most to the health risk.*

- **Recycling Plastics from WEEE: A Review of the Environmental and Human Health Challenges Associated with Brominated Flame Retardants<sup>34</sup>** – Restructa Ltd., Irvine, UK - University of the West of Scotland, Paisley, UK - CCL (North) Ltd., Irvine, UK - January 2022

*Waste electrical and electronic equipment (WEEE) presents the dual characteristic of containing both hazardous substances and valuable recoverable materials.*

**Mainly found in WEEE plastics, brominated flame retardants (BFRs) are a component of particular interest.**

**Several actions have been taken worldwide to regulate their use and disposal, however, in countries where no regulation is in place, the recovery of highly valuable materials has promoted the development of informal treatment facilities, with serious consequences for the environment and the health of the workers and communities involved.**

<sup>34</sup> <https://www.mdpi.com/1660-4601/19/2/766>

*Overall, the presence of BFRs in WEEE plastics is a matter of concern when it comes to their management and focus must be put on aiming to prevent potential negative impacts to both the environment and public health.*

*That is why it is imperative that knowledge on the subject continues to be developed and deepened in order to provide all actors involved in WEEE management with the necessary tools to develop strategies to prevent any harmful impacts.*

*Adequate concentration limits need to be defined that, in addition to protecting health and the environment, allow the treatment of these plastics by means that favour the circularity of the material, i.e., recycling as opposed to incineration.*

*Currently, the industrial processes developed and in place present low levels of recyclability, which is explained by the difficulty of determining the content of restricted BFRs.*

- **Addressing the toxic chemicals problem in plastics recycling<sup>35</sup>** – University of Gothenburg, Gothenburg, Sweden - University of Nigeria, Nsukka, Nigeria - Wageningen University & Research, Wageningen, The Netherlands - RWTH Aachen University, Aachen, Germany - International Pollutants Elimination Network, Gothenburg, Sweden - January 2025

***The amounts and types of chemicals in plastics products vary, and there are little requirements for transparency and reporting.***

***Additionally, they are inherently contaminated with reaction by-products and other nonintentionally added substances (NIASs).***

*As the chemical composition of plastics wastes is largely unknown, and many plastics chemicals are hazardous, they therefore hinder safe recycling since recyclers are not able to exclude materials that contain hazardous chemicals.*

*To address this problem, we suggest the following policy strategies: 1) improved reporting, transparency and traceability of chemicals in plastics throughout their full life cycle; 2) chemical simplification and group-based approaches to regulating hazardous chemicals; 3) chemical monitoring, testing and quality control; 4) economic incentives that follow the waste hierarchy; and 5) **support for a just transition to protect people, including waste pickers, impacted throughout the plastics life cycle.***

***Data show that plastics recycling has repeatedly failed to operate in a safe and circular manner*** (Allen et al., Reference Allen, Spoelman, Linsley and Johl<sup>2024</sup>; Carroll, Reference Carroll<sup>2023</sup>).

*Scientists have therefore warned that policy initiatives focused on recycling technologies risk creating infrastructure “lock-in” and increased waste production (Syberg, Reference Syberg<sup>2022</sup>).*

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<sup>35</sup> <https://www.cambridge.org/core/journals/cambridge-prisms-plastics/article/addressing-the-toxic-chemicals-problem-in-plastics-recycling/552E550968DC2E0119DB937925505DC6>

*This process normally involves mixing of different products and therefore, different cocktails of chemicals (Hahladakis et al., Reference Hahladakis, Velis, Weber, Iacovidou and Purnell2018). This mixing has, for example, been demonstrated in food-grade plastics, including polyethylene terephthalate (PET).*

***Even though PET is often collected in separated waste streams, recycled PET can still contain >800 different food contact chemicals (Geueke et al., Reference Geueke, Phelps, Parkinson and Muncke2023).***

*Other technologies than mechanical recycling exist, including so-called **chemical recycling technologies, but currently do not work at scale, in part due to risks associated with chemical impurities in feedstocks, and these technologies have also been shown to cause high emissions of toxic chemicals (Al-Salem et al. , Reference Al-Salem, Antelava, Constantinou, Manos and Dutta2017; Bell et al., Reference Bell, Gitlitz, Congdon and Rollinson2023; Quicker, Reference Quicker2024; Rollinson and Oladejo, Reference Rollinson and Oladejo2019; Uekert et al., Reference Uekert, Singh, DesVeaux, Ghosh, Bhatt, Yadav, Afzal, Walzberg, Knauer, Nicholson, Beckham and Carpenter2023).***

***The consequence is that it is rarely possible for downstream users, producers or recyclers to know anything about the chemicals used in the plastics that they encounter.***

*In addition to chemicals that were in the original primary plastics materials, recent work shows that recycled plastics materials contain numerous other contaminants that likely sorbed to the materials during use, handling, processing or while the materials were out in the environment (if the plastics were collected from dump sites or the open environment; Carmona et al., Reference Carmona, Rojo-Nieto, Rummel, Krauss, Syberg, Ramos, Brosche, Backhaus and Almroth2023).*

*These chemicals include various pesticides, pharmaceuticals and biocides, which renders the recycled plastics unfit for use in many products, especially in children's toys and food contact materials.*

*Therefore, beyond the limited efficacy of different recycling methodologies and practices, there are several concerns about consumers exposed to chemicals during the use of products and materials made from recycled plastics (Gerassimidou et al., Reference Gerassimidou, Lanska, Hahladakis, Lovat, Vanzetto, Geueke, Groh, Muncke, Maffini, Martin and Iacovidou2022; Geueke et al., Reference Geueke, Phelps, Parkinson and Muncke2023; Hawkins et al., Reference Hawkins, Potter and Race2015; Yang et al., Reference Yang, Ma, Thompson and Flower2018) **and about the safety of waste pickers and other people working with plastics wastes and recycling.***

*For workers, it has, for example, been shown that heavy metals were present in recycled plastics at or above the US EPA levels and that there was a clear exposure-risk association between heavy metals and worker health (Huang et al., Reference Huang, Xie, Li and Zhang2021).*

***Waste pickers in Africa are exposed to hazardous materials including toxic chemicals (Binion and Gutberlet, Reference Binion and Gutberlet2012; Uhumamure et al., Reference Uhumamure, Edokpayi and Shale2021).***

- **“The human face of the UN plastics treaty”? The role of waste pickers in intergovernmental negotiations to**

**end plastic pollution and ensure a just transition**<sup>36</sup> - University of St Andrews, St Andrews, Fife, UK - Norwegian Institute for Water Research, Oslo, Norway – April 2024

*It is estimated that waste pickers collect 58% of all post-consumer plastic waste recovered for recycling worldwide (Lau et al., Reference Lau, Shiran, Bailey, Cook, Stutchey, Koskella, Velis, Godfrey, Boucher, Murphy, Thompson, Janokwska, Castillo, Pilditch, Dixon, Koerselman, Kosior, Favoino, Gutberlet, Baulch, Atreya, Fischer, He, Petit, Sumaila, Neil, Berhofen, Lawrence and Palardy2020).*

*Commonly, it is estimated that waste pickers constitute a significant workforce of 15–20 million people globally (see, e.g., ILO, 2018; Morais et al., Reference Morais, Corder, Golev, Lawson and Ali2022).*

*However, by scaling up uncertain estimates to account for development patterns, it is plausible that 34 million people around the world could be involved in this type of work (UNCTAD, 2022; see Cook et al. (Reference Cook, Derks and Velis2023, Reference Cook, Cano and Velis2024) for a recent discussion of different estimates).Footnote<sup>1</sup>*

**Despite being the “backbone of collection and recycling systems in the world” (Chweya, in Laville, Reference Laville2023), waste pickers are particularly vulnerable to the adverse impacts of plastic pollution and associated chemicals; they often work in direct contact with contaminated waste materials under hazardous and sometimes exploitative working conditions, with limited access to social protection (WIEGO, 2018; Ferronato and Torretta, Reference Ferronato and Torretta2019; Harriss-White, Reference Harriss-White2020).**

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact**

**during their use, disposal and recycling**<sup>37</sup> - University of Leeds, Leeds, United Kingdom - POPs Environmental Consulting, Schwäbisch Gmünd, Germany – Feb 2018

*In particular the use of material that has been recycled from plastic waste by non-environmentally sound technologies and open burning in developing and transition economies, especially in Asia and Africa, result in environmental and human pollution.*

*Furthermore technical and economic difficulties in recycling plastics may also involve, lack of fiscal incentives, poor waste separation, high energy cost, contamination by other materials, difficulty in cleaning process, unstable economic market, etc. [175].*

**In this temperature area a range of hazardous substances (e.g. toxic metals, volatile organic compounds (VOCs), phthalates, polycyclic aromatic hydrocarbons (PAHs), PBDEs, PAEs, polybrominated dibenzo-p-dioxins and furans (PBDD/F) may be released from this process with associated exposure [180], [182], [183], [184], [185].**

*Pivnenko et al. [180] studied a number of selected phthalates in samples of virgin, waste and recycled plastics, and concluded that DBP, DiBP and DEHP had the highest frequency of detection in the samples analysed, with 360 µg g<sup>-1</sup>, 460 µg g<sup>-1</sup> and 2700 µg g<sup>-1</sup> being the maximum concentrations measured, respectively [180].*

<sup>36</sup> <https://www.cambridge.org/core/journals/cambridge-prisms-plastics/article/human-face-of-the-un-plastics-treaty-the-role-of-waste-pickers-in-intergovernmental-negotiations-to-end-plastic-pollution-and-ensure-a-just-transition/8AFA653D53C5B771373AF7DC5E520B62>

<sup>37</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X#bib0915>

A health risk assessment that was also performed to evaluate the results of the aforementioned study indicated that for the non-cancer risk, benzene, toluene, ethylbenzene, styrene, methylene chloride and trichloroethylene were the major contributors to the chronic health effects in these workshops; while acrylonitrile, styrene, ethylbenzene and 1,2-dichloromethane were the major contributors to cancer risks, like tumour of the lungs, liver, kidneys, and brain via inhalation exposure [186], [187].

Huang et al. [183] demonstrated that **the exhaust gases emitted from plastic waste recycling granulation have an effect on the ambient environment in Xingtian, Guangdong, China** [183].

**Also PAHs were detected inside and outside of the recycling granulation plants in the area. In the same study, PAEs were largely distributed in the particle-phase.**

**High levels of DBP and DEHP could be detected inside the plants. The detected DiBP, DnBP and DEHP inside the Huachang plant were 30, 20 and 5 times greater than background concentrations of the area, respectively.**

Despite there is no standard for PAEs emitted from plastic waste recycling plants, the occupational health effects on workers should be further considered and evaluated because of their long term exposures [183].

Many metals such as Cd, Pb, Sb and Sn (as organotin) that have been used as plastic additives, have now been found to be toxic. According to the present restriction of hazardous substances (RoHS) directive, plastics containing Cd, Pb, Hg and Cr<sup>6+</sup> may not be recycled if the content is higher than 1000 ppm of Pb, Hg or Cr<sup>6+</sup> or 100 ppm of [188].

However, assessments on the release of these toxic metals into the environment in areas where plastic waste recycling is carried out by non-environmentally sound methods, and the potential ecological and human risks of such releases may be high, are still under scrutiny [189], [190].

Tang et al. [191] demonstrated that **the surface soils and sediments have suffered from moderate to high Cd and Hg pollution. The mean concentrations of Cd and Hg were 0.355 and 0.408 mg kg<sup>-1</sup>, respectively, in the soils and 1.53 and 2.10 mg kg<sup>-1</sup>, respectively, in the sediments** [191].

Tang et al. [192] reported that **in road dust samples collected from an area where intense mechanical recycling of plastic wastes occurs (Wen'an, north China), PBDE concentrations were found to be 1–2 orders of magnitude higher than concentrations in outdoor or road dusts from other areas.**

**This indicated that plastic waste processing is a major source of toxic pollutants in road dusts in that area.**

Song and Li [189] reviewed the reported in literature effects from recycling activities of “e-waste” (mostly known as Waste Electric and Electronic Equipment, WEEE) in China in air [193], soil [194], [195], sediments [196] and plants [194], [197]. **Compared with the levels of the toxic metals in the outdoors, pollution from toxic metals indoors, specifically in WEEE workshops (formal and informal e-waste recycling enterprises) was more critical** [189].

More specifically, **the mean Pb concentrations in workshop dust were much higher than those from other studies** the share of Pb from plastic or other source was not clarified in the studies [193], [198], [199]. Furthermore, Bi et al. [200] investigated Sb (used as synergist of BFR retarded plastic) distributions in indoor dust from 13 “e-waste” recycling villages in Guiyu, Guangdong area, in China.

**Results revealed significantly elevated concentrations of Sb (6.1–232 mg kg<sup>-1</sup>) in dust within all the villages. There were villages where the levels appeared to be 3.9–147 times higher than those from the non-WEEE sites, indicating that WEEE recycling was an important source of Sb pollution** [200].

*Asante et al. [201] reported human contamination by multi-trace elements (TEs) in “e-waste” recycling site at Agbogbloshie, Accra in Ghana. Levels of Sb in workers were significantly higher compared to reference sites in urine and most likely stem from “e-waste” plastic and related releases from open burning.*

*Also levels of As, Fe, and Pb in urine of the workers were found significantly higher than those of reference sites indicating that the recycling workers are exposed to these TEs through the recycling activity [201].*

*In the life cycle of flame retarded plastic, in particular the end of life treatment brominated and chlorinated flame retardants, brominated, chlorinated, and mixed halogenated dibenzo-p-dioxins/dibenzofurans, PAHs and other organic pollutants are released with associated human exposure [23].*

*Feldt et al. [202] studied PAH contamination in urine of e-waste recycling workers in Agbogbloshie where plastic from cables and other e-waste plastic are frequently burned.*

*Results indicated that urinary PAH metabolite concentrations were significantly higher in individuals who were exposed to e-waste recycling, compared to controls who were not exposed to e-waste recycling activities [202]. PBDE exposure above reference dose (RfD) values have been found at e-waste sites in China [185].*

*High levels of PBDE were also found in human milk in Chinese e-waste sites [203].*

*It also appears that neonates, due to the mothers’ exposure to e-waste and related recycling in developing countries, are facing potential health effects, e.g. the neonates from the e-waste exposure areas have been influenced by toxic organic pollutants and toxic metals, including mental health outcomes, growth, changes in cellular expression, and DNA effects [194], [209].*

- **Safety risks faced by workers in plastic recycling industries<sup>38</sup>** - Plastics For Change – February 2025

*According to a study by the Indian Institute of Technology (IIT) Delhi, women make up around 60% of the informal waste worker population. **A Toxics Link study revealed that 90% of workers in Delhi’s informal plastic recycling sector suffer from respiratory issues due to constant exposure to toxic fumes and particulate matter.***

*A survey by the Centre for Education and Communication (CEC) in Mumbai revealed alarming statistics: **60% of workers experienced frequent headaches, 40% reported nausea, and 30% experienced skin irritation due to lack of proper safety measures.***

*Beyond immediate health hazards, **research has uncovered long-term consequences, including elevated levels of heavy metals like lead (found in 75% of workers) and cadmium (found in 65% of workers) in the blood samples of workers at plastic recycling facilities in Kolkata.***

<sup>38</sup> <https://www.plasticsforchange.org/blog/safety-risks-faced-by-workers-in-plastic-recycling-industries>

- **Occupational Health Hazards and Use of Personal Protective Equipment (PPE) among Plastic Recycling Workers in Bangladesh<sup>39</sup>** - University of Memphis, Tennessee, US - Square Hospital Limited, Dhaka, Bangladesh - Texas Tech University, Texas, U – March 2025

*This cross-sectional study was conducted from September 2024 to November 2024 in Matuail, Shonir Akhra, Jatrabari, Pallabi, which are among the largest plastic recycling areas in Dhaka city.*

***A research study investigating sanitation and waste workers detected that 60 percent failed to maintain stable usage of protective gear even though their work constantly exposed them to dangerous materials [7].***

***Workers fail to maintain adequate PPE practices because of several issues, which include limited funding for personal protective equipment, unavailability of workplace safety equipment and insufficient training about workplace health dangers [8].***

*The health risks informal recycling workers face in low and middle-income countries (LMICs) are parallel to those documented in other LMICs, as reported in [9].*

***Table 3 outlines the reported occupational health issues. Musculoskeletal disorders were most common, with back pain (47.3%), shoulder pain (29.8%), and joint pain (27.5%) frequently reported. Fatigue (38.9%) and headaches (33.6%) were also prevalent.***

***Respiratory issues included cough (19.1%) and breathing difficulty (14.5%). Skin problems, such as itchy skin (19.8%) and rashes (13.7%), were notable. Work-related injuries affected 21.4% of workers.***

***Research by Yohannessen et al., demonstrated equivalent patterns of respiratory issues among e-waste laborers in Chile [12]. According to Thompson et al., plastic processing releases microplastic particles and hazardous chemicals when spread through the air [13].***

***Many workers suffered from dermatological problems such as rash and itchy skin. The combination of unprotected contact with processing chemicals and improper glove utilization leads to skin irritations. According to Meem et al., workers at the e-waste sites faced identical dermatological health problems [14]***

- **“It’s As If They’re Poisoning Us”- The Health Impacts of Plastic Recycling in Turkey<sup>40</sup>** – Human Rights Watch – September 2022

*As of April 2022, official figures show there were 167 licensed plastic recycling facilities in Adana and 232 licensed plastic recycling facilities in Istanbul, many of which are located near residences, medical clinics, schools, and parks. In Turkey, some of the plastic recycling facility workers and residents told Human Rights Watch that they experienced respiratory problems, severe headaches, skin ailments, worked without protective equipment, and had little to no access to medical treatment for occupational illnesses.*

<sup>39</sup> <https://www.saspublishers.com/article/21805/download/>

<sup>40</sup> <https://www.hrw.org/report/2022/09/21/its-if-theyre-poisoning-us/health-impacts-plastic-recycling-turkey>

Human Rights Watch found that licensed **facilities in Adana and Istanbul are often located dangerously close to homes in contravention of Turkish law, which requires recycling facilities to be a “healthy” setback from settlements, which include residences, schools, and hospitals, so facilities do not cause any harms to the health or quality of life to those residing nearby.**

*The close proximity of facilities to homes is threatening the health of nearby residents. In addition to health problems, local residents say intense odors and pollution from plastic recycling prevent them from sleeping, opening their windows, and spending time outside.*

*Residents, current and former recycling facility workers, medical providers, and facility owners said they did not have information about risks from toxic exposure from recycling facilities or how to mitigate those risks.*

- **Plastic pollution and health**<sup>41</sup> – e Clinical Medicine / Part of THE LANCET Discovery Science – June 2023

*Despite this being an early area of research, the presence of **microplastics has been linked to respiratory complications, endocrine disruption, inflammatory bowel disease symptom severity, narrowing of fetal capillaries, and stomach and oesophageal cancers.***

*Endocrine disruption is the most well studied of these risks, with the endocrine-disrupting chemicals found within plastics (eg, phthalates, perfluoroalkylsubstances, bisphenol A, and flame retardants) being linked to a myriad of health effects from endometriosis and breast cancer to heart disease and obesity.*

*The underlying mechanisms for these potential effects via microplastics are, as yet, unclear. It also remains to be elucidated how long microplastics remain in the body before being excreted or exhaled.*

*In addition to microplastics, the health impacts of plastics are felt at every stage of the plastic lifecycle.*

*As outlined in a recent report by the Center for International Environment Law (Plastic & Health: The Hidden Costs of a Plastic Planet) and The Minderoo-Monaco Commission on Plastics and Human Health, the occupational harms of plastic pollutants are vast and diverse.*

***Although recycling has a key part to play, evidence has shown that this process might be making the microplastics problem worse. Moreover, current recycling systems cannot handle the huge global volume of plastic produced and usually rely on the export of plastic waste from high-income to low-income countries—with illegal exports and dumpsites now widespread.***

*More research is needed into the harms that plastic pollutants pose to humans, but we know enough to see that change is needed. Urgently.*

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<sup>41</sup> <https://pmc.ncbi.nlm.nih.gov/articles/PMC10314155/>

- **Study: Plastic Waste and Recycling Workers Face Toxic Exposures from Hazardous Plastic Chemicals<sup>42</sup>** – IPEN – November 2024

A **new study** by EARTH and IPEN finds that plastic waste and **recycling workers in Thailand** are exposed to **greater numbers of and higher levels of hazardous plastic chemicals compared to Thai workers in occupations without significant exposures to plastics.**

**Chemicals assessed in the study include phthalates that are known endocrine disruptors, highly toxic flame retardants, cancer-causing polycyclic aromatic hydrocarbons (PAHs), and other plastic chemicals.**

The study is being released today ahead of the Plastics Treaty INC-5 negotiations in Busan, Republic of Korea this November 25 to December 1.

**Volker Türk, the United Nations High Commissioner for Human Rights and a participant in the IPEN study asserted,** *“Plastics and their byproducts are made of chemicals that are seriously harmful to people and the environment. They are present in every ecosystem on the planet, accumulating in food chains, contaminating water, soil, and air, and releasing hazardous substances into the environment.*

*Most plastics derive from fossil fuels and emit greenhouse gases throughout their life cycle, exacerbating the multiple planetary crises. Each stage of the plastics life cycle from extraction through disposal, adversely impacts human rights, including the rights to health and to a clean, healthy and sustainable environment.*

*Participants from the three groups of workers wore wristbands that capture environmental exposures to chemicals for five days. The wristbands were analyzed at an independent lab for 73 chemicals in six chemical groups: PAHs, phthalates, phthalate alternatives, OPFRs, benzotriazole UV stabilizers, and bisphenols and phenols (eg, BPA).*

*The new study with workers from Thailand finds that:*

- *All workers experienced chemical exposures to all six types of chemicals. Each worker was exposed to at least 21 chemicals, and 14 chemicals were found in every wristband tested. The findings overall are consistent with previous studies showing that we are all at risk of exposures to toxic plastic chemicals.*
- *Plastic waste and recycling workers were exposed to more chemicals than the office workers. Plastic waste workers were exposed to the highest number of chemicals, but for some chemicals, recycling workers had the greatest number and/or higher levels of exposures.*
- *Phthalates, including some that are known endocrine disrupting chemicals (EDCs), were detected at the highest concentrations of all the chemicals. All workers across the three groups were exposed to the phthalate DEHP, with plastic waste handlers exposed to very high levels. DEHP is an EDC banned in certain products in the EU, US, Australia, and China and some other Asian countries but unregulated in many countries across Africa and Latin America.*
- *Polycyclic aromatic hydrocarbons (PAHs) are cancer-causing chemicals found in plastics and generated when burning plastics. Both plastic recyclers and plastic waste handlers were exposed to higher concentrations and higher numbers of PAHs than the office workers.*
- *Exposures to organophosphate flame retardants (OPFRs), chemicals linked to neurodevelopmental issues and endocrine disruption, were higher in recycling workers compared to the plastic waste handlers and office workers.*

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<sup>42</sup> <https://stoppoisonplastic.org/blog/study-plastic-waste-and-recycling-workers-face-toxic-exposures-from-hazardous-plastic-chemicals/>

- **Toxic threats from plastic waste: human health impacts, challenges, and policy solutions**<sup>43</sup> - College of

Engineering, King Saud University, Riyadh, Saudi Arabia - Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh, Saudi Arabia - St. Joseph's College of Engineering, OMR, Chennai, India - Saveetha School of Engineering, Saveetha Institute of Medical and Technical Science (SIMATS), Chennai, India - Sathyabama Institute of Science and Technology, Chennai, India - Dwaraka Doss Goverdhan Doss Vaishnav College, Chennai, Tamil Nadu, India – Oct 2025

*Each year, nearly eight billion tons of plastic enter aquatic ecosystems, disrupting marine biodiversity and increasing risks of human exposure to toxic byproducts.*

***As plastics degrade, they release hazardous compounds such as bisphenol A (BPA), dioxins, phthalates, furans, and heavy metals—substances linked to respiratory illnesses, endocrine disruption, and cancer.***

*These pollutants find pathways into the environment through soil leaching, air transport, and bioaccumulation across the food chain.*

***Alarming data points highlight the gravity of the issue: BPA concentrations in freshwater bodies have exceeded 12  $\mu\text{g L}^{-1}$ , and dioxin levels near open waste combustion sites have reached over 1000 ng TEQ per kg both surpassing WHO's safety thresholds.***

***In Poland, phthalate levels in leachate from landfills have been recorded at more than 303  $\mu\text{g L}^{-1}$ , while fish specimens from Swedish waters have shown heavy metal concentrations more than 2.26 ng  $\text{g}^{-1}$  moist weight, raising potential food safety hazards and chronic exposure risks.***

*Ineffective trash disposal infrastructure disproportionately affects vulnerable communities in countries with low to middle-incomes (LMICs), especially in Sub-Saharan Africa, where only 39–45% of solid waste is adequately treated due to infrastructural and financial limitations.*

***The problem is most severe in Sub-Saharan Africa, where the most vulnerable people are at the greatest risk of exposure.***

***Emerging evidence highlights that plastic pollution is not only an ecological issue but also a direct human health concern.***

***During production, use, and degradation, plastics release toxic compounds such as BPA, phthalates, dioxins, furans, and heavy metals.***<sup>6-8</sup>

***These chemicals are recognized for their ability to interfere with hormonal systems and contribute to chronic illnesses.***

***Scientific studies have increasingly associated exposure to such pollutants with disruptions in endocrine function, developmental abnormalities, reproductive disorders, immune system impairment, and a heightened risk of certain cancers, underscoring the urgent need for public health intervention and stricter environmental safeguards.***<sup>9</sup>

*Contamination has been documented in soil, water, and air, raising concerns about multiple exposure routes. Particularly vulnerable populations including infants and pregnant women—may face disproportionate risks.*

***Yet, the pathways of exposure remain insufficiently understood, and the combined or synergistic effects of multiple plastic-derived chemicals are rarely studied, leaving critical gaps in knowledge.***<sup>10,11</sup>

<sup>43</sup> <https://pmc.ncbi.nlm.nih.gov/articles/PMC12557311/>

*While efforts such as recycling and improved waste management have been promoted to reduce plastic pollution, these initiatives often emphasize environmental protection over direct health outcomes.<sup>12</sup>*

*Moreover, technological constraints such as incomplete detoxification during recycling reduce their effectiveness. In many low- and middle-income countries (LMICs), weak waste treatment infrastructure further undermines plastic waste management, exacerbating both environmental and health risks.<sup>13</sup>*

*Improper methods of plastic trash disposal include open dumping or else unrestrained incineration pose a significant environmental risk due to the potential release of toxic heavy metals.*

*As plastic materials degrade under environmental conditions like sunlight, mechanical friction, and moisture, embedded additives, including heavy metals, can slowly leach into surrounding ecosystems.<sup>65</sup>*

*This is especially true for plastics like polyvinyl chloride (PVC), which often contain lead (Pb) and cadmium (Cd) as stabilizing agents.*

*When these materials are placed in landfills, they can persist for decades.*

*Heavy metals have the potential to move into the local groundwater and soil during this period, which might have an impact on drinking water supplies and agricultural areas. Studies indicate that even minimal concentrations of lead around 10 parts per million can disrupt soil chemistry and suppress plant growth.*

*Cadmium, similarly, tends to accumulate in crops cultivated near contaminated zones, raising concerns about food chain contamination and dietary exposure to harmful substances.<sup>66</sup>*

*In parts of Sub-Saharan Africa, for example, cities in Nigeria, Kenya, and Liberia formally manage only 39–45% of their total waste. The remainder is frequently burned in open areas or dumped into the environment without oversight, contributing to significant ecological and public health hazards.<sup>105</sup>*

*While it appears to offer a practical means of reuse, this method has a major flaw: with each recycling cycle, plastic degrades in quality a phenomenon known as downcycling. As a result, the recycled output frequently fails to meet the stringent purity standards required for applications such as food packaging.*

*Additionally, mechanical recycling does not remove hazardous chemicals commonly added to plastics, including bisphenol A, phthalates, and heavy metals. These substances remain in recycled materials and continue to pose risks to human health.<sup>110</sup>*

*Furthermore, these processes can create additional environmental problems, such as toxic emissions and hazardous by-products, raising concerns about their sustainability.*

*They both emit dangerous chemicals including hazardous metals and dioxins. Even in developed nations such as the United States, where annual plastic waste exceeds 35.7 million tons, overall recycling rates remain under 10%, with composite plastics being among the most difficult to recover.<sup>113</sup>*

*This not only reduces recycling efficiency but also increases the likelihood of toxic exposure during processing. In areas without reliable systems for separating waste common in many Southeast Asian regions contamination is widespread, limiting the effectiveness of recycling efforts and worsening the environmental and public health risks linked to plastic waste.<sup>114</sup>*

- **Beyond the bin: Decent work deficits in the waste management and recycling industry<sup>44</sup>** – International Labor Organization – August 2024

Also notable is that, while contributing to environmental sustainability, workers in the waste management and recycling industry often face significant health hazards.

**These include exposure to toxic chemicals, biological agents, and physical risks from handling hazardous materials and operating heavy machinery.**

**These risks are compounded in developing countries, where occupational safety and health (OSH) regulations are often weaker or poorly enforced, leaving workers more vulnerable to injuries, respiratory issues, and long-term health conditions.**

This stark contrast between the industry’s role in promoting a green economy and the unsafe conditions many workers endure highlights the need for stronger OSH protections, particularly in regions where regulatory frameworks are less robust.

Conversely, self-employment is the predominant status in employment in the waste management and recycling industry in many developing countries, such as Peru, Albania, Zimbabwe, Honduras, Colombia, Indonesia, India, Türkiye, Occupied Palestinian Territory, Iran (Islamic Republic of), and Nepal.

These workers face a higher degree of economic risk and are more likely to experience decent work deficits.

- **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal<sup>45</sup>**

*Objective - The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous wastes and other wastes requiring special consideration.*

*Its scope of application covers a wide range of wastes defined as “hazardous wastes” based on their origin and/or composition and their characteristics, as well as four types of wastes defined as “other wastes” - household waste, incinerator ash, certain plastic wastes and certain electronic and electrical wastes.*

You are here: Basel Convention > Countries > Status of Ratifications > Parties & Signatories

### Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal



Click on the map located in the left to view an interactive world map showing the current status of ratifications, or scroll down to see the information in a table format.

Date of Adoption: 22/3/1989

Place of Adoption: Basel

Date of Entry into Force: 5/5/1992

Registration: 5 May 1992, No. 28911

Number of Signatories: 53

Number of Parties: 191<sup>1</sup>

Show introduction

Participant	Signature, Succession to Signature ...	Ratification, Acceptance ... Approval (AA), Accessio...	Entry into force
Afghanistan	22/03/1989	25/03/2013	23/06/2013
Albania		29/06/1999 (a)	27/09/1999
Algeria		15/09/1998 (a)	14/12/1998
Andorra		23/07/1999 (a)	21/10/1999
Angola		06/02/2017 (a)	07/05/2017
Antigua and Barbuda		05/04/1993 (a)	04/07/1993
Argentina	28/06/1989	27/06/1991	05/05/1992
Armenia		01/10/1999 (a)	30/12/1999
Australia		05/02/1992 (a)	05/05/1992

<sup>46</sup>

<sup>44</sup> <https://ilostat.ilo.org/beyond-the-bin-decent-work-deficits-in-the-waste-management-and-recycling-industry/>

<sup>45</sup> <https://www.basel.int/theconvention/overview/tabid/1271/default.aspx>

<sup>46</sup> <https://www.basel.int/Countries/StatusofRatifications/PlasticWasteamendments/tabid/8377/Default.aspx>

- **Trading Plastic Waste in a Global Economy: Soundly Regulated by the Basel Convention?**<sup>47</sup> - *Journal of Environmental Law*, Volume 34, Issue 3,- November 2022

*These consequences include contributing to resource depletion and greenhouse gas emissions; leading to the leakage of plastics and toxic chemicals into the environment, which causes significant physical and toxicological harm on the ecosystems; as well as the loss of economic value of plastic following single or short use.*<sup>2</sup>

**Hazardous and other plastic wastes that are now clearly included within the scope of the Basel Convention are subject to the Convention's different mechanisms and principles.**

**The overarching aim of these is to protect human health and the environment.**<sup>22</sup>

*The country of export has an important role to play here, as it is under the obligation to take the appropriate measures not to allow exports of Basel-controlled waste 'if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner'.<sup>50</sup>*

**It can be noted with concern that common plastic waste streams almost always are contaminated with hazardous chemicals (eg plasticisers, compatibilisers, dyes, fillers, UV stabilisers and so on), which negatively affects their recycling potential.**<sup>71</sup>

- **Plastic waste reprocessing for circular economy: A systematic review of risks to occupational and public health from legacy substances and extrusion**<sup>48</sup> – University of Leeds - M&A Transaction Services, Deloitte, London

**Our assessment indicates that the highest risk results from exposure to these substances during extrusion by mechanical reprocessors in contexts where only passive ventilation, dilution and dispersion are used as control measures.**

*This trade is often characterized by unsorted mixed plastics exported from high income countries (HICs) to low- and middle-income countries (LIMICs), predominantly in South and South East Asia (Brooks et al., 2018).*

**However, there are growing concerns that the residues from sorting and reprocessing these materials are being mismanaged in recipient countries (and may also be leaking into the aquatic environment) (Secretariat of the Basel Convention, 2019).**

*Specifically, in high-income countries, plastic waste is managed by being disposed of in landfill; recovered as fuel in energy-from-waste plants; or mechanically recycled (Tejaswini et al., 2022).*

**Yet, this formal waste industry collectively has one of the highest occupational accident rates of all industrial sectors in many countries (Health and Safety Executive, 2018; Doherty, 2019).**

*Virtually all of the material collected for recycling in LIMICs is carried out by waste pickers (Velis et al., 2022); informal entrepreneurs who may number between 10 and 20 million (Wilson et al., 2015; Lau et al., 2020).*

<sup>47</sup> <https://academic.oup.com/jel/article/34/3/477/6713994>

<sup>48</sup> <https://www.sciencedirect.com/science/article/pii/S0048969722074873>

**Plastic sorting and reprocessing operations are often smaller, and in some cases poorly regulated, without any environmental or occupation and public health protection in place** (Kosgeroglu et al., 2004).

In the study by Wang et al. (2011), water and soil samples from a plastics reprocessing region in China were analysed for phthalate concentration and compared with reference samples. The plastics reprocessing area samples had concentrations orders of magnitude greater than the reference (control) areas indicating that the plastics reprocessing operations were a significant source.

To add context, Wang et al. (2011) also analysed blood of occupationally exposed reprocessing workers, concluding that working in the plastics reprocessing industry is a significant independent predictor of higher urinary 8-OHdG (OR = 2.323,  $p < 0.01$ ) for male workers, but not female workers (Table S21).

This review identified three studies at **11 plastics reprocessing facilities in China reprocessing nine polymers, each of which had limited or no emission controls; relying instead on dispersion and dilution through open windows and doors to reduce exposure to the workers**. The studies analysed atmospheric concentrations of 20 to 30 different VOCs – though only total VOCs are compared in Table S22.

**Levels of VOCs in one of the ABS plants and one of the PS plants** studied by Mitchell (2015) were very high in comparison to all other facilities investigated.

In both cases, styrene dominated the emission profile (data not shown here), representing 63 % (ABS: 630,000  $\mu\text{g}\cdot\text{m}^{-3}$ ) and 65 % (PS: 310,000  $\mu\text{g}\cdot\text{m}^{-3}$ ) of the total VOCs emitted.

Mitchell (2015) extrapolated their field sampling to model long-term risk from VOC exposure, finding no risk to extrusion workers in the PP, PE and PC plants, but chronic and acute risks in the ABS and PS plants (Table S23).

They also sampled air in so-called ‘residential microenvironments’, defined by the authors as being homes in the same building or the same room as the extrusion activities.

As with the workers, the hazard index for residents living in close proximity to the PP, PE and PC plants was below one, however emissions of VOCs from PS, PA, ABS and PVC plants would lead to a risk of cancer over their lifetimes.

The attention placed on circular economy principles and practice in recent decades has resulted in a drift of focus from the formative driver for modern waste management, which was to protect public health and safety.

**Here, we report for the first time (answering RQ1), a global systematic review of evidence that indicates harm to human health for those who work with waste plastics and those who are affected by plastic waste processing activities, including the controlled operations of plastics reprocessors.**

We derived prevalent risk scenarios of hazard-pathway-receptor combinations (answering RQ2). These were mapped into a conceptual flow and then ranked according to the indicative risk to human health, allowing us to indicate priorities for future research agenda.

- **Household waste and health risks affecting waste pickers and the environment in low- and middle-income countries**<sup>49</sup> – University of Victoria, Victoria, Canada - June 2018

Abstract - ***Waste pickers in low- and medium-income countries work on dumps and landfills, sifting through highly contaminated household waste and are exposed to health hazards.***

*Research shows that a higher occurrence of anti-hepatitis A virus (+) is found among the municipal waste workers than the non-waste-exposed group [48]. A review of occupational health problems and their possible causes shows that the health issues may be caused by the exposure of waste collectors to bio-aerosols (e.g. microorganisms) and volatile compounds (metabolites and toxins from these microorganisms) during the waste handlings [45].*

***Household hazardous waste not only has direct impacts on human health but also contaminates groundwater and increases the risk of contaminating wildlife's habitats [40]. Pollutants can leach from littered household waste into the ground, contaminating the soil.***

***The vegetation near landfill sites is often damaged due to the replacement of oxygen by other gases produced in the root zones, causing the death of plants on the long term [85,92].***

***Research confirms that plants die due to various gas mixtures generated in typical landfill sites [93]. A range of hazardous pollutants (e.g. NO<sub>x</sub>, SO<sub>x</sub>, carbon dioxide, ozone) are emitted during waste collection processes, posing potential hazards to human health and the environment [94].***

***The spaces where the separation of recyclable material happens, for example recycling cooperatives and associations, community recycling depots, as well as the scrap dealers' or middlemen' premises often don't have adequate ventilation or present leaking roofs which promotes bacterial growth and the development of fungus, which can cause respiratory disease to the workers in this environment.***

- **A comprehensive review on exposure to toxins and health risks from plastic waste: Challenges, mitigation measures, and policy interventions**<sup>50</sup> – University of Liberia, Monrovia, Liberia - International University, Kampala, Kampala International University, Bushenyi-Ishaka, Uganda - September 2025

*This study reviews exposure pathways and bioaccumulation mechanisms of plastic-derived toxins, their health risks, mitigation strategies, and policy interventions. The findings reveal that BPA concentrations in rivers can exceed 12 µg/L, and dioxins in soil surpass 1000 ng Toxic Equivalency Quotient (TEQ)/kg in areas with open burning, exceeding WHO thresholds. In Poland, landfill leachate shows phthalate levels over 303 µg/L, while heavy metals in fish tissue reached over 2.26 ng/g wet weight in Sweden.*

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<https://pmc.ncbi.nlm.nih.gov/articles/PMC6147112/#:~:text=Household%20hazardous%20waste%20includes%20chemical,waste%20generates%20environmental%20health%20problems>

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[https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20\(BPA,impacts%20of%20phthalates%20and%20BPA](https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20(BPA,impacts%20of%20phthalates%20and%20BPA)

Recent literature has expanded to consider the toxicological effects of plastic waste, specifically the release of harmful chemicals such as phthalates, bisphenol A (BPA), dioxins, and heavy metals during plastic degradation (Basak et al., 2020). These substances are known endocrine disruptors and carcinogens with the potential to cause severe health problems.

Studies like those by Gore et al., 2024, Plunk and Richards, 2020, Singla, 2023, Stevens et al., 2024, Rani and Meenu, 2023 and Ullah et al. (2023) have demonstrated the presence of such toxicants in various environmental matrices, including water, soil, and air, indicating widespread exposure risks.

While several studies, such as those by Babaremu et al., 2022, Jayasinghe et al., 2023, Maitlo et al., 2022, Ng et al., 2023, Pandey et al., 2023, and Yusuf et al. (2023), have explored recycling and waste management practices as strategies to reduce plastic pollution, the focus has primarily been on waste reduction rather than the minimization of human exposure to toxins. These studies often account for the limitations of recycling technologies in eliminating harmful chemicals from recycled products.

In many cities across the Global South, the waste management infrastructure is fragmented, often relying on informal waste collectors and community-based systems that operate outside of regulatory frameworks (Nguyen et al., 2023). **This informal sector plays a critical role in waste collection and disposal, but it typically lacks the necessary equipment, training, and resources to safely handle hazardous materials, including plastics containing toxic substances such as heavy metals, phthalates, and BPA.**

In countries like India and the Philippines, informal waste pickers, who are often exposed to toxic plastics through handling and sorting waste, collect and recycle plastic waste (Borongan and NaRanong, 2022, Singh et al., 2024), but they do so under hazardous conditions, contributing to environmental contamination and personal health risks (Pathak et al., 2023).

- **Forever Toxic: The Science on Health Threats from Plastic Recycling<sup>51</sup> - Greenpeace – May 2023**

*Leaching of toxic substances into plastic waste: Numerous studies show that plastics can absorb contaminants via direct contact and through the absorption of volatile compounds.<sup>3</sup>*

*When plastics are tainted by toxins in the waste stream and the environment and are then recycled, they produce recycled plastics that contain a stew of toxic chemicals.*

*For example, plastic containers for pesticides, cleaning solvents, and other toxic chemicals that enter the recycling chain can result in contamination of recycled plastic.*

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<sup>51</sup> [https://storage.googleapis.com/planet4-usa-stateless/2024/11/6a9ccbcc-greenpeaceusa\\_forevertoxic\\_eng.pdf](https://storage.googleapis.com/planet4-usa-stateless/2024/11/6a9ccbcc-greenpeaceusa_forevertoxic_eng.pdf)

*New toxic chemicals created by the recycling process: When plastics are heated in the recycling process, this can generate new toxic chemicals that make their way into the recycled plastics.*

*For example, brominated dioxins are created when plastics containing brominated flame retardants are recycled,<sup>4</sup> and a stabilizer used in plastic recycling can degrade to a highly toxic substance found in recycled plastics.<sup>5</sup>*

*While virgin plastics contain unknown and untested harmful chemicals, studies show that recycled plastics often contain higher levels of chemicals that can poison people and contaminate communities.<sup>8</sup> Chemicals in recycled plastics have been linked to cancer, cardiovascular disease, obesity, and other health issues.<sup>9</sup>*

*Recycled plastic products expose consumers to toxic chemicals, including chemicals that have been globally banned. Recycling can combine toxic chemicals from different plastics and create new hazardous chemicals, all of which end up in recycled plastic products.*

***A 2013 study<sup>11</sup> found harmful air-polluting chemicals around and inside plastic recycling facilities in China, with potential health impacts on workers and local residents. Concentrations of harmful chemicals near the facilities were higher than those at a reference site.***

*Two studies<sup>12</sup> from China found high levels of plastic flame retardant chemicals in soils, sediment, and road dust near plastic recycling facilities compared to low levels in samples from areas where no plastic recycling takes place.*

***A 2020 study<sup>15</sup> of plastic recycling workers (waste pickers) in the Gaza Strip found that most had been exposed to hazardous materials in the previous 12 months, and most reported occupational illnesses.***

***A 2015 study<sup>19</sup> by researchers from Czechia and Germany found that recycled plastics used in food packaging and other products contained toxic flame retardants, including banned POPs, with potential health impacts on children and consumers.***

*A 2022 IPEN report<sup>24</sup> summarized data on recycled plastic products from China, Indonesia, and Russia, finding that all of the products contained toxic chemicals, including substances banned under international conventions. All 73 products analyzed contained one or more globally banned flame retardant chemicals.*

***A 2022 study<sup>25</sup> found that recycled plastic bottles had higher concentrations of toxic chemicals than bottles made with new plastics, indicating that the recycling process can intensify chemical threats.***

*A 2022 study<sup>26</sup> by IPEN, Arnika, and partners in 11 African and Arabic countries found toxic chemicals in recycled plastic toys, kitchen utensils, and other products. Out of 83 products analyzed, 61 had levels of POPs that would define the products as POPs waste under limits proposed by African countries.*

**A 2023 study<sup>27</sup> from the Fraunhofer Institute and IES Landau tested post-consumer plastic recyclates from different European countries, finding 51 chemicals with intermediate to high toxicity risks and 30 that could not be identified (under EU law, only authorized substances can be used in food grade plastics<sup>28</sup>).**

**A 2023 IPEN study of recycled plastic products purchased in Kenya<sup>29</sup> found that 14 of the 18 products contained high levels of toxic flame retardants, exceeding a definition of hazardous POPs waste proposed by African countries. One sample, a toy car, was tested for brominated dioxins and contained the toxic chemicals at higher concentrations than levels found in ash from waste incineration.**

- **Tackling plastic pollution: 'We can't recycle our way out of this'<sup>52</sup> – France<sup>24</sup> - May 2023**

**Microplastic release is not the only flaw in the system.**

**Recycling plastics means working with unregulated toxic chemicals.**

*Plastics are made with as many as 13,000 chemicals, according to a [UN report this month](#), and 3,200 of those have "hazardous properties" that could affect human health and the environment.*

**Many more have never been assessed and may also be toxic, according to a [report from Greenpeace](#) released last week.**

**In addition, "only a very, very small portion of those chemicals are regulated globally", said Therese Karlsson, science and technical adviser at the International Pollutants Elimination Network (IPEN).**

**"Since there's no transparency [in the market], there's no way for people to know which plastics contain toxic chemicals and which don't."**

*The risk these chemicals pose increases among recycled plastics, as products with unknown compositions are heated and mixed together.*

*"The outcome is a completely unknown product that is reintroduced onto the market," Karlsson said.*

**Greenpeace's report also detailed increased health risks for recycling centre workers exposed to toxic chemicals, including long-term health conditions such as cancer and harm to reproductive systems.**

*It also found [higher levels of toxic chemicals](#) in recycled plastic than in their virgin counterparts, including kitchen utensils, children's toys and food packaging.*

**The spread does not end there. "We've done studies on eggs that are close to places that recycle plastics and found that these chemicals are making their way into the food chain," Karlsson said.**

*"Plastics can act as carriers of these chemicals even to really remote places."*

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<sup>52</sup> <https://www.france24.com/en/environment/20230530-tackling-plastic-pollution-we-can-t-recycle-our-way-out-of-this>

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact**

**during their use, disposal and recycling**<sup>53</sup> – University of Leeds, Leeds, United Kingdom - POPs Environmental Consulting, Schwäbisch Gmünd, Germany

*For instance, brominated flame retardants including POPs, phosphorous flame retardants and phthalates have been found in children toys from recycling [20], [177], [178]. BFRs have also been detected in food contact materials and household products [22], [179].*

*One concern is e.g. the potential of several metal-containing additives to form pro-oxidants and photo-oxidation catalysts, which promote the degradation of plastics during reprocessing (melting/extruding) or even during their use-life phase [181]. In particular, metal salts or oxides such as Fe<sub>2</sub>O<sub>3</sub>, Cu<sub>x</sub>O and ZnO have been found to act as pro-oxidants [181].*

***Tang et al. [192] reported that in road dust samples collected from an area where intense mechanical recycling of plastic wastes occurs (Wen'an, north China), PBDE concentrations were found to be 1–2 orders of magnitude higher than concentrations in outdoor or road dusts from other areas.***

***This indicated that plastic waste processing is a major source of toxic pollutants in road dusts in that area.***

***Song and Li [189] reviewed the reported in literature effects from recycling activities of “e-waste” (mostly known as Waste Electric and Electronic Equipment, WEEE) in China in air [193], soil [194], [195], sediments [196] and plants [194], [197].***

***Compared with the levels of the toxic metals in the outdoors, pollution from toxic metals indoors, specifically in WEEE workshops (formal and informal e-waste recycling enterprises) was more critical [189].***

***More specifically, the mean Pb concentrations in workshop dust were much higher than those from other studies the share of Pb from plastic or other source was not clarified in the studies [193], [198], [199].***

- **A National framework for recycled content traceability**<sup>54</sup> – DCCEEW - March 2025

## 2.3 Principles to support the framework

***6. Precautionary principle: If there are threats of serious or irreversible environmental or human harm arising from use of recycled content, lack of full scientific certainty should not be used as a reason for postponing measures to prevent such harm.***

*In the application of the precautionary principle, public and private decisions should be guided by careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment or human health*

<sup>53</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X>

<sup>54</sup> <https://www.dcceew.gov.au/sites/default/files/documents/national-framework-recycled-content-traceability.pdf>

- **Amid efforts to end plastic pollution, millions of waste pickers become a focus<sup>55</sup>** - United Nations Environment Program – May 2025

***In developing countries without formal reuse and recycling systems, these waste pickers are on the frontlines of the effort to tackle plastic pollution, which experts say is a mounting threat to the environment.***

***In 2024 alone, humanity generated an estimated 400 million tonnes of plastic waste, contributing to an ongoing plastic pollution crisis experts say is damaging fragile ecosystems and exposing people to potential risk of exposure to harmful chemicals in plastics and also pollutants, like microplastics.***

*Waste pickers like Briones, whether informal or part of a cooperative, are responsible for almost 60 per cent of all the plastic waste collected globally, according to one study. But waste pickers often have few employment rights and no access to health insurance, the latter especially problematic in a field where cuts and infections are common, experts say.*

***“As we move toward a more sustainable future, it is vital that this transition is just and inclusive, and that waste pickers are guaranteed Fundamental Principles and Rights at Work – including the right to a safe and healthy working environment,” says Moustapha Kamal Gueye, Director of the Action Programme on Just Transition at the International Labour Organization.***

***“A just transition must leave no one behind, and that includes the millions of waste pickers and workers whose labour underpins recycling systems around the world.”***

*Experts point to cooperatives, like San Jose Sico, as a model for the just transition. The organization has 500 members who receive a regular income, accident insurance and paid sick leave. **For UNEP’s Tonda, extended producer responsibility schemes could create opportunities to integrate informal waste pickers into solutions across the life cycle, including waste management systems.***

- **Widespread chemical contamination of recycled plastic pellets globally<sup>56</sup>** – IPEN (International Pollutants Elimination Network) - December 2021

*Increased recycling rates is a proposed solution to the current health and environmental crisis that is caused by the massive overproduction of plastics. **However, almost all plastics contain toxic chemicals that are not removed during recycling but are carried over to the new products, and the recycling process can even generate new toxic chemicals such as dioxins.***

***The increased recycling is intended to contribute to a so-called circular economy, but plastics containing toxic chemicals should not be recycled. Instead, they should be considered non-circular materials.***

*This study aimed at increasing the amount of information available about toxic chemicals transferred from plastic waste into recycled plastic pellets globally.*

***Therefore, pellets made from recycled high-density polyethylene, intended for use in new products, were purchased from 24 recycling facilities in 23 countries. The pellets were analyzed to determine the presence of 18 substances, representing three types of toxic chemicals: 11 brominated flame retardants, 6 benzotriazole UV stabilizers and bisphenol A.***

<sup>55</sup> <https://www.unep.org/news-and-stories/story/amid-efforts-end-plastic-pollution-millions-waste-pickers-become-focus>

<sup>56</sup> <https://ipen.org/documents/widespread-chemical-contamination-recycled-plastic-pellets-globally>

**None of the samples were free from all the targeted chemicals, and 21 samples contained all three types of chemicals.**

**More than half of the samples contained 11 or more chemicals, and 17 samples contained five or more endocrine disrupting chemicals.**

**Brominated flame retardants were present in 22 of the samples, with DecaBDE being the most frequently detected, despite its listing under the Stockholm Convention for global elimination in 2017 without any exemptions**

**for recycling. Bisphenol A is increasingly being regulated in many countries because of its health impacts on children but was still detected in 22 of the samples.**

*All pellet samples contained the UV stabilizer UV-326. Evidence is still emerging, but there are indications that it can impact gene expression related to inflammation and immune responses.*

**The benzotriazole UV stabilizer UV-327 is classified as a Substance of Very High Concern in the EU and was detected in 19 samples. The large number of toxic chemicals in many of the samples highlights the need to also consider the potential for combination effects.**

- **Plastic Recycling Practices in Vietnam and Related Hazards for Health and the Environment<sup>57</sup> –**

University of Natural Resources & Life Sciences, Austria - Vietnam Cleaner Production Centre Co. Ltd, Hanoi, Vietnam - School of Environmental Science & Technology, Hanoi University of Science & Technology, Hanoi, Vietnam - University of Science, Vietnam National University, Hanoi, Vietnam – April 2021

***This paper analyzes how plastic waste is handled in Vietnam, a country with a fast-growing industry and growing consumption.***

*A number of craft villages have focused on recycling activities.*

***However, due to a lack of state-of-the-art technology for recycling and a low degree of organization, the typical processes for plastic recycling in craft villages come along with health risks for workers and neighbours and a high potential of environmental pollution.***

***This includes dust from sorting and shredding, wastewater from washing steps, and the uncontrolled disposal of residuals including uncontrolled burning.***

***A major source of contamination is the emissions of VOC from the extrusion process.***

### 3.1.1. Overview of the Plastic Industry in Vietnam

*Vietnam's plastic industry is one of the industries with relatively fast growth compared to the national economy in general. During the period from 2012 to 2017, Vietnam's plastic industry grew on average 11.6% a year, faster than the world plastics industry's 3.9% growth and faster than Vietnam's average GDP growth of 6.2% over the same period [12]. The plastic industry volume in 2017 was estimated at around USD 15 billion, equivalent to about 6.7% of Vietnam's GDP in 2017 [12].*

***The majority of the product sectors are packaging (37%), household furniture (29%), construction (18%), and electronic appliances (29%) [13]. Therefore, Vietnam has become one of the top 20 global plastic products exporters and exports plastic products to more than 55 different countries [14].***

<sup>57</sup> <https://www.mdpi.com/1660-4601/18/8/4203>

However, the plastic emissions during recycling activities are not inherently hazardous, but they should be regarded as potentially toxic substances (PoTSs) as defined by Hahladakis et al. [31]. Their toxicity arises from environmental conditions and stresses, exposure pathways, concentration, exposure duration, and other social-economic factors.

### 3.1.5. Management of Plastic Waste in Vietnam

The awareness of the majority of people of the sorting, collection, transportation, and treatment of MSW, especially plastic waste and plastic bags, is still limited. People are usually not aware of the harmful effects of plastic waste disposal to the environment and the ecosystem.

The collection and sorting of recyclable plastic waste from households is done by informal collectors. The collection rate for plastic waste is low, specifically for plastic bags, which are made of thin films and difficult to recycle. Producers of plastic packaging and other plastic products do not have a responsibility for the management of plastic waste.

**The recycling materials are mainly paper and plastics, which are processed manually and with outdated technology causing high emissions rates.**

**Minh Khai village has a processing capacity of between 550–600 t/day of input material, which mostly consists of waste PE, PP, PVC, PS, HDPE, and LDPE plastics.**

**It originates both from domestic and from international markets such as China, South Korea, Australia, and European countries.**

About 85–90% of input material is used for waste plastic recycling, 5–10% consists of other recyclables, and approx. 3–5% is disposed of in the proximity of the village in dumpsites and roadsides [29].

The main production outputs from Minh Khai village are PE and PP granules (90% purity), while the remaining outputs consist of other plastic products, such as plastic bags, trays, ropes, and buckets, and other recycling services, such as plastic shredding and trading in waste materials.

### 4.1. Environmental Impacts

Waste plastics contain a wide range of different additives, which are mixed up with the polymer substrate in order to improve plastic characteristics such as durability, colour, and flammability.

The most commonly used additives can be classified into the following categories with descending average concentration in the polymer substrate: plasticisers, flame retardants, stabilizers and antioxidants, slip agents, curing agents, biocides, colorants and pigments, and fillers [30].

During the informal recycling activities, waste plastics are exposed to mechanical, thermal, and chemical stresses, and a combination of these in uncontrolled conditions.

**For this reason, plastic additives tend to be released during the recycling process with the potential to cause adverse effects on health and the environment [29]. However, the plastic emissions during recycling activities are not inherently hazardous, but they should be regarded as potentially toxic substances (PoTSs) as defined by Hahladakis et al. [31].** Their toxicity arises from environmental conditions and stresses, exposure pathways, concentration, exposure duration, and other social-economic factors.

### 4.2. Health Risks Arising from Informal Recycling

However, the exceeding of parameters and the contamination of the air and surface water can lead to health problems.

Informal recycling sites are known hotspots of dioxins and dioxin-related compounds (DRC), since they are formed during incomplete combustion at temperatures between 200 and 800 °C under the presence of BFRs and other halogenated FR as their chemical catalysts [58].

*Such conditions are abundantly present during the open burning of waste plastics [59,60]. Dioxins are highly lipophilic compounds and insoluble in water, which triggers an easy transition from the environment to living organisms and subsequently humans [61]. Tue et al. [62] investigated the accumulation levels and profiles of DRC in breast milk samples from women living in the proximity of separate informal recycling sites.*

*The results showed that women who are living in the proximity of informal recycling sites but are not directly involved, do not have significantly higher concentrations of World Health Organization toxicity equivalents (WHO-TEQ) compared to the control group of the Vietnamese background range (0.22–7.4 vs. 1.1–3.0 pg/g lipid).*

***However, women directly involved in the informal recycling activities did have significantly higher concentrations of polychlorinated dibenzofurans PCDFs (13–15 pg/g lipid) and polybrominated dibenzofurans PBDFs (1.1–1.5 pg/g lipid) compared to the background range of 2.3–8.8 pg/g lipid and <1.1 pg/g lipid for PCDFs and PBDFs, respectively.***

*Cao et al. [63] assessed bioaccessibility and human health risk of Cu, As, Cd, Sb, and Pb in the soil near e-waste and waste plastic burning sites in Accra, Ghana using in vitro assay.*

*The results of this study show elevated total concentrations of 211–20,400 mg/kg for Cu, 10–29 mg/kg for As, 7–29 mg/kg for Cd, 24–9450 mg/kg for Sb, and 24–10,800 mg/kg for Pb.*

***The results for bioaccessibility-corrected human health risk assessment revealed noncarcinogenic risk for local inhabitants in half of the analyzed sites, while the carcinogenic risk was within an acceptable range.***

***Sb together with Cu and Pb were identified to be one of the major metals of concern that contributed the most to the health risk.***

- **Recycling Plastics from WEEE: A Review of the Environmental and Human Health Challenges Associated**

**with Brominated Flame Retardants<sup>58</sup>** – Restructa Ltd., North Newmoor Industrial Estate, UK - University of the West of Scotland, Paisley, UK - CCL (North) Ltd., Meadowhead Industrial Estate, Irvine, UK - School of Health & Life Sciences, University of the West of Scotland, UK – January 2022

***Waste electrical and electronic equipment (WEEE) presents the dual characteristic of containing both hazardous substances and valuable recoverable materials. Mainly found in WEEE plastics, brominated flame retardants (BFRs) are a component of particular interest.***

***Several actions have been taken worldwide to regulate their use and disposal, however, in countries where no regulation is in place, the recovery of highly valuable materials has promoted the development of informal treatment facilities, with serious consequences for the environment and the health of the workers and communities involved.***

*Overall, the presence of BFRs in WEEE plastics is a matter of concern when it comes to their management and focus must be put on aiming to prevent potential negative impacts to both the environment and public health.*

*That is why it is imperative that knowledge on the subject continues to be developed and deepened in order to provide all actors involved in WEEE management with the necessary tools to develop strategies to prevent any harmful impacts.*

<sup>58</sup> <https://www.mdpi.com/1660-4601/19/2/766>

- **Addressing the toxic chemicals problem in plastics recycling**<sup>59</sup> – University of Gothenburg,

Gothenburg, Sweden - Helmholtz-Centre for Environmental Research, Germany - University of Nigeria, Nsukka, Nigeria - Wageningen University & Research, The Netherlands - Institute for Environmental Research, RWTH Aachen University, Aachen, Germany - International Pollutants Elimination Network, Gothenburg, Sweden – January 2025

**Plastics contain a vast range of chemicals, including monomers, polymers, processing agents, fillers, antioxidants, plasticizers, pigments, microbiocides and stabilizers.**

**The amounts and types of chemicals in plastics products vary, and there are little requirements for transparency and reporting.**

**Additionally, they are inherently contaminated with reaction by-products and other nonintentionally added substances (NIASs). As the chemical composition of plastics wastes is largely unknown, and many plastics chemicals are hazardous, they therefore hinder safe recycling since recyclers are not able to exclude materials that contain hazardous chemicals.**

**In the European Union (EU), for example, several legislative initiatives of the EU support a circular economy and aim to increase recycling, but the EU currently has no regulations that call for reduction in primary plastics production at the top of the waste hierarchy and start of the plastics life cycle.**

Similarly, the EU Packaging and Waste Directive (94/62/EC; European Parliament, [2018](#) ; COM/2023/304; EC, [2023](#)) calls for increased masses of recycled materials. The European Strategy for Plastics in a Circular Economy (COM/2018/028; European Commission, [2018](#)) addresses design standards and production of plastics and products, highlighting reuse, repair and recycling and the need for more sustainable materials.

**Data show that plastics recycling has repeatedly failed to operate in a safe and circular manner** (Allen et al., Reference Allen, Spoelman, Linsley and Juhl2024; Carroll, Reference Carroll2023). Estimates indicate that only 9% of plastics have been recycled (Geyer et al. 2017).

This leaves a massive gap to the scenarios that highlight recycling as a means to curb plastics pollution, since those scenarios call for true recycling rates of 60% by 2060 according to the OECD ([2023a](#)).

Another study shows that a seven-fold increase compared to 2019 baselines, with an increase to 95% collection rates and 15–68% recycling rates, would be required (Shiran et al., Reference Shiran, de la Fuente, Ragot, von Boetticher, Fuchs, Mauth, Lingeswaran, Hahn and Stein2023).

**There are several challenges with plastics recycling. These include material complexity (e.g., materials containing multiple layers of different polymers and chemicals) and polymer degradation (e.g., degradation of polymer backbones; Ragaert et al., Reference Ragaert, Delva and Van Geem2017), lack of economic incentives (Larrain et al., Reference Larrain, Van Passel, Thomassen, Van Gorp, Nhu, Huysveld, Van Geem, De Meester and Billen2021), chemical contamination (Carmona et al., Reference Carmona, Rojo-Nieto, Rummel, Krauss, Syberg, Ramos, Brosche, Backhaus and Almroth2023), spread of microplastics (Stapleton et al., Reference Stapleton, Ansari, Ahmed and Hai2023) and energy inefficiency (Vogt et al., Reference Vogt, Stokes and Kumar2021).**

**Scientists have therefore warned that policy initiatives focused on recycling technologies risk creating infrastructure “lock-in” and increased waste production (Syberg, Reference Syberg2022).**

<sup>59</sup> <https://www.cambridge.org/core/journals/cambridge-prisms-plastics/article/addressing-the-toxic-chemicals-problem-in-plastics-recycling/552E550968DC2E0119DB937925505DC6>

**Other technologies than mechanical recycling exist, including so-called chemical recycling technologies, but currently do not work at scale, in part due to risks associated with chemical impurities in feedstocks, and these technologies have also been shown to cause high emissions of toxic chemicals (Al-Salem et al., Reference Al-Salem, Antelava, Constantinou, Manos and Dutta<sup>2017</sup>; Bell et al., Reference Bell, Gitlitz, Congdon and Rollinson<sup>2023</sup>; Quicker, Reference Quicker<sup>2024</sup>; Rollinson and Oladejo, Reference Rollinson and Oladejo<sup>2019</sup>; Uekert et al., Reference Uekert, Singh, DesVeaux, Ghosh, Bhatt, Yadav, Afzal, Walzberg, Knauer, Nicholson, Beckham and Carpenter<sup>2023</sup>).**

**The consequence is that it is rarely possible for downstream users, producers or recyclers to know anything about the chemicals used in the plastics that they encounter.**

**In addition to chemicals that were in the original primary plastics materials, recent work shows that recycled plastics materials contain numerous other contaminants that likely sorbed to the materials during use, handling, processing or while the materials were out in the environment (if the plastics were collected from dump sites or the open environment; Carmona et al., Reference Carmona, Rojo-Nieto, Rummel, Krauss, Syberg, Ramos, Brosche, Backhaus and Almroth<sup>2023</sup>).**

**These chemicals include various pesticides, pharmaceuticals and biocides, which renders the recycled plastics unfit for use in many products, especially in children's toys and food contact materials.**

**Therefore, beyond the limited efficacy of different recycling methodologies and practices, there are several concerns about consumers exposed to chemicals during the use of products and materials made from recycled plastics (Gerassimidou et al., Reference Gerassimidou, Lanska, Hahladakis, Lovat, Vanzetto, Geueke, Groh, Muncke, Maffini, Martin and Iacovidou<sup>2022</sup>; Geueke et al., Reference Geueke, Phelps, Parkinson and Muncke<sup>2023</sup>; Hawkins et al., Reference Hawkins, Potter and Race<sup>2015</sup>; Yang et al., Reference Yang, Ma, Thompson and Flower<sup>2018</sup>) and about the safety of waste pickers and other people working with plastics wastes and recycling.**

**For workers, it has, for example, been shown that heavy metals were present in recycled plastics at or above the US EPA levels and that there was a clear exposure-risk association between heavy metals and worker health (Huang et al., Reference Huang, Xie, Li and Zhang<sup>2021</sup>).**

**Waste pickers in Africa are exposed to hazardous materials including toxic chemicals (Binion and Gutberlet, Reference Binion and Gutberlet<sup>2012</sup>; Uhunamure et al., Reference Uhunamure, Edokpayi and Shale<sup>2021</sup>).**

**Studies on materials and products made from recycled plastics have also shown that chemicals contaminate recycled materials, including food packaging and toys made from recycled plastics (Brosché et al., Reference Brosché, Strakova, Bell and Karlsson<sup>2021</sup>; Chibwe et al., Reference Chibwe, De Silva, Spencer, Teixeira, Williamson, Wang and Muir<sup>2023</sup>; Gerassimidou et al., Reference Gerassimidou, Lanska, Hahladakis, Lovat, Vanzetto, Geueke, Groh, Muncke, Maffini, Martin and Iacovidou<sup>2022</sup>; Horodytska et al., Reference Horodytska, Cabanes and Fullana<sup>2020</sup>).**

***The chemicals include POPs such as brominated flame retardants, benzotriazole UV stabilizers and PFAS and endocrine disrupting chemicals such as bisphenols.***

***Improved reporting, transparency and traceability of chemicals in plastics throughout their full life cycle***

*A compulsory, globally standardized mandate that ensures transparent reporting of information regarding the chemicals used in plastics, including monomers, polymers, additives and nonintentionally added substances (NIASs) is an essential cornerstone for facilitating a safer and more sustainable reuse, refill, repurpose and recycling market.*

*The ongoing negotiations for a future plastics treaty presents an opportunity to improve transparency and traceability through the implementation of suitable control measures.*

*To facilitate informed decisions regarding restrictions, bans and elimination of hazardous chemicals, it is important that a globally standardized public database with curated data on production and use of processing aids, additives and monomers and polymers within materials, products and their chemical constituents becomes publicly available.*

- **“Chemical Recycling” Is a Toxic Trap<sup>60</sup>** – National Resources Defence Council – March 2025

*What pyrolysis mostly produces is fuels, yet fuel production and use do not constitute “recycling.” What’s more, these fuels can be highly toxic. In 2023, the U.S. Environmental Protection Agency (EPA) approved 18 new chemical mixtures derived from plastic waste for use as fuels, even though EPA scientists had also determined that some of these chemicals posed astoundingly high cancer risks.*

***One of the chemical mixtures, intended to be used as jet fuel, was estimated to pose a one in four cancer risk (meaning that one in every four people regularly exposed to it throughout their life would likely develop cancer). The EPA later rescinded the approvals and is reassessing the chemicals.***

*At the same time, the pyrolysis process creates large amounts of hazardous waste.*

*EPA reporting data shows that between 2021 and 2024, just three pyrolysis facilities that were processing plastic waste generated more than 2 million pounds of hazardous waste and shipped it off-site for disposal.*

*If all 26 of the pyrolysis facilities that are currently proposed or under construction are actually built and put into operation, this could mean between 624,000 and 10.8 million additional pounds of hazardous waste generated in, transported through, and disposed of in communities across the country.*

Read the full issue briefs:

- More Recycling Lies: What the Plastics Industry Isn't Telling You About "Chemical Recycling" - Issue Brief (PDF)<sup>61</sup>
- Recycling Lies: “Chemical Recycling” of Plastic Is Just Greenwashing Incineration - Issue Brief (PDF)<sup>62</sup>
- “Chemical Recycling” Is Not Recycling: The Plastic Industry Is Greenwashing Incineration - Fact Sheet (PDF)<sup>63</sup>

<sup>60</sup> <https://www.nrdc.org/resources/chemical-recycling>

<sup>61</sup> [https://www.nrdc.org/sites/default/files/2025-03/More\\_Recycling\\_Lies\\_IB\\_25-02-A\\_07\\_locked.pdf](https://www.nrdc.org/sites/default/files/2025-03/More_Recycling_Lies_IB_25-02-A_07_locked.pdf)

<sup>62</sup> <https://www.nrdc.org/sites/default/files/chemical-recycling-greenwashing-incineration-ib.pdf>

<sup>63</sup> <https://www.nrdc.org/sites/default/files/chemical-recycling-plastic-greenwashing-incineration-fs.pdf>

- **Unpacking the complexity of the polyethylene food contact articles value chain: A chemicals perspective<sup>64</sup> -**

Brunel University London, United Kingdom - Food Packaging Forum Zurich, Switzerland – Swiss Federal Institute of Aquatic Science & Technology, Switzerland - Qatar University, Doha, Qatar - University College London, UK - College of Health, Medicine and Life Sciences, Brunel University London, United Kingdom – April 2023

***Polyethylene (PE) is the most widely used type of plastic food packaging, in which chemicals can potentially migrate into packaged foods.***

*The implications of using and recycling PE from a chemical perspective remain underexplored.*

***This study is a systematic evidence map of 116 studies looking at the migration of food contact chemicals (FCCs) across the lifecycle of PE food packaging.***

***It identified a total of 377 FCCs, of which 211 were detected to migrate from PE articles into food or food simulants at least once.***

***These 211 FCCs were checked against the inventory FCCs databases and EU regulatory lists. Only 25% of the detected FCCs are authorized by EU regulation for the manufacture of food contact materials.***

***Furthermore, a quarter of authorized FCCs exceeded the specific migration limit (SML) at least once, while one-third (53) of non-authorized FCCs exceeded the threshold value of 10 µg/kg.***

***5. Discussion Our in-depth analysis reveals the migration potential of 377 FCCs from PE-FCMs, of which 211 FCCs have been found to migrate at detectable levels at least once.***

***Grouping the detected FCCs into IAS and NIAS was not possible, as there is a lack of clear indications on whether an FCC was intentionally or non-intentionally added to the PE food packaging. However, BPA has been detected in PE bottles at levels below the SML [35,83,84]. BPA is included in the databases as it is an IAS for other polymers (e.g., PVC or PC).***

***The SML of BPA may not guarantee human safety [72], as evidenced by a recent EFSA opinion that has suggested lowering the tolerable daily intake (TDI) 100,000 times compared to the current TDI [53].***

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<sup>64</sup> <https://discovery.ucl.ac.uk/id/eprint/10169661/1/1-s2.0-S0304389423007057-main.pdf>

- **Recycled plastic food wrappers spark safety concerns<sup>65</sup>** - Brunel University London, University College London - Qatar University - the Food Packaging Forum – May 2023

*Researchers at Brunel University London, University College London and Qatar University, working with the Food Packaging Forum, analysed 116 studies into how PE packaging chemicals leach into the food and potentially be absorbed into the body.*

*The team identified 377 'food contact chemicals' in PE packaging, such as the bisphenol A and phthalates that can disrupt hormones and lead to health risks. Some 211 of these 377 chemicals seep into food at least once during the plastic's life cycle.*

*Alarmingly, only a quarter of those is authorised by EU regulation, a third of which are above the safe limit. "The number of non-authorised chemicals was unexpectedly high," said Dr Eleni Iacovidou, who lectures in environmental management.*

*"This finding highlights the lack of traceability and harmonisation of existing regulations.*

*"We found a lack of sufficient evidence to show PE can be safely recycled into new food-grade packaging," she said, explaining that many of the studies they looked at don't have enough detail such as what the bag or container is used for, how thick it is, how it would be stored and how many times it might be reused.*

*"Recycled PE is increasingly sought after in the production of new food-grade packaging, yet the quality of recycled PE poses critical questions from a chemical safety perspective." Dr Iacovidou said.*

- **Fingerprinting risk from recycled plastic products using physical and chemical properties<sup>66</sup>** – Environmental Plastic Innovation Cluster, Global Innovative Centre for Advanced Nanomaterials, College of Engineering, Science and Environment, The University of Newcastle, Australia – May 2025

*This study compared the physical and chemical characteristics of recycled plastic products intended for food, oral, or skin contact applications with similar virgin plastic products.*

*The results revealed significant changes in the surface morphology and elevated concentration of organic and inorganic chemicals in the recycled plastics compared to the virgin plastics.*

*Specifically, metal(loids) concentrations were over 10 times higher, PFAS levels were twice as high, and PAH levels were three times higher in the recycled plastics.*

*The calculated Hazard Index (HI) indicates up to a twofold increase in recycled plastics for both adults and children compared to virgin plastics, specifically through microplastic ingestion.*

*The HI values exceed 1 for recycled plastic ingestion, therefore it falls in high-risk category due to the associated chemical exposure from microplastics.*

<sup>65</sup> <https://www.brunel.ac.uk/news-and-events/news/articles/Recycled-plastic-food-wrappers-spark-safety-concerns>

<sup>66</sup> <https://www.sciencedirect.com/science/article/abs/pii/S0304389425004194>

**Recycled plastics can serve as vectors for releasing these concerning additives, posing additional risks to both human health and the environment. They can also migrate from food packaging, contaminating the food matrix [44].**

Recently several studies have quantified the release of harmful chemical substances such as metals, [68] brominated flame retardants (BFR), [28] persistent organic pollutants (POPs) [18], phosphorous flame retardants, and phthalates [14], [22], [34] from recycled plastic products.

For example Pivnenko et al. [48], quantified phthalates in recycled plastic and found dibutyl phthalate (DBP), diisobutyl phthalate (DiBP), and Di (2-ethylhexyl) phthalate (DEHP) at concentrations of up to 360 µg/g, 460 µg/g, and 2700 µg/g, respectively.

The other study in China reported up to 169,000 ng/g of halogenated flame retardants in recycled plastic products [10]. Target analysis of recycled plastic flakes and pellets conducted by Chibwe et al. [15], identified organophosphorus ester flame retardants and plasticizers as the most frequently detected compounds with the highest concentrations, followed by brominated/chlorinated flame retardants and perfluoroalkyl acids.

Non-target analysis (NTA) further revealed a variety of chemical categories, including plasticizers, fragrances, flame retardants, and antioxidants.

**Per- and polyfluoroalkyl substances (PFAS) have also been reported in fluorinated high-density polyethylene (HDPE) food containers, with an average concentration of 63.8 ng/g for total PFAS and the leaching levels reaching up to 7.2 ng/g into food matrices [66].**

This could introduce an additional exposure route when such containers enter the recycling stream.

- **Understanding intentionally and non-intentionally added substances and associated threshold of toxicological concern in post-consumer polyolefin for use as food packaging materials<sup>67</sup> – Polymer & Food Protection Consortium, Iowa State University, USA - Dept of Food Science & Human Nutrition, Iowa State University, USA – December 2023**

**This study aimed to identify potentially harmful substances, including non-intentionally added substances (NIAS) and unapproved intentionally added substances (IAS), in polyolefin samples from material recovery facilities using gas-chromatography mass-spectrometry.**

Selected phthalates and bisphenols were quantified by targeted gas-chromatography tandem mass-spectrometry.

**The analysis detected 9 compounds in virgin polymers and 52 different compounds including alcohols, hydrocarbons, phenols in virgin and hydrocarbons, aromatic, phthalates, organic acids, per- and polyfluoroalkyl substances (PFAS) in PCR polymers.**

**The PCR sample showed a slightly higher proportion of Cramer Class III compounds (48.08 %) than the virgin sample (44.44 %), indicating higher toxicity potential.**

Quantification **detected bisphenols only in PCR material including BPA** ( $2.88 \pm 0.53$  µg/g), BPS ( $5.12 \pm 0.003$  µg/g), BPF ( $3.42 \pm 0.01$  µg/g), and BADGE ( $4.638$  µg/g). **Phthalate concentrations were higher in PCR than virgin samples, with the highest levels detected as DIDP, at  $6.18 \pm 0.31$  µg/g for PCR and  $6.04 \pm 0.02$  for virgin.**

<sup>67</sup> <https://pmc.ncbi.nlm.nih.gov/articles/PMC10770487/>

*This study provides critical understanding of the safety and potential risks associated with using PCR polyolefins from different sources in food contact applications.*

*Meanwhile, hydrocarbons and aromatics have the highest composition in PCR materials, both at 23.08 %, **with notable amounts of phthalates (7.69 %) and PFAS (3.84 %) also present.***

*The composition of compounds in materials is crucial to consider for a variety of reasons.*

*For example, **the presence of phthalates and PFAS in plastic materials has been linked to health issues such as cancer and endocrine modulation.***

***Therefore, the higher concentration of phthalates in PCR materials compared to virgin materials may pose a risk in certain applications.***

***The composition of organic compounds in PCR materials can vary depending on their source and processing method, which can affect their suitability for different applications.***

*The detected compounds in the xylene extract were classified as hydrocarbons, phenols, alcohols, phthalates, organic acids, per- and polyfluoroalkyl substances (PFAS), ketones, amides, and amines.*

***Phthalates and (PFAS) were detected in the recycled materials but not in the virgin materials from survey analysis.***

*Functional group analysis revealed that phenol has the highest proportion in virgin materials, while hydrocarbons, aromatics, phthalates, and PFAS are notable components of PCR materials used in packaging. Some of the compounds detected were degradation products or processing aids mainly in PCR samples that could remain in the final product.*

***The presence of potentially harmful compounds in polyolefin materials can have various impacts on human health and the environment. For example, phthalates and PFAS have been linked to adverse health effects such as endocrine disruption/modulation, developmental and reproductive toxicity, and cancer.***

- Food Service Packaging Institute<sup>68</sup> - May 2023

***Due to regulatory constraints on incorporation of recycled content for food contact packaging materials, even when materials were recovered and reprocessed, the resulting recyclate typically could not be used for certain foodservice applications, including the single-use items from which the material originated.***

***In short, the current recycling infrastructure, with its emphasis on mechanical recycling processes, is unable to meet market demands.***

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<sup>68</sup> <https://www.regulations.gov/comment/FTC-2022-0077-1075>

- **Exxon Mobil<sup>69</sup>** – May 2023

*While mechanical recycling provides a successful recycling outlet for some polymers, like PET and HDPE, this technology is not able to address all society's recycling needs.*

*For example, there is a risk that contaminants from the waste system can accumulate in mechanically recycled plastic, making it challenging to use mechanically recycled plastic in more sensitive applications, such as in food contact, personal hygiene, and medical products.*

*As a result, these important, consumer facing industries are not able to effectively participate in and support a circular economy.*

*Given that plastic waste in advanced recycling is frequently combined with other feedstocks (materials used in the creation of plastics and chemicals), it is often infeasible or impractical to physically segregate or track where the individual molecules resulting from the plastic waste end up.*

- **An Assessment of Mass Balance Accounting Methods for Polymers Workshop Report** – National Institute of Standards and Technology<sup>70</sup> - February 2022

*In fact, a recent investigation revealed the use of more than 10,000 chemical substances in plastic product formulation, only a fraction of which have been widely studied and many of which are known as substances of potential concern [11].*

*Many of these substances are not chemically bound to the polymer matrix and, therefore, have the potential to be released throughout the lifecycle of the plastic.*

- **STINA (2021), Assessing the State of Food Grade Recycled Resin in Canada & the United States<sup>71</sup>** - Environment and Climate Change Canada – 2021

*Because polyolefins are more prone to absorbing additives and volatiles from products, or consumer secondary use, into the thickness of the plastic, the migration of these from the bottle or package back into food or beverage products is a particular concern with these resins.*

*Consumer packaged goods company (CPG) interviewees noted that these concerns are not limited to just food product packaging but include concerns about many personal care product packages as well.*

*The use of PCR is application dependent at the brand level and some products aren't likely to ever use mechanically recycled material because of concerns or uncertainties about perceived safety of the recycled plastic.*

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<sup>69</sup> <https://www.regulations.gov/comment/FTC-2022-0077-0925>

<sup>70</sup> <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1500-206.pdf>

<sup>71</sup> [https://www.plasticsmarkets.org/jsfcontent/ECCC\\_Food\\_Grade\\_Report\\_Oct\\_2021\\_jsf\\_1.pdf](https://www.plasticsmarkets.org/jsfcontent/ECCC_Food_Grade_Report_Oct_2021_jsf_1.pdf)

- **Why are some plastics harder to recycle?<sup>72</sup>** – Exxon Mobil - July 2024

Two of the key challenges are: Contaminated plastic. Products with layers of different types of plastic.

**Many used plastic products – like food packaging or bottles of motor oil – are contaminated with oil and grease. That’s hard to remove with mechanical recycling, where plastic waste is ground up and melted down to make new products from the same material.**

**Which means mechanical recycling normally doesn’t work for plastic products with very high safety and hygiene standards. For example, plastic film and containers used in food packaging and other items for the food and medical sectors. In these fields, you need uncontaminated virgin-quality plastic.**

- **A comprehensive review on exposure to toxins and health risks from plastic waste: Challenges,**

**mitigation measures, and policy interventions<sup>73</sup>**– College of Science, Technology, Environment and Climate University of Liberia, Monrovia, Liberia - College of Engineering, University of Liberia, Monrovia, Liberia - Kampala International University, Kampala, Uganda - School of Pharmacy, University of Liberia, Monrovia, Liberia - Department of Pharmacology and Toxicology, Kampala International University, Bushenyi-Ishaka, Uganda - Department of English and Language Studies, Amos C. Sawyer College of Social Sciences and Humanities, University of Liberia, Monrovia, Liberia - September 2025

**Furthermore, mechanical recycling is ill-equipped to handle the removal of toxic additives like phthalates, bisphenol A, and heavy metals embedded in the plastic matrix. These substances persist in recycled products, potentially reintroducing health risks to consumers (Hahladakis et al., 2018).**

Another critical challenge lies in the inability of recycling technologies to effectively process multi-layered and composite plastics, which are increasingly prevalent in consumer packaging.

These materials, composed of layers of different polymers and often combined with metals or other substances, are resistant to mechanical recycling due to their heterogeneous nature (Chanda, 2021).

As a result, they are frequently incinerated or landfilled, contributing to the release of toxic substances such as dioxins and heavy metals (Yusuf et al., 2022).

Moreover, contamination remains a persistent issue in recycling streams. Plastic waste contaminated with food residues, oils, or hazardous chemicals is often deemed unsuitable for recycling, leading to its diversion to landfills or incinerators.

This contamination not only reduces the efficiency of recycling operations but also poses additional risks of toxin release during processing (Singh and Walker, 2024).

In regions with inadequate waste segregation systems, such as parts of Southeast Asia, high contamination rates significantly undermine the effectiveness of recycling initiatives, perpetuating the cycle of environmental and health hazards associated with plastic waste toxins (Ng et al., 2023, Omeyer et al., 2022).

<sup>72</sup> <https://corporate.exxonmobil.com/locations/european-region/european-newsroom/why-are-some-plastics-harder-to-recycle>

<sup>73</sup>

[https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20\(BPA,impacts%20of%20phthalates%20and%20BPA](https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20(BPA,impacts%20of%20phthalates%20and%20BPA)

- **Effect of recycled content and rPET quality on the properties of PET bottles, part I: Optical and mechanical**

**properties and Effect of recycled content and rPET quality on the properties of PET bottles, part III: Modelling of repetitive recycling**<sup>74 75</sup> - Wageningen Food & Biobased Research, Biobased Products Business Unit, Wageningen, The Netherlands - Top Institute Food and Nutrition, Wageningen, The Netherlands – January 2020

*The presence of contaminants in polyethylene terephthalate (PET) bottles and derived materials from the various steps in the recycling loop is studied. Based on these measurements, a model is proposed to generically describe the accumulation of these contaminants within closed-loop recycling schemes for PET bottles.*

*The measured levels of particle contamination and chlorine content of PET bottles, pellets, and intermediate recycling products are used to derive the modelling parameters. Previously determined relations between these measured parameters and critical bottle properties are used to model the effect of the accumulation of the contaminants on the bottle properties. The measurements reveal that the type of collection system influences the accumulation of contaminants in PET bottles greatly.*

**PET bottles in mono-collection systems accumulate less contaminants than PET bottles in co-collection systems do.** *Therefore, PET bottles within recycling schemes using mono-collection systems can contain more recycled content than those from co-collection systems, without exceeding acceptance limits on critical bottle properties such as haziness, yellowing, and migration.*

*Only a few papers report on the particle and polymeric contamination of recycled plastics.<sup>4, 5, 17, 18</sup> This is especially relevant for PET bottles since small amounts of particle and/or polymeric contamination in the rPET matrix reduce the optical transparency (haze).<sup>4, 19</sup> Moreover, small amounts of polyvinyl chloride (PVC) and polystyrene (PS) in the PET bottle matrix are held responsible for initiating reactions that result in the formation of undesired molecular contaminants which migrate to the contained beverage.<sup>20</sup>*

*Two previous papers have described the impact of RC and rPET quality on two critical properties of PET bottles: the migration of volatile compounds and the optical properties.<sup>19, 20</sup> In these papers, correlations were found between two core parameters of rPET (chlorine content and particle contamination) and the two abovementioned critical bottle properties. A clear relationship was found between the migration of volatile compounds and chlorine content of rPET.<sup>20</sup>*

## 5 CONCLUSIONS

*The contamination of rPET with particles and chlorine has been measured at various locations in the recycling loop for PET beverage bottles.*

**Mono-collection systems were found to accumulate less contaminants in the rPET material than co-collection systems.**

**These increments in contamination levels per recycling loop were used to model the accumulation of these contaminants after multiple recycling loops.**

**Under the condition of a closed recycling system with the same types of virgin PET and rPET as feedstock, the contamination will reach asymptotic values of which the height depends on the RC.**

<sup>74</sup> <https://onlinelibrary.wiley.com/doi/full/10.1002/pts.2489>

<sup>75</sup> <https://onlinelibrary.wiley.com/doi/full/10.1002/pts.2490>

- **Plastic Recycling Practices in Vietnam and Related Hazards for Health and the Environment<sup>76</sup>** – BOKU

University, Austria – Vietnam National University, Hanoi – April 2021

*This paper analyzes how plastic waste is handled in Vietnam, a country with a fast-growing industry and growing consumption.*

*A number of craft villages have focused on recycling activities. However, due to a lack of state-of-the-art technology for recycling and a low degree of organization, the typical processes for plastic recycling in craft villages come along with health risks for workers and neighbours and a high potential of environmental pollution.*

*This includes dust from sorting and shredding, wastewater from washing steps, and the uncontrolled disposal of residuals including uncontrolled burning.*

***A major source of contamination is the emissions of VOC from the extrusion process.***

#### 4.1. Environmental Impacts

*Waste plastics contain a wide range of different additives, which are mixed up with the polymer substrate in order to improve plastic characteristics such as durability, colour, and flammability. The most commonly used additives can be classified into the following categories with descending average concentration in the polymer substrate: plasticisers, flame retardants, stabilizers and antioxidants, slip agents, curing agents, biocides, colorants and pigments, and fillers [30].*

***During the informal recycling activities, waste plastics are exposed to mechanical, thermal, and chemical stresses, and a combination of these in uncontrolled conditions.***

***For this reason, plastic additives tend to be released during the recycling process with the potential to cause adverse effects on health and the environment***

- **A comprehensive review on exposure to toxins and health risks from plastic waste: Challenges, mitigation**

**measures, and policy interventions** – University of Liberia, Monrovia, Liberia - Department of Biological & Environmental Sciences, Kampala International University, Kampala, Uganda - Department of Pharmacology and Toxicology, Kampala International University, Bushenyi-Ishaka, Uganda - September 2025

***Furthermore, chemical recycling often produces byproducts, including hazardous residues and greenhouse gases, raising concerns about its environmental impact (Kassab et al., 2023).***

*In countries like India, which generates approximately 9.5 million metric tons of plastic waste annually (Times of India, 2024), deploying such technologies is hindered by infrastructural deficits and economic constraints, leading to continued reliance on unsustainable disposal methods.*

*Another critical challenge lies in the inability of recycling technologies to effectively process multi-layered and composite plastics, which are increasingly prevalent in consumer packaging.*

*These materials, composed of layers of different polymers and often combined with metals or other substances, are resistant to mechanical recycling due to their heterogeneous nature (Chanda, 2021).*

<sup>76</sup> <https://www.mdpi.com/1660-4601/18/8/4203>

- **No Plastic in Nature: Assessing Plastic Ingestion from Nature to People<sup>77</sup>** – World Wildlife Fund - 2019

*Further, toxins from ingested plastic have also been shown to harm breeding and impair immune systems*

*The long-term effects of plastic ingestion on the human body are not yet well documented.*

*But studies have shown that beyond a certain exposure level, inhalation of plastic fibres seem to produce mild inflammation of the respiratory tract<sup>22</sup>.*

*In marine animals, higher concentrations of microplastics in their digestive and respiratory system can lead to early death<sup>23</sup>.*

*Research studies have demonstrated toxicity in vitro to lung cells, the liver, and brain cells<sup>24</sup>.*

*Some types of plastic carry chemicals and additives with potential effects on human health.*

*Identified health risks are due to production process residues, additives, dyes and pigments found in plastic<sup>25</sup>, some of which have been shown to have an influence on sexual function, fertility and increased occurrence of mutations and cancers<sup>26,27</sup>.*

*Airborne microplastics may also carry pollutants from the surrounding environment. In urban environments, they may carry PAHs – molecules found in coal and tar – and metals<sup>28</sup>.*

- **Circular Claims Fall Flat Again<sup>78</sup>** - Greenpeace - 2022

*According to a 2021 report published by the Canadian Government, toxicity risks in recycled plastic prohibit “the vast majority of plastic products and packaging produced” from being recycled into food-grade packaging*

*[https://www.plasticsmarkets.org/isfcontent/ECCC\\_Food\\_Grade\\_Report\\_Oct\\_2021\\_isf\\_1.pdf](https://www.plasticsmarkets.org/isfcontent/ECCC_Food_Grade_Report_Oct_2021_isf_1.pdf)*

*Due to toxicity risks, post-consumer recycled plastic from household waste is not being produced at commercial scale for food-grade uses globally or in the U.S., and likely never will be.*

*While there is limited availability of food-grade PET#1 for beverage bottles only, there are growing toxicity concerns there, too - <https://pubmed.ncbi.nlm.nih.gov/35295000/>. **Unpacking the complexity of the PET drink bottles value chain: A chemicals perspective – 2022***

<sup>77</sup> [https://awsassets.panda.org/downloads/plastic\\_ingestion\\_press\\_singles.pdf](https://awsassets.panda.org/downloads/plastic_ingestion_press_singles.pdf)

<sup>78</sup> [https://www.greenpeace.org/static/planet4-usa-stateless/2024/11/0ca48867-gpus\\_finalreport\\_2022.pdf](https://www.greenpeace.org/static/planet4-usa-stateless/2024/11/0ca48867-gpus_finalreport_2022.pdf)

**Plastic waste reprocessing for circular economy: A systematic review of risks to occupational and public health from legacy substances and extrusion<sup>79</sup>** – University of Leeds - 2020

*Researchers at Leeds University in the United Kingdom performed a review of over 4,000 sources of information to evaluate the risks of (1) toxics in recycled plastics and (2) toxic exposure to workers and communities in plastic recycling operations. Workers were found to be exposed to toxics in mechanical plastic recycling operations. Our critical analysis highlights that despite stringent regulation, industrial diligence and enforcement, occasionally small amounts of potentially hazardous substances are able to pass through these safeguards and re-enter in the new product cycle. Several studies showed emission control by passive ventilation, through open doors and windows followed by dilution and dispersion in the atmosphere, resulting in increased occupational exposure. It is recommended that further investigations are undertaken to establish the scale and magnitude of such phenomena, especially given the limited evidence base, with results informing improved future risk management protocols of a circular economy for plastics.*

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact**

**during their use, disposal and recycling<sup>80</sup>** - School of Civil Engineering, University of Leeds, Woodhouse Lane, United Kingdom - POPs Environmental Consulting Schwäbisch Gmünd, Germany – 2018

*Conclusions*

*The present overview on the implications and potential environmental impact of several additives and various other PoTSs, during the use, disposal and recycling phase of plastic products highlighted the following:*

*It is important to quantify the migration of the compound that is under investigation, depending on the toxicity level and packaging material type.*

***Foods with a higher fat content have typically been reported to stimulate a higher level of migration.***

*In addition, MW heating was found to be a reliable technique in food processing, causing lower migration of additives than conventional oven heating under similar processing conditions. PVC was found unsuitable for MW heating.*

***Given the current situation on what can be placed on the market, while in compliance with all legal requirements that ensure the safety of plastic food contact materials, it can be concluded that only a limited part of the plastic waste stream might not be suitable for recycling purposes.***

*Such plastic materials could be either those with a not well enough defined origin or others coming from long-life applications, thereby failing to meet specific requirements.*

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[https://www.researchgate.net/publication/347393100\\_Plastic\\_waste\\_reprocessing\\_for\\_circular\\_economy\\_A\\_systematic\\_review\\_of\\_risks\\_to\\_occupational\\_and\\_public\\_health\\_from\\_legacy\\_substances\\_and\\_extrusion](https://www.researchgate.net/publication/347393100_Plastic_waste_reprocessing_for_circular_economy_A_systematic_review_of_risks_to_occupational_and_public_health_from_legacy_substances_and_extrusion)

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<https://www.sciencedirect.com/science/article/pii/S030438941730763X#:~:text=Despite%20how%20useful%20these%20additives,health%20protection%20at%20all%20times>

*Several PoTSs (e.g. toxic metals, BFRs, POPs and PAHs) could potentially be released by the application of various recycling techniques, especially in underdeveloped countries where the sorting-reprocessing-recycling conditions are most of the time uncontrolled; it is in fact these stages-steps that influence the final quality of the recyclate. In addition, part of the plastic waste generated in Europe comes from products that have been produced outside of Europe, as in the case of electronic and electrical devices.*

- **A comprehensive review on exposure to toxins and health risks from plastic waste: Challenges, mitigation measures, and policy interventions**<sup>81</sup> - University of Liberia Monrovia, Liberia - College of Engineering, University of Liberia, Monrovia, Liberia - Kampala International University Kampala, Uganda – September 2025

*Toxins such as phthalates, bisphenol A (BPA), dioxins, furans, and heavy metal residues released from plastic degradation cause severe health risks, including endocrine disruption, carcinogenesis, and respiratory diseases.*

*This study reviews exposure pathways and bioaccumulation mechanisms of plastic-derived toxins, their health risks, mitigation strategies, and policy interventions. The findings reveal that BPA concentrations in rivers can exceed 12 µg/L, and dioxins in soil surpass 1000 ng Toxic Equivalency Quotient (TEQ)/kg in areas with open burning, exceeding WHO thresholds. In Poland, landfill leachate shows phthalate levels over 303 µg/L, while heavy metals in fish tissue reached over 2.26 ng/g wet weight in Sweden.*

*Recent literature has expanded to consider the toxicological effects of plastic waste, specifically the release of harmful chemicals such as phthalates, bisphenol A (BPA), dioxins, and heavy metals during plastic degradation (Basak et al., 2020). These substances are known endocrine disruptors and carcinogens with the potential to cause severe health problems.*

*Studies like those by Gore et al., 2024, Plunk and Richards, 2020, Singla, 2023, Stevens et al., 2024, Rani and Meenu, 2023 and Ullah et al. (2023) have demonstrated the presence of such toxicants in various environmental matrices, including water, soil, and air, indicating widespread exposure risks. However, these studies often lack a comprehensive assessment of the exposure pathways and the long-term health impacts on humans, particularly in vulnerable populations such as children and pregnant women.*

*Additionally, there is limited understanding of the synergistic effects of these chemicals when multiple plastic-derived toxins interact, which could potentially amplify health risks.*

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[https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20\(BPA,impacts%20of%20phthalates%20and%20BPA](https://www.sciencedirect.com/science/article/pii/S2949750725000331#:~:text=Phthalates%20and%20bisphenol%20A%20(BPA,impacts%20of%20phthalates%20and%20BPA)

While several studies, such as those by Babaremu et al., 2022, Jayasinghe et al., 2023, Maitlo et al., 2022, Ng et al., 2023, Pandey et al., 2023, and Yusuf et al. (2023), have explored recycling and waste management practices as strategies to reduce plastic pollution, the focus has primarily been on waste reduction rather than the minimization of human exposure to toxins. These studies often account for the limitations of recycling technologies in eliminating harmful chemicals from recycled products.

In many cities across the Global South, the waste management infrastructure is fragmented, often relying on informal waste collectors and community-based systems that operate outside of regulatory frameworks (Nguyen et al., 2023).

This informal sector plays a critical role in waste collection and disposal, but it typically lacks the necessary equipment, training, and resources to safely handle hazardous materials, including plastics containing toxic substances such as heavy metals, phthalates, and BPA. In countries like India and the Philippines, informal waste pickers, who are often exposed to toxic plastics through handling and sorting waste, collect and recycle plastic waste (Borongan and NaRanong, 2022, Singh et al., 2024), but they do so under hazardous conditions, contributing to environmental contamination and personal health risks (Pathak et al., 2023).

#### **Limitations of current recycling technologies**

Mechanical recycling, the most widely used method globally, involves collecting, sorting, and processing plastic waste into new materials (Babaremu et al., 2024). While this approach offers a straightforward solution, it is constrained by the quality degradation of plastics after each recycling cycle, commonly known as downcycling.

**This limits the ability of mechanically recycled plastics to re-enter high-value applications, particularly in industries such as food packaging, which require stringent safety standards** (Nguyen et al., 2024).

**Furthermore, mechanical recycling is ill-equipped to handle the removal of toxic additives like phthalates, bisphenol A, and heavy metals embedded in the plastic matrix.**

**These substances persist in recycled products, potentially reintroducing health risks to consumers** (Hahladakis et al., 2018).

**Furthermore, chemical recycling often produces byproducts, including hazardous residues and greenhouse gases, raising concerns about its environmental impact** (Kassab et al., 2023).

**In countries like India, which generates approximately 9.5 million metric tons of plastic waste annually** (Times of India, 2024), **deploying such technologies is hindered by infrastructural deficits and economic constraints, leading to continued reliance on unsustainable disposal methods.**

Another critical challenge lies in the inability of recycling technologies to effectively process multi-layered and composite plastics, which are increasingly prevalent in consumer packaging. These materials, composed of layers of different polymers and often combined with metals or other substances, are resistant to mechanical recycling due to their heterogeneous nature (Chanda, 2021).

**As a result, they are frequently incinerated or landfilled, contributing to the release of toxic substances such as dioxins and heavy metals** (Yusuf et al., 2022).

Even in advanced economies like the United States, where over 35.7 million tons of plastic waste are generated annually, less than 10 % is recycled, with composite plastics being among the least processed categories (US EPA, 2024b).

- **Toxicity evaluation and prioritization of recycled plastic food contact materials using in silico**

**tools**<sup>82</sup>– College of Medicine, National Cheng Kung University, Taiwan - Faculty of Public Health, Universitas Airlangga, Indonesia - May 2025

*This study assessed the toxicity of virgin and recycled plastic food contact materials (FCMs) at various recycling stages, migrated in four food simulants (water, 20 % ethanol, 4 % acetic acid, and n-heptane), using cytotoxicity and high-content screening (HCS) bioassays. Toxicity was correlated with migrating substances identified through chemical analyses, and samples were ranked by toxicity priority.*

*In response, plastic waste recycling has become a heavy focus under the principles of circular plastic economy [6].*

*During recycling, unknown chemical mixtures can react with one another, leading to the formation of non-intentionally added substances (NIAS) [3], which include impurities, contaminants, degradation products, and reaction byproducts [1].*

*Additionally, intentionally added substances (IAS), such as plasticizers, flame retardants, colorants, and antioxidants, that are integrated into the final plastic product during manufacturing to enhance its functional properties, can persist or transform during recycling [7].*

*Contaminants that occur incidentally due to prior use and misuse by consumers, cross-contamination from waste disposal, and environmental pollutants may also be present during recycling [8].*

*Consequently, the use of recycled plastics increases the diversity and concentrations of hazardous chemicals, including carcinogenic, mutagenic, and reprotoxic IAS and NIAS, that can migrate from packaging into foodstuffs [1], [9], posing potential risks to human health.*

*In fact, numerous chemicals have been identified as migrating from FCMs into food [10].*

- **Forever Toxic: The Science on Health Threats from Plastic Recycling**<sup>83</sup> – Greenpeace - 2023

**Leaching of toxic substances into plastic waste: Numerous studies show that plastics can absorb contaminants via direct contact and through the absorption of volatile compounds.**<sup>3</sup>

*When plastics are tainted by toxins in the waste stream and the environment and are then recycled, they produce recycled plastics that contain a stew of toxic chemicals.*

*For example, plastic containers for pesticides, cleaning solvents, and other toxic chemicals that enter the recycling chain can result in contamination of recycled plastic.*

*New toxic chemicals created by the recycling process: When plastics are heated in the recycling process, this can generate new toxic chemicals that make their way into the recycled plastics.*

<sup>82</sup>

<https://www.sciencedirect.com/science/article/pii/S0304389425003796#:~:text=Environmental%20implication,health%20impacts%20from%20plastic%20waste>

<sup>83</sup> [https://storage.googleapis.com/planet4-usa-stateless/2024/11/6a9ccbcc-greenpeaceusa\\_forevertoxic\\_eng.pdf](https://storage.googleapis.com/planet4-usa-stateless/2024/11/6a9ccbcc-greenpeaceusa_forevertoxic_eng.pdf)

***For example, brominated dioxins are created when plastics containing brominated flame retardants are recycled,4 and a stabilizer used in plastic recycling can degrade to a highly toxic substance found in recycled plastics.5***

*While virgin plastics contain unknown and untested harmful chemicals, studies show that recycled plastics often contain higher levels of chemicals that can poison people and contaminate communities.8*

*Chemicals in recycled plastics have been linked to cancer, cardiovascular disease, obesity, and other health issues.9 Recycled plastic products expose consumers to toxic chemicals, including chemicals that have been globally banned. Recycling can combine toxic chemicals from different plastics and create new hazardous chemicals, all of which end up in recycled plastic products.*

*A 2013 study11 found harmful air-polluting chemicals around and inside plastic recycling facilities in China, with potential health impacts on workers and local residents.*

*Concentrations of harmful chemicals near the facilities were higher than those at a reference site.*

*Two studies12 from China found high levels of plastic flame retardant chemicals in soils, sediment, and road dust near plastic recycling facilities compared to low levels in samples from areas where no plastic recycling takes place.*

*A 2020 study15 of plastic recycling workers (waste pickers) in the Gaza Strip found that most had been exposed to hazardous materials in the previous 12 months, and most reported occupational illnesses.*

*A 2015 study19 by researchers from Czechia and Germany found that recycled plastics used in food packaging and other products contained toxic flame retardants, including banned POPs, with potential health impacts on children and consumers.*

*A 2022 IPEN report24 summarized data on recycled plastic products from China, Indonesia, and Russia, finding that all of the products contained toxic chemicals, including substances banned under international conventions. All 73 products analyzed contained one or more globally banned flame retardant chemicals.*

*A 2022 study25 found that recycled plastic bottles had higher concentrations of toxic chemicals than bottles made with new plastics, indicating that the recycling process can intensify chemical threats.*

*A 2022 study26 by IPEN, Arnika, and partners in 11 African and Arabic countries found toxic chemicals in recycled plastic toys, kitchen utensils, and other products. Out of 83 products analyzed, 61 had levels of POPs that would define the products as POPs waste under limits proposed by African countries.*

A 2023 study<sup>27</sup> from the Fraunhofer Institute and IES Landau tested post-consumer plastic recyclates from different European countries, finding 51 chemicals with intermediate to high toxicity risks and 30 that could not be identified (under EU law, only authorized substances can be used in food grade plastics<sup>28</sup>).

A 2023 IPEN study of recycled plastic products purchased in Kenya<sup>29</sup> found that 14 of the 18 products contained high levels of toxic flame retardants, exceeding a definition of hazardous POPs waste proposed by African countries. One sample, a toy car, was tested for brominated dioxins and contained the toxic chemicals at higher concentrations than levels found in ash from waste incineration.

- **A dataset of organic pollutants identified and quantified in recycled polyethylene pellets<sup>84</sup>** – Department of Biological & Environmental Sciences, University of Gothenburg, Sweden - Helmholtz-Centre for Environmental Research, Leipzig, Germany - Roskilde University, Roskilde, Denmark - IPEN, The International Pollutants Elimination Network Gothenburg, Sweden - RWTH Aachen University, Aachen, Germany

*The dataset presented here provides the **chemical analysis of 28 samples of recycled High-Density Polyethylene (HDPE) pellets obtained from various regions of the Global South, along with a reference sample of virgin HDPE.***

*The analysis comprises both Target and Non-Targeted Screening approaches, employing Liquid Chromatography-High-Resolution Mass Spectrometry (LC-HRMS) and Gas Chromatography-High-Resolution Mass Spectrometry (GC-HRMS).*

*In total, 491 organic compounds were detected and quantified, with an additional 170 compounds tentatively annotated. These compounds span various classes, including pesticides, pharmaceuticals, industrial chemicals, plastic additives.*

*The results highlight the prevalence of certain chemicals, such as N-ethyl-o-Toluesulfonamide, commonly used in HDPE processing, found in high concentrations.*

*The paper provides a dataset advancing knowledge of the complex chemical composition associated with recycled plastics.*

*The 28 analysed recycled PE plastic pellets are from recycle treatment plants from the following countries:*

- Argentina
- Cameroon
- India
- Indonesia
- Malaysia
- Mauritius
- Nepal
- Nigeria
- Serbia
- Taiwan
- Tanzania
- Thailand
- Togo

*The samples were purchased by different NGOs (Non-Governmental Organisations) operating locally, but the specific sites of the recycling facilities and names of companies are not revealed (see Limitations).*

<sup>84</sup> <https://www.sciencedirect.com/science/article/pii/S2352340923008090>

## 2. Data Description

***This dataset offers the chemical analysis of 28 different recycled plastic pellets produced and purchased in the Global South, in countries in Africa, South-America, Asia as well as one country in Europe. When purchasing samples from recycling facilities, we requested high density polyethylene (HDPE) pellets.***

*Results of the FT-IR analyses are found in the Zenodo repository in **Tables 004-263**, and all samples were confirmed to consist of HDPE. Furthermore, a pellet produced from virgin HDPE was analysed in order to compare with the recycled samples and used as sample blank.*

*A target analysis with 625 organic compounds for the LC-HRMS and 200 for the GC-HRMS was performed. 491 compounds were detected and quantified (**Table 2 in Zenodo - Results Target**). A Non-Targeted Screening (NTS) analysis was also performed and around 170 compounds were tentatively annotated in different orders of identification [3] (**Table 3 in Zenodo - Non-Target Screening**).*

*The majority of the detected pollutants in the Target Screening are pesticides, followed by pharmaceuticals and industrial compounds (Table 1). These chemical classes represent the majority of entries in the target database.*

Table 1. Overview of the numbers of different chemicals detected in target analysis, indicated by class, detected at least in one sample.

Class of chemical	Number
Pesticides and biocides	162
Pharmaceuticals	89
Industrial chemicals	65
Plastic additives	45
Polycyclic aromatic hydrocarbons (PAHs)	21
Food ingredient	12
Polychlorinated biphenyls (PCBs)	12
Surfactants	10
Fragrances	8
UV filters	6
Dye	4
Stimulants	4
Corrosion inhibitor	3
Polybrominated diphenyl ethers (PBDEs)	2
Repellents	2
Human metabolites	2
Polychlorinated naphthalene (PCNs)	1

- **Non-intentionally added substances (NIAS) in recycled plastics<sup>85</sup>** – Chemical Engineering Department, University of Alicante, Alicante, Spain - July 2020

***Nevertheless, a high level of contamination originated during the product's life cycle restricts its use. The first step to change this must be identifying the undesired substances in post-consumer plastics and performing an effective risk assessment.***

***In this study, 134 substances including volatile and semi-volatile compounds have been identified in recycled LDPE and HDPE from domestic waste.***

*Headspace and solvent extraction followed by GC/MS were used. The possible origin of each substance was studied. The main groups were additives, polymer and additives breakdown products, and contamination from external sources. The results suggest that recycled LDPE contains a broader number of additives and their degradation products.*

***Some of them may cause safety concerns if reused in higher added value applications. Regarding recycled HDPE, the contaminants from the use phase are predominant creating problems such as intense odors.***

***Based on the abovementioned facts, the lack of knowledge about the composition of the contaminants remaining in the polymer matrix after use as well as the limiting technology for recycling at present are the main bottlenecks for the reuse of recycled post-consumer plastic waste.***

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling<sup>86</sup>** – School of Civil Engineering, University of Leeds, United Kingdom - POPs Environmental Consulting, Schwäbisch Gmünd, Germany – Feb 2018

***For instance, brominated flame retardants including POPs, phosphorous flame retardants and phthalates have been found in children toys from recycling [20], [177], [178].***

***BFRs have also been detected in food contact materials and household products [22], [179].***

*One concern is e.g. the potential of several metal-containing additives to form pro-oxidants and photo-oxidation catalysts, which promote the degradation of plastics during reprocessing (melting/extruding) or even during their use-life phase [181].*

*In particular, metal salts or oxides such as Fe<sub>2</sub>O<sub>3</sub>, Cu<sub>x</sub>O and ZnO have been found to act as pro-oxidants [181].*

***Tang et al. [192] reported that in road dust samples collected from an area where intense mechanical recycling of plastic wastes occurs (Wen'an, north China), PBDE concentrations were found to be 1–2 orders of magnitude higher than concentrations in outdoor or road dusts from other areas.***

***This indicated that plastic waste processing is a major source of toxic pollutants in road dusts in that area.***

*Song and Li [189] reviewed the reported in literature effects from recycling activities of "e-waste" (mostly known as Waste Electric and Electronic Equipment, WEEE) in China in air [193], soil [194], [195], sediments [196] and plants [194], [197].*

*Compared with the levels of the toxic metals in the outdoors, pollution from toxic metals indoors, specifically in WEEE workshops (formal and informal e-waste recycling enterprises) was more critical [189].*

<sup>85</sup> <https://www.sciencedirect.com/science/article/abs/pii/S004565352030566X>

<sup>86</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X>

- **Assessing the environmental and health impacts of plastic production and recycling<sup>87</sup>** - Independent

Researcher, California, USA - Dept of Electrical Engineering, The University of Nebraska-Lincoln, USA - Saltwire Network, Halifax, Canada - YMCA GTA, Canada - FieldCore, part of GE Vernova, Canada - Darey.io, UK – Feb 2024

*While recycling is often promoted as a solution to mitigate the environmental impact of plastics, its effectiveness is limited by various factors. Challenges such as contamination, inadequate infrastructure, and low rates of collection and recycling hinder the potential benefits. Moreover, the recycling process itself can generate pollutants and emissions, albeit to a lesser extent than primary production.*

*Beyond environmental concerns, the health implications of plastic use are increasingly recognized.*

***Plastics contain additives such as phthalates and bisphenols, which have been linked to endocrine disruption, reproductive issues, and other health problems in humans and wildlife.***

***Furthermore, the accumulation of microplastics in the environment raises concerns about potential bioaccumulation and transfer through the food chain, with implications for human health.***

*Addressing the environmental and health impacts of plastic production and recycling requires a multifaceted approach, including reduction of plastic consumption, improvement of recycling infrastructure and technologies, development of alternative materials, and policy interventions to promote sustainable practices.*

- **Scientific review reveals the chemicals migrating from PET drink bottles<sup>88</sup> – Food Packaging Forum – from**

**Unpacking the complexity of the PET drink bottles value chain: A chemicals perspective<sup>89</sup>** - Sustainable Plastics Research Group (SPlasH), Qatar University, Doha, Qatar - Italian Agency for Development Cooperation (AICS), Addis Ababa Office, Kebena, Addis Ababa, Ethiopia - Centro Internazionale per l'Infanzia e la Famiglia (CIFA) Onlus, Hawassa Field Office, Hawassa, Ethiopia - Food Packaging Forum (FPF), Switzerland - Eawag – Swiss Federal Institute of Aquatic Science and Technology, Switzerland - Independent Consultant, Frederick, MD, USA – March 2022

***A systematic evidence map published on March 4, 2022, in the Journal of Hazardous Materials shows that out of 193 chemicals investigated, 150 have been measured to migrate from polyethylene terephthalate (PET, CAS 25038-59-9) bottles into drinks.***

*Spyridoula Gerassimidou of Brunel University, London, and co-authors, including scientists from the Food Packaging Forum, reviewed 91 studies that analyzed migration of chemicals from PET bottles into water, soda, juice, milk, and other drinks. Migration levels were found to vary depending on the geographic location of bottle production, length of storage time, number of reuses, and content.*

***Of the 150 chemicals found in drinks, 18 were measured at levels exceeding EU regulatory limits. These include several phthalates and nickel (Ni, CAS 7440-02-0). Most of the samples exceeding regulatory limits were in fatty foods or food simulants.***

<sup>87</sup> <https://wjbphs.com/content/assessing-environmental-and-health-impacts-plastic-production-and-recycling>

<sup>88</sup> <https://foodpackagingforum.org/news/scientific-review-reveals-the-chemicals-migrating-from-pet-drink-bottles->

<sup>89</sup> <https://www.sciencedirect.com/science/article/pii/S0304389422001984>

Only 41 of the 150 detected chemicals are included in the European Union's regulation on plastic food contact materials (FCMs) "positive list." In addition, 102 out of 150 are included in the Food Packaging Forum's food contact chemicals database ([FCCdb](#)) which provides an overview of chemicals intentionally used to produce FCMs.

**According to Gerassimidou and co-authors, many of the chemicals that migrate from PET, especially those not included on regulatory lists, may be non-intentionally added substances (NIAS), for which risk assessors lack official guidance (FPF reported).**

**The presence of NIAS in the original PET bottles plus additional contaminants entering the plastic during the recycling process can over time concentrate potentially hazardous chemicals in bottles made from recycled PET (rPET, FPF reported, also [here](#)). Gerassimidou et al. made seven recommendations that can help increase the use of recycled PET in drinks bottles while still ensuring chemical safety.**

- **The Foodservice Packaging Institute appreciates the opportunity to comment on the Federal Trade Commission's Request for Public Comment on its Guides for the Use of Environmental Marketing Claims, as attached<sup>90</sup> - Food Service Packaging Institute – May 2023**

*Due to regulatory constraints on incorporation of recycled content for food contact packaging materials, even when materials were recovered and reprocessed, the resulting recyclate typically could not be used for certain foodservice applications, including the single-use items from which the material originated.*

- **Plastics recycled content requirements - Environment Working Paper No.236<sup>91</sup> – OECD - May 24**

*Integration of recycled content in food contact materials is a safety challenge, including concerns with odours and contamination due to the resin composition of the packaging.*

*For example, some laboratory tests have identified higher migration rates of Sb (antimony) and Bisphenol A (an endocrine disruptor) in secondary PET (rPET) as compared with its primary equivalent (Gerassimidou et al., 2022[92]).*

*A recent study commissioned by Environment and Climate Change Canada argued that most plastic produced in the United States and Canada are not suitable for making food grade post-consumer recyclates, because, among other reasons, the material was made with non-food-grade material, suggesting the presence of additives or the leaching of non-food safe contaminants (STINA, 2021[93]).*

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<sup>90</sup> <https://www.regulations.gov/comment/FTC-2022-0077-1075>

<sup>91</sup> [https://one.oecd.org/document/ENV/WKP\(2024\)6/en/pdf](https://one.oecd.org/document/ENV/WKP(2024)6/en/pdf)

- **Assessing the State of Food Grade Recycled Resin in Canada & the United States<sup>92</sup> - Environment and Climate Change Canada (Canadian Government) – June 2022**

*In the case of natural HDPE bottles, fewer products that are suitable for food grade PCR are being generated for market. The list of potential contaminants (e.g., chemicals) in the marketplace either contained in packaged products or in the packaging itself, poses risks to recyclers, converters, and CPGs.*

*Reclaimers and converters are currently hamstrung by lack of suitable supply because most of the material collected for recycling today is not of suitable quality to be processed into food grade PCR.*

*Key Question: What is the most cost-effective way to bring transparency to products and packages that may contain contaminants that are not food safe to reduce the risk to recyclers, converters, and CPGs working to increase recycled content in food-contact applications?*

*Because polyolefins are more prone to absorbing additives and volatiles from products, or consumer secondary use, into the thickness of the plastic, the migration of these from the bottle or package back into food or beverage products is a particular concern with these resins.*

*Consumer packaged goods company (CPG) interviewees noted that these concerns are not limited to just food product packaging but include concerns about many personal care product packages as well.*

- **Cheng, X. et al. (2010), “Assessment of metal contaminations leaching out from recycling plastic bottles upon treatments”, Environmental Science and Pollution Research<sup>93</sup>, - Missouri University of Science and Technology, USA - University of Kansas, USA – 2010**

*The aim and scope of this study were to assess metal contaminations leaching out from a series of recycling plastic bottles upon treatments.*

*Results - Heating and microwave can lead to a noticeable increase of antimony leaching relative to the controls in bottle samples A to G, and some even reached to a higher level than the maximum contamination level (MCL) of the US Environmental Protection Agency (USEPA) regulations.*

*This interesting result showed that higher antimony concentration was detected in experiments with no washing procedures compared with those experiments with washing procedures.*

*Our study results indicate that partial antimony leaching from PET bottles comes from contaminations on the surface of plastic during manufacturing process, while major antimony leaching comes from conditional changes.*

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<sup>92</sup> [https://www.plasticsmarkets.org/jsfcontent/ECCC\\_Food\\_Grade\\_Report\\_Oct\\_2021\\_jsf\\_1.pdf](https://www.plasticsmarkets.org/jsfcontent/ECCC_Food_Grade_Report_Oct_2021_jsf_1.pdf)

<sup>93</sup> [https://www.researchgate.net/publication/42390711\\_Assessment\\_of\\_metal\\_contaminations\\_leaching\\_out\\_from\\_recycling\\_plastic\\_bottles\\_upon\\_treatments](https://www.researchgate.net/publication/42390711_Assessment_of_metal_contaminations_leaching_out_from_recycling_plastic_bottles_upon_treatments)

- **Material Recycling of Plastics—A Challenge for Sustainability**<sup>94</sup> - BZL Kommunikation und Projektsteuerung

GmbH, Oyten, Germany – August 2024

*However, it is not only the polymers that end up in the recyclate and the products made from it in today's plastics recycling process, but also the other components such as additives [5]—including substances that are now banned or strictly regulated due to their harmfulness to humans and/or the environment (“legacy additives”).*

*Many plastics today are highly developed, unique materials for sophisticated technical applications, and the variety of additives is still growing. Recycling cycles are no longer limited to Europe but are global.*

*Problematic additives in used plastics are now returning to Europe in the form of products from plastic recycling in Asia, for example [7].*

*Experts had already warned early on [8]: “What kind of cycles do we want; what must be done with hazardous substances that potentially may enter recycling schemes; where are the final destinations for these substances that cannot be recycled?”*

*“Plastics without additives are not viable. Additives are essential to making thermoplastics processable and to improving end-use properties” [13].*

*During material recycling, all of the substances in the plastic compound end up in the recycled product [48].*

*In this context, we use the term ‘Risk Cycle’ [49] for the material recycling of plastics contaminated with substances that are now banned (‘legacy chemicals’).*

*In addition, there are pollutants that are only formed during the service life phase of products [50,51] and during the recycling process itself (non-intentionally added substances—NIAS) [52,53,54,55].*

*Conclusion 1: Unsafe plastic recyclates from material recycling should generally no longer be used for ‘contact-sensitive products’—products that are very close to consumers (children’s toys, food contact material/packaging, kitchen tools, indoor products, textiles, etc.).*

*Conclusion 2: Material recycling of mixed post-consumer plastic waste will not be capable of meeting the current and, moreover, the future requirements for system solutions in the plastics sector (high-tech plastics).*

- **Plastics recycled content requirements – OECD – May 2024**<sup>95</sup>

*Integration of recycled content in food contact materials is a safety challenge, including concerns with odours and contamination due to the resin composition of the packaging.*

*For example, some laboratory tests have identified higher migration rates of Sb (antimony) and Bisphenol A (an endocrine disruptor) in secondary PET (rPET) as compared with its primary equivalent (Gerassimidou et al., 2022[92]).*

*A recent study commissioned by Environment and Climate Change Canada argued that most plastic produced in the United States and Canada are not suitable for making food grade post-consumer recyclates, because, among other*

<sup>94</sup> <https://www.mdpi.com/2071-1050/16/15/6630>

<sup>95</sup> [https://www.oecd.org/content/dam/oecd/en/publications/reports/2024/05/plastics-recycled-content-requirements\\_c6de64b7/b311ee60-en.pdf](https://www.oecd.org/content/dam/oecd/en/publications/reports/2024/05/plastics-recycled-content-requirements_c6de64b7/b311ee60-en.pdf)

reasons, the material was made with non-food-grade material, suggesting the presence of additives or the leaching of non-food safe contaminants (STINA, 2021[93]).

The risk of chemical migration can be partially mitigated with recycling improvements in collection, separation, and decontamination, such as when fillers wash rPET bottles before first use (Cheng et al., 2010[94]).

Additional improvements in decontamination could include high-temperature treatment; vacuum or inert gas treatment; and surface treatment with non-hazardous chemicals (Welle, 2011[95]).

As such, supply-based policy improvements will be particularly pertinent where recycled content requirements are in place for food contact materials like beverage containers, which typically use rPET.

- **Plastic waste reprocessing for circular economy: A systematic review of risks to occupational and public health from legacy substances and extrusion**<sup>96</sup> – University of Leeds - M&A Transaction Services, Deloitte, London EC4A 3HQ, United Kingdom – November 2022

Substances intentionally added to primary polymers to modify their characteristics such as bulking agents, impact modifiers, flame retardants (Hahladakis et al., 2018);

Residual substances from primary plastic production such as unreacted monomers, catalysts and oligomers (Geueke, 2018);

Residues of materials that have become attached (adhered to, adsorbed) to the surface of plastics or which have been absorbed into the space between polymer chains (hereafter unintentionally added substances), which can be categorized as:

Residues that have arisen during the use phase (e.g. cooking oil which has sorbed onto the surface of a polyethylene terephthalate (PET) bottle; food which has become attached to the surface of an item of food packaging; garden pesticides which have been absorbed into a high density polyethylene (HDPE) milk bottle that has been repurposed) (Roosen et al., 2020); and Residues that have arisen during the end-of-life (after-use) phase (for example, engine oil which has become attached to the surface of an item of food packaging after being deposited in household recycling; battery acid that has leaked onto the surface of plastics during e-waste comminution) (Huysveld et al., 2019).

<sup>96</sup> <https://www.sciencedirect.com/science/article/pii/S0048969722074873>

- **EPA Approved a Fuel Ingredient Even Though It Could Cause Cancer in Virtually Every Person<sup>97</sup> Exposed –**

Chevron — News Stories About Plastic Pollution — Beyond Plastics - Working To End Single-Use Plastic Pollution – August 2023

***The Environmental Protection Agency approved a component of boat fuel made from discarded plastic that the agency's own risk formula determined was so hazardous, everyone exposed to the substance continually over a lifetime would be expected to develop cancer. Current and former EPA scientists said that threat level is unheard of.***

***It is a million times higher than what the agency usually considers acceptable for new chemicals and six times worse than the risk of lung cancer from a lifetime of smoking.***

*ProPublica and The Guardian in February reported on the risks of other new plastic-based Chevron fuels that were also approved under an EPA program that the agency had touted as a "climate-friendly" way to boost alternatives to petroleum-based fuels.*

*That story was based on an EPA consent order, a legally binding document the agency issues to address risks to health or the environment.*

*In the Chevron consent order, the highest noted risk came from a jet fuel that was expected to create air pollution so toxic that 1 out of 4 people exposed to it over a lifetime could get cancer.*

- **The role of safe chemistry and healthy materials in unlocking the circular economy<sup>98</sup>- Ellen MacArthur**

Foundation – Google – 2018

***Toxicity data still isn't available for many human and environmental health endpoints. Animal testing has been significantly reduced over the last three decades due, in part, to voluntary or government bans, ethical issues and cost. If companies do engage in animal testing, they often don't make those studies available to the public or scientific community.***

***More importantly, this means that we are currently cycling materials that were never optimized for human and environmental health.***

*For example, polymeric materials such as foam, plastic food packaging, paper, rubber and textiles contain a range of coatings, modifiers, catalysts, residuals, and other performance enhancing additives. When we recycle them into the current system, the output tends to be highly contaminated, non-homogeneous, and impure.*

***It is very difficult to assess them thoroughly for toxicological impacts. It's certainly not feasible to obtain full formulation information of mixed streams since there is no molecular chain of custody, and it would be impractical to attempt to reverse engineer a contaminated lot of material to identify all chemical constituents.***

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<sup>97</sup> <https://www.beyondplastics.org/news-stories/tag/Chevron>

<sup>98</sup> <https://content.ellenmacarthurfoundation.org/m/1a270dba9b937bb/original/The-role-of-safe-chemistry-and-healthy-materials-in-unlocking-the-circular-economy.pdf>

- **Evidence of bad recycling practices: BFRs in children’s toys and food-contact articles**<sup>99</sup> – University of Birmingham - Institute for Testing and Certification – 2017

***Brominated flame retardants (BFRs) have been used intentionally in a wide range of plastics, but are now found in an even wider range of such materials (including children's toys and food contact articles) as a result of recycling practices that mix BFR-containing waste plastics with "virgin" materials.***

*In this study Br was quantified in toy and food contact samples on the assumption that its concentration can be used as a metric for BFR contamination. Subsequently, compound specific determination of BFRs was performed to evaluate the validity of the aforementioned assumption, crucial to render rapid, inexpensive, in situ Br determination in non-laboratory environments (such as waste handling facilities) a viable option for sorting wastes according to their BFR content.*

***61% of all samples were Br positive: of these samples, 45% had decaBDE concentrations exceeding the concentration limits for PBDEs and their main constituent polymer was - according to the REE signature of such samples - Acrylonitrile Butadiene Styrene (ABS), uses of which include copying equipment, laptops and computers.***

*The ability to better track chemicals of concern and their trends in products is the main requirement for high-level management and control of material cycles to become non-toxic in the future as proposed in the EU's 7<sup>th</sup> Environmental Action Plan.*

- **Recycled plastic food wrappers spark safety concerns**<sup>100</sup> – Brunel University of London – 2023

***The team identified 377 'food contact chemicals' in PE packaging, such as the bisphenol A and phthalates that can disrupt hormones and lead to health risks.***

***Some 211 of these 377 chemicals seep into food at least once during the plastic's life cycle.***

***Alarmingly, only a quarter of those is authorised by EU regulation, a third of which are above the safe limit.***

*"The number of non-authorised chemicals was unexpectedly high," said Dr Eleni Iacovidou, who lectures in environmental management. "This finding highlights the lack of traceability and harmonisation of existing regulations.*

*"We found a lack of sufficient evidence to show PE can be safely recycled into new food-grade packaging," she said, explaining that many of the studies they looked at don't have enough detail such as what the bag or container is used for, how thick it is, how it would be stored and how many times it might be reused.*

*"Recycled PE is increasingly sought after in the production of new food-grade packaging, yet the quality of recycled PE poses critical questions from a chemical safety perspective." Dr Iacovidou said.*

<sup>99</sup> <https://pubmed.ncbi.nlm.nih.gov/28636053/>

<sup>100</sup> <https://www.brunel.ac.uk/news-and-events/news/articles/Recycled-plastic-food-wrappers-spark-safety-concerns>

- **The fraud of plastic recycling<sup>101</sup>** – Center for Climate Integrity – 2024

*One study estimates that humans ingest up to five grams or the equivalent of one credit card worth of plastic per week.<sup>3</sup> Some of the largest oil and gas companies are among the 20 petrochemical companies responsible for more than half of all single-use plastics generated globally.<sup>4</sup> ExxonMobil, for example, is the world's top producer of single-use plastic polymers.<sup>5</sup>*

**Research paper from the above report**

Production, Use, and Fate of All Plastics Ever Made<sup>102</sup> – Bren School of Environmental Science and Management, University of California, Santa Barbara, USA - College of Engineering, University of Georgia, Athens, GA, USA - Sea Education Association, Woods Hole, MA, USA.

***The only way to permanently eliminate plastic waste is by destructive thermal treatment, such as combustion or pyrolysis. Thus, near-permanent contamination of the natural environment with plastic waste is a growing concern. Furthermore, contamination and the mixing of polymer types generate secondary plastics of limited or low technical and economic value.***

- **The Fraud of Plastic Recycling<sup>103</sup>** – Center for Climate integrity – Feb 2024

***Big Oil and the plastics industry—which includes petrochemical companies, their trade associations, and the front groups that represent their interests—should be held accountable for their campaign of deception much like the producers of tobacco, opioids, and toxic chemicals that engaged in similar schemes.***

*This report lays the foundation for such a claim.*

- *Part II provides an overview of the well-established technical and economic limitations of plastic recycling.*
- *Part III describes how—in response to repeated waves of public backlash against plastic waste and subsequent threats of regulation—the plastics industry has “sold” plastic recycling to the American public to sell plastic.*
- *Part IV outlines the evidence of the plastics industry’s fraudulent and deceptive campaigns, which are more fully detailed in Appendix C.*

*Petrochemical companies and the plastics industry should be held liable for their coordinated campaign of deception and the resulting harms that communities are now facing.*

*True accountability will put an end to the industry’s fraud of plastic recycling and open the door to real solutions to the plastic waste crisis that are currently out of reach.*

***Companies like ExxonMobil, Shell, Chevron Phillips, and Dow—independently and through their industry trade associations—have colluded to deceive the public for half a century, despite extensive evidence that recycling is not a viable solution to the plastic waste problem.***

<sup>101</sup> <https://climateintegrity.org/uploads/media/Fraud-of-Plastic-Recycling-2024.pdf>

<sup>102</sup> <https://www.science.org/doi/10.1126/sciadv.1700782>

<sup>103</sup> <https://climateintegrity.org/uploads/media/Fraud-of-Plastic-Recycling-2024.pdf>

- **Micro- and Nano-Plastic-Induced Adverse Health Effects on Lungs and Kidneys Linked to Oxidative Stress and Inflammation**<sup>104</sup> – Kyung Hee University, Republic of Korea - March 2025 -

*This review examines the existing research on the impact of MNP inhalation on human lung and kidney health based on in vitro and in vivo studies. Over the past decades, a wide range of studies suggest that MNPs can impact both lung and kidney tissues under both healthy and diseased conditions.*

*Evidence gathered from previous studies indicates that prolonged exposure to MNPs can generate ROS and activate cellular inflammatory signaling pathways, potentially resulting in severe adverse effects. Extensive research is required to fully comprehend the implications of MNPs and devise strategies to mitigate their accumulation in ecosystems.*

- **The Lancet Countdown on health and plastics**<sup>105</sup> – September 2025

*Plastics are a grave, growing, and under-recognised danger to human and planetary health.*

*Plastics cause disease and death from infancy to old age and are responsible for health-related economic losses exceeding US\$1.5 trillion annually.*

*These impacts fall disproportionately upon low-income and at-risk populations. The principal driver of this crisis is accelerating growth in plastic production—from 2 megatonnes (Mt) in 1950, to 475 Mt in 2022 that is projected to be 1200 Mt by 2060.*

*Plastic pollution has also worsened, and 8000 Mt of plastic waste now pollute the planet. Less than 10% of plastic is recycled. Yet, continued worsening of plastics' harms is not inevitable.*

*Similar to air pollution and lead, plastics' harms can be mitigated cost-effectively by evidence-based, transparently tracked, effectively implemented, and adequately financed laws and policies.*

*To address plastics' harms globally, UN member states unanimously resolved in 2022 to develop a comprehensive, legally binding instrument on plastic pollution, namely the Global Plastics Treaty covering the full lifecycle of plastic. Coincident with the expected finalisation of this treaty, we are launching an independent, indicator-based global monitoring system: the Lancet Countdown on health and plastics.*

- **Microplastics, bisphenols, phthalates and pesticides in odontocete species in the Macaronesian Region (Eastern North Atlantic)**<sup>106</sup> – December 2021 -

*All animals contained microplastics: most of them being fibres (98.06%). Except for two plastic labels, no other macrodebris was found. Bisphenol concentrations (4-984 ng/g) were found in 94.44% of the tissue samples.*

- *DEHP, detected in 88% of the samples, ranged from 102 to 1533 ng/g.*

*Microplastics do not correlate with levels of organic persistent contaminants.*

<sup>104</sup> <https://www.mdpi.com/2075-1729/15/3/392>

<sup>105</sup> [https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(25\)01447-3/abstract?ftag=MSF0951a18](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(25)01447-3/abstract?ftag=MSF0951a18)

<sup>106</sup> <https://www.sciencedirect.com/science/article/pii/S0025326X21011395>

- **Twenty years of microplastic pollution research—what have we learned?**<sup>107</sup> – September 2024

*Twenty years after the first publication that used the term microplastic, we review current understanding, refine definitions, and consider future prospects.*

***Microplastics arise from multiple sources, including tires, textiles, cosmetics, paint, and the fragmentation of larger items.***

***They are widely distributed throughout the natural environment, with evidence of harm at multiple levels of biological organization.***

***They are pervasive in food and drink and have been detected throughout the human body, with emerging evidence of negative effects.***

*Environmental contamination could double by 2040, and wide-scale harm has been predicted. Public concern is increasing, and diverse measures to address microplastic pollution are being considered in international negotiations.*

*Clear evidence on the efficacy of potential solutions is now needed to address the issue and to minimize the risks of unintended consequences.*

- **Addressing the toxic chemicals problem in plastics recycling** – January 2025<sup>108</sup>

*Plastics recycling is challenged by major issues, leading us to conclude that we cannot rely on recycling to end the plastics pollution crisis as things are done today.*

*One of the major underlying reasons is the presence of toxic chemicals in plastics, either intentionally added or sorbed at various stages of the life cycle of a plastic item.*

*The global Plastics Treaty negotiations should address these challenges with new policy obligations to support a future where recycling is safer and more sustainable. Improvements both upstream, midstream and downstream in the plastics life cycle are needed.*

*A substantial reduction in the multitude of chemicals used in plastics manufacturing should be mandated in upstream interventions, in line with a “chemical simplification.”*

*This effort should prioritize bans of chemicals known to be detrimental to both human health and the environment.*

*Transparent reporting, tracking and monitoring of chemicals throughout the full life cycle will allow for safer and more sustainable systems, supporting reuse, repurposing and sectorial recycling.*

*Downstream improvements in waste management infrastructure and strict regulations governing the discretionary use of recycled plastics must be enforced.*

*The methodologies for implementing the strategies described here would be several and would require that changes in policy and best practices be adopted and implemented by several actors throughout the plastics value chain, including law makers, plastics producers, manufacturers, agencies responsible for monitoring and compliance, among others.*

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<sup>107</sup> <https://www.science.org/doi/abs/10.1126/science.adl2746>

<sup>108</sup> <https://www.cambridge.org/core/journals/cambridge-prisms-plastics/article/addressing-the-toxic-chemicals-problem-in-plastics-recycling/552E550968DC2E0119DB937925505DC6>

- **‘Cocktail of contaminants’- Burning plastic and emitting toxic gases has become central to plastic offsetting claims<sup>109</sup>** – February 2025

*Twice a day, sirens sound in the shadow of Touk Meas Mountain in Kampot province, Cambodia. A few minutes later, there is a loud boom and a plume of brown dust rises from the rocks.*

*“We’re often coughing,” said Pheara, a 32-year-old mother of a six-year-old whose house abuts the perimeter wall of the cement plant. Like other locals, she describes developing respiratory problems since it opened in 2018.*

*Cement-making is a dirty business. As well as creating hazardous dust from quarrying, manufacturers emit greenhouse gases from their kilns, and the industry is thought to account for 8 per cent of carbon emissions worldwide. Yet the kiln next to Pheara’s house is supposedly at the heart of a global fight against pollution.*

*That’s because **the cement plant, operated by Chip Mong Group, a company linked to Cambodia’s ruling family, is fuelled by burning thousands of tonnes of waste plastic.** The waste is collected in the neighbouring province of Preah Sihanouk and delivered in trucks by a company called Tontoton, which says the material would otherwise end up in the ocean.*

*For each tonne of waste burned, Tontoton generates a thousand credits sold to customers around the world to ‘cancel out’ their own plastics pollution. Its clients include the accountants Ernst & Young and Royal Caribbean, the world’s second-biggest cruise ship operator.*

*Tontoton says it created “the world’s first plastic credit” in 2021, kickstarting a global trade. Now predicts plastic credits could generate \$4.3 billion of revenue annually by 2050, according to research by BloombergNEF.*

*In Cambodia, all kinds of bottles are burned—“shampoo bottles, water bottles”, said Vork, 39, a machine operator who works eight-hour shifts at the cement plant and like others interviewed for this story asked to be referred to only by his first name. Most of those bottles are made of PET, a type of plastic that can be recycled.*

***Burning them in kilns not designed to filter out dangerous substances releases “a whole new cocktail of contaminants”, said Lee Bell, a policy advisor at the International Pollutants Elimination Network.***

***Those include cancer-causing dioxins and so-called ‘forever chemicals’, or PFAS, which can lead to further serious health problems.***

- **Plastic pollution a global threat to human rights, say UN experts<sup>110</sup>** – November 2024

***Every stage of the plastic cycle generates plastic pollution that threatens the effective enjoyment of human rights. The mandate given by the UN Environment Assembly to the Intergovernmental Negotiating Committee was clear: the instrument under negotiation must address the full lifecycle of plastics.***

*Transparency for plastic pollution in all stages of the plastics cycle means the public must have access to accurate and accessible information on the chemicals of concern used in plastic polymers and products, the type and amounts of pollutants emitted or released in each of the stages of the plastic lifecycle, and the volumes of plastics produced.*

*This information is critical for the protection of human rights from the harmful impacts of plastics, as well as for adequate monitoring and enforcement of states duties and business responsibilities, including in respect of the reductions of plastic production that need to be established by the new instrument.*

<sup>109</sup> [https://www.researchgate.net/profile/Haradhan-](https://www.researchgate.net/profile/Haradhan-Mohajan/publication/390236941_Plastic_Pollution_A_Potential_Threat_on_Health_and_Environment/links/67e575258a5ab03f97157dff/Plastic-Pollution-A-Potential-Threat-on-Health-and-Environment.pdf)

[Mohajan/publication/390236941\\_Plastic\\_Pollution\\_A\\_Potential\\_Threat\\_on\\_Health\\_and\\_Environment/links/67e575258a5ab03f97157dff/Plastic-Pollution-A-Potential-Threat-on-Health-and-Environment.pdf](https://www.researchgate.net/profile/Haradhan-Mohajan/publication/390236941_Plastic_Pollution_A_Potential_Threat_on_Health_and_Environment/links/67e575258a5ab03f97157dff/Plastic-Pollution-A-Potential-Threat-on-Health-and-Environment.pdf)

<sup>110</sup> <https://www.ohchr.org/en/press-releases/2024/11/plastic-pollution-global-threat-human-rights-say-un-experts>

- **Chemicals Used in Plastic Materials: An Estimate of the Attributable Disease Burden and Costs in the United States<sup>111</sup>** – Feb 2024

**Results - We identified PRFs of 97.5% for bisphenol A (96.25-98.75% for sensitivity analysis), 98% (96%-99%) for di-2-ethylhexylphthalate, 100% (71%-100%) for butyl phthalates and benzyl phthalates, 98% (97%-99%) for PBDE-47, and 93% (16%-96%) for PFAS.**

*In total, we estimate \$249 billion (sensitivity analysis: \$226 billion-\$289 billion) in plastic-attributable disease burden in 2018. The majority of these costs arose as a result of PBDE exposure, though \$66.7 billion (\$64.7 billion-67.3 billion) was due to phthalate exposure and \$22.4 billion was due to PFAS exposure (sensitivity analysis: \$3.85-\$60.1 billion).*

**Conclusion - Plastics contribute substantially to disease and associated social costs in the United States, accounting for 1.22% of the gross domestic product.**

*The costs of plastic pollution will continue to accumulate as long as exposures continue at current levels. Actions through the Global Plastics Treaty and other policy initiatives will reduce these costs in proportion to the actual reductions in chemical exposures achieved.*

- **The carcinogenic consequences of the plastic pollution crisis<sup>112</sup>** – Feb2026

*One clue about the carcinogenic impacts of plastic can be found among workplace exposures.*

*Workers exposed to polyvinyl chloride microplastics have an increased risk of liver cancers, such as angiosarcomas and hepatocellular carcinomas, and those working in plastic and rubber manufacturing are at increased risk of cancers of the breast, lung, prostate, liver, stomach, and kidney (6, 7).*

*Another clue is at the population health level, where we are witnessing an unsettling rise in the rates of early-onset cancers in individuals aged 35–50, pointing to a potential environmental or lifestyle change (or both) associated with this group.*

*This age range corresponds to the generations born into the “modernized” world that brought about elevated rates of plastic ingestion, and one hypothesis is that the chronic ingestion of plastic is spurring these increases in cancer risk.*

**Consistent with this hypothesis, elevated levels of MNPs are observed in colorectal cancer specimens as compared with noncancer colon tissue (8), and feeding studies exposing fish to MNPs have shown increased rates of liver neoplasias (9).**

<sup>111</sup> <https://academic.oup.com/jes/article/8/2/bvad163/7513992>

<sup>112</sup> <https://www.jci.org/articles/view/203775>

- **Breathing plastics: Influence of airborne microplastics on the respiratory microbiome and health of human lungs (Review)<sup>113</sup>** – Feb 2026 - <https://www.spandidos-publications.com/10.3892/wasj.2026.435>

*Studies have found MPs and NPs are present in human blood, placenta and feces (7–9).*

*The ingestion of MPs is a prevalent route of exposure, with MPs being detected in food and beverages such as seafood, drinking water and beer (4).*

*Exposure models in mice have shown that MPs and NPs accumulate in the stomach, intestine, liver and other organs (10,11).*

*Due to the high corrosion resistance of MPs and NPs entering into the digestive tract, digestive fluid changes the surface roughness and particle size of MPs and NPs, making them more stable in the lining of the digestive tract and more prone to adsorption of toxic substances (12).*

*The barriers within the tissues do not prevent invasion of MPs and NPs. After MPs and NPs enter the body, small plastic particles can cross the epithelial barrier of the digestive system (13–15) and enter the lymphatic and blood circulation.*

*For example, NPs with a size of 0.1–10 µm cross the blood-brain barrier and the placenta (16–18). Ingested MPs and NPs with a particle size >150 µm pass through the intestinal epithelial cells with difficulty, resulting in ~90% of MPs being excreted through feces, with the rest having a localized effect outside the intestinal epithelial cell membranes. When nanosized plastic particles with diameter <150 µm come into contact with the villi of the small intestine, they pass through the small intestinal epithelial cells (19), enter the lymphatic system (20) and bloodstream (21), and reach the portal vein through the capillaries and are spread throughout the body (22–24).*

*NPs with diameter <150 and >10 µm reach other organs and cell membranes (17), while those with a size of <5 µm are absorbed by lymphocytes (19).*

*Smaller nanoparticles diffuse into the bloodstream via bypass of intercellular tight junctions (25). Mucus secreted by the intestinal epithelial cup cells promotes bypass diffusion of the nanoparticles (19). Larger nanoparticles (diameter, 50–200 nm) tend to cross intestinal epithelial cells by endocytosis; 40 nm diameter may be the optimal size for non-phagocytic uptake (26), while 200 nm may be the optimal size for crossing the blood-brain barrier (27). In vivo studies have found that intestinal cells internalize nanoscale particulate matter using different endocytosis mechanisms; additionally phagocytes can internalize them through phagocytosis (28), whereas non-phagocytes internalize smaller nanoparticles with the help of lattice proteins or cell-membrane-invasion-mediated endocytosis (25), in which actin serves an important role (29). In addition, energy-dependent pathways serve a key role in the mechanisms of endocytosis in intestinal epithelial cells (29).*

*An increasing number of studies have found that MPs and NPs affect the immune system, as evidenced by the induction of intestinal flora dysbiosis by MPs and NPs, leading to immune imbalance and uptake of NPs by lymphocytes (40,57,85).*

*However, studies of toxic effects of MPs and NPs on immune cells are limited, and there is lack of studies investigating the toxic effects of MPs and NPs on the immune system as a whole (59).*

*The gut microbiota, which is not only an important component of immune and metabolic health but also affects the central nervous system, has been shown to communicate through several pathways of the 'brain-gut axis,' as identified*

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<sup>113</sup> <https://www.spandidos-publications.com/10.3892/wasj.2026.435>

using animal models (44,63,86). Therefore, the toxic effects and mechanisms of MPs and NPs on the brain-gut axis following gut flora disruption should be further investigated.

*The gastrointestinal tract and liver are key organs for absorption, metabolism and detoxification.*

*The harmful effects of MPs and NPs involve the intestinal-hepatic axis, causing oxidative stress, inflammation, apoptosis and disorders of hepatic glucose and lipid metabolism in the gastrointestinal tract, resulting in gastroenteritis, hyperglycemia and hyperlipidemia (43).*

*MPs and NPs also indirectly affect the brain-gut axis through the intestinal flora. Therefore, the toxic effects of MPs and NPs on the gastrointestinal tract and liver and their mechanisms should be investigated further.*

- **Micro-Nano Plastics and 6-PPD-Q in Cardio-Pulmonary Health: Environmental Sources, Systemic Exposure, and Mechanistic Insights**<sup>114</sup> – Jan 2026

*This review identifies tire wear particles (TWPs) as a primary source of both airborne and waterborne MNPs, as well as 6-PPD, which readily oxidizes into the highly toxic 6-PPD-Q.*

*These contaminants have been detected across diverse environmental compartments including air, soil, water, and remote ecosystems highlighting their global distribution and persistence.*

***Human exposure occurs primarily through inhalation, ingestion, and dermal contact. Although mechanistic studies remain limited, available evidence indicates that MNPs and 6-PPD-Q induce oxidative stress, inflammation, mitochondrial dysfunction, apoptosis, and endothelial damage, particularly in pulmonary and cardiovascular tissues.***

***Their detection in human tissues and excreta raises urgent public health concerns.***

*Beyond human health, these toxicants adversely affect soil microbial communities, aquatic organisms, and crop productivity, underscoring their broader ecological footprint within a One Health framework.*

- **Occupational Exposure to Gaseous Emissions in Molded Plastic Manufacturing: Health Impacts and Workforce Implications**<sup>115</sup> – January 2026

***Molded plastic manufacturing in small- and medium-scale facilities poses significant health risks due to exposure to Volatile Organic Compounds (VOCs), styrene, formaldehyde and other thermal degradation by-products.***

***Air monitoring revealed pollutant levels exceeding OSHA and NIOSH limits, particularly in purging and overheating areas. Workers reported eye and throat irritation, headaches, dizziness and slight reductions in lung function, indicating that chronic low-level exposure affects health. Workforce attrition due to discomfort further highlights the link between environmental hazards and job retention.***

<sup>114</sup> <https://onlinelibrary.wiley.com/doi/abs/10.1002/cph4.70092>

<sup>115</sup> [https://www.researchgate.net/profile/Hamza-Saad-6/publication/400145444\\_Occupational\\_Exposure\\_to\\_Gaseous\\_Emissions\\_in\\_Molded\\_Plastic\\_Manufacturing\\_Health\\_Impacts\\_and\\_Workforce\\_Implications/links/697a43fe42f94d1212a487e3/Occupational-Exposure-to-Gaseous-Emissions-in-Molded-Plastic-Manufacturing-Health-Impacts-and-Workforce-Implications.pdf](https://www.researchgate.net/profile/Hamza-Saad-6/publication/400145444_Occupational_Exposure_to_Gaseous_Emissions_in_Molded_Plastic_Manufacturing_Health_Impacts_and_Workforce_Implications/links/697a43fe42f94d1212a487e3/Occupational-Exposure-to-Gaseous-Emissions-in-Molded-Plastic-Manufacturing-Health-Impacts-and-Workforce-Implications.pdf)

6/publication/400145444\_Occupational\_Exposure\_to\_Gaseous\_Emissions\_in\_Molded\_Plastic\_Manufacturing\_Health\_Impacts\_and\_Workforce\_Implications/links/697a43fe42f94d1212a487e3/Occupational-Exposure-to-Gaseous-Emissions-in-Molded-Plastic-Manufacturing-Health-Impacts-and-Workforce-Implications.pdf

- **The Impact of Microplastics on Human Health: An Urgent Public Health Concern<sup>116</sup>** – January 2026

*Polyethylene and polypropylene stand out for their high toxicity due to their very low LC50 and EC50 values (Table 2).*

*Furthermore, polyethylene terephthalate and Nylon 66 (N-66) MPs are more biodegradable than other plastic types; therefore, prioritizing these materials may be more appropriate when considering alternatives.*

*Additionally, MPs have the potential to adsorb other pollutants, allowing them to enter living organisms and exert synergistic toxic effects.*

*Weathered plastics are continuously transported in the environment and act as vectors for pollutants due to the contaminants they adsorb or are exposed to.<sup>47</sup> Because these plastics are hydrophobic, they generally exhibit a high adsorption capacity and may accumulate in lipid-rich tissues.*

*Microplastic exposure to the human gastrointestinal system is a growing concern, as humans are estimated to ingest significant amounts of MPs weekly, with particles detected in various human biological samples, including feces, saliva, sputum, lungs, liver, and breast milk.<sup>49</sup>*

*Once ingested, these MPs can enter the human body and translocate to the lymphatic and circulatory systems, accumulating in various organs.<sup>50</sup>*

*Microplastics have been detected in sputum, bronchoalveolar lavage fluid, and lung tissue.*

***These findings highlight direct exposure routes and the accumulation of MPs within the human respiratory system.<sup>31,45,46</sup> Evidence from both in vitro and in vivo models indicates that MPs may impair respiratory function.***

***These effects are characterized by pulmonary inflammation, metabolic alterations at the cellular level, and dysregulation of proteins associated with apoptosis.<sup>46</sup>***

- **The effects of plastic exposures on children's health and urgent opportunities for prevention<sup>117</sup>** – Nov 2025

*Children face an urgent threat in the form of hazards posed by plastics in the environment.*

*Despite robust and rapidly accumulating evidence on the effects of plastic on children's health, plastic presents a paradox for child health providers: while plastic is a vehicle for so many interventions, **robust evidence from laboratory and human studies show that chemicals used to produce plastics contribute to chronic conditions in multiple organ systems and disrupt hormone function, and exposure to plastic-derived toxins is associated with adverse birth outcomes, metabolic conditions, neurodevelopmental disease and disability, and reproductive conditions.***

*Evidence-based, safe, simple, and low-cost steps exist for child health providers in primary care to help families limit children's exposure to plastic-derived toxins.*

<sup>116</sup> <https://jcpres.com/storage/upload/pdfs/1769761814-en.pdf>

<sup>117</sup> [https://www.thelancet.com/journals/lanchi/article/PIIS2352-4642\(25\)00212-3/abstract](https://www.thelancet.com/journals/lanchi/article/PIIS2352-4642(25)00212-3/abstract)

## PFAS

- **Shaping a federal strategy for chemical recycling<sup>118</sup>: Moving toward sensible applications of emerging technologies in US plastic waste management** – University of Wisconsin-Madison, USA – January 2024

Communities' approval of a chemical recycling plant would be incomplete without comprehensive understanding of its environmental impacts, which is not yet available for many chemical recycling processes.

*Chemical recycling technologies face technical limitations as well.*

*For example, conversion technologies under the chemical recycling umbrella (pyrolysis and gasification) cannot selectively produce either feedstocks or fuel. Instead, their products are split between the two categories<sup>55</sup> and cannot exclusively fulfill a P2P purpose, leading to lower contributions to plastics circularity.*

***Chemical recycling technologies, and recycling systems in general, also have difficulty addressing toxic pollutants such as PFAS and other “forever chemicals” that may appear as NIAS in plastic waste feedstocks.<sup>67, 68</sup>***

*It is also not clear how the PCR content of plastic products that incorporate chemically recycled feedstocks should be measured.*

***While some LCA studies have estimated that chemical recycling technologies present environmental benefits relative to incineration<sup>70</sup> and similar global warming potentials to mechanical recycling,<sup>71</sup> others have concluded that chemical recycling has greater environmental impacts than existing methods.<sup>72</sup>***

- **Unraveling Plastic-Related Chemical Exposures during Pregnancy and Their Associations with Pregnancy Outcomes Using Suspect Screening Analysis<sup>119</sup>** – January 2026

*We observed a strong correlation in the peak area of three frequently detected chemicals: diisobutyl phthalate, acetyl tributyl citrate, and progesterone.*

*These three chemicals are commonly associated with high-density polyethylene (HDPE), low-density polyethylene (LDPE), and other thermoplastic materials, which are widely used in consumer products such as food packaging, water pipes, and plastic bags. (62) These findings suggest that plastic-related chemicals migrating from these materials pose a universal threat to all participants in our study.*

*Previous studies have linked per- and polyfluoroalkyl substances (PFAS) to elevated risk of GDM. (66) PFOS has been associated with increased GDM risk among pregnant individuals in both the U.S. [OR = 1.33 (95% CI: 0.89, 2.01)] (50) and China [OR = 1.11 (95% CI: 0.83, 1.50)] (67) during the second and third trimesters, respectively.*

<sup>118</sup> <https://aiche.onlinelibrary.wiley.com/doi/full/10.1002/ep.14333>

<sup>119</sup> <https://pubs.acs.org/doi/full/10.1021/envhealth.5c00197>

*When combined with these findings, our results [OR = 1.14 (95% CI: 0.57, 2.26)] support the interpretation that PFOS is a likely risk factor for adverse maternal health outcomes.*

*Our study also fills important knowledge gaps by identifying associations between acetyl tributyl citrate and 8-hydroxyquinoline with preterm birth.*

*The association between acetyl tributyl citrate and preterm birth has not been reported in previous studies. 8-Hydroxyquinoline has only been detected at low frequencies in cord blood samples. (69) **This is the first study to link exposure to these compounds with preterm birth.***

*We identified nine chemicals with level 1 confidence, including three—1,3-diphenylguanidine, 1-octyl-2-pyrrolidone, and undecanedioic acid—that appear to be under-reported in existing studies.*

*A total of 441 chemicals (557 LC-MS features) were tentatively identified at confidence level 2, 69% of which were detected at high frequency in our study population.*

*Nearly 48% have high production volumes; 45% have broad industrial functions; and 43% have chemical structures similar to lipids. Notably, 230 of these chemicals are under-reported in the Blood Exposome database. PFOS and undecanedioic acid were linked to higher odds of gestational diabetes mellitus.*

***Five plastic-related chemicals were identified as potential risk factors for preterm birth. Four level 2 chemicals were associated with GDM and eight with gestational hypertension.***

*Demographic differences emerged with higher PFOS exposure among non-Hispanic White participants and those with higher educational attainment.*

***Overall, our findings indicate that pregnant individuals face notable exposure to plastic-related chemicals, many of which are poorly characterized and may pose risks during critical stages of pregnancy and fetal development.***

*These results underscore the urgency for biomonitoring and regulatory action targeting under-reported and insufficiently characterized plastic pollutants.*

- **Research Progress in Current and Emerging Issues of PFASs' Global Impact: Long-Term Health Effects and**

**Governance of Food Systems<sup>120</sup>** – March 2025

## 1.2. The Nexus Between PFASs and Microplastics: An Emerging Threat to Public Health and the Environment

***As we continue to assess the environmental toll of PFASs, another critical issue has emerged: their interactions with microplastics, further complicating their environmental impact [12].***

*PFASs and microplastics represent two significant environmental contaminants. While they have been studied individually, understanding their combined impact—the PFASs and microplastics nexus—is increasingly critical for public health, consumer awareness, and environmental sustainability [13,14].*

*Studies have revealed a critical interaction between microplastics and PFASs, where the former can act as carriers, helping PFASs move through and persist within different ecosystems [17].*

*The hydrophobic nature of microplastics enables them to absorb PFASs from contaminated water, leading to concentrated microplastics that act as new sources of PFAS pollution as they move through food webs [18].*

*The delayed response and mismanagement of PFASs and plastic waste have had severe human costs. Communities near manufacturing sites have experienced higher rates of cancer, thyroid disease, and other health issues linked to PFAS exposure.*

*The economic burden of healthcare costs and environmental cleanup is staggering, with estimates running into trillions of dollars [23,24,25].*

*The nexus between PFASs and microplastics represents a multifaceted environmental and public health challenge. As research continues to elucidate the complex interactions and impacts of these contaminants, informed policies and consumer practices are necessary to address the pervasive threat they pose to health and the environment.*

- **Pharmaceuticals, Pesticides, and PFAS: Quantifying Endocrine Disrupting Compounds in Plastics and Fish Tissues Using Solvent Extraction and LC-MS/MS<sup>121</sup>** – Feb 2025

*Here, an efficient method for the detection and quantification of a broad suite of compounds in marine samples was developed.*

***Five extraction methods were trialed for the analysis of 21 pesticides, PFAS, and pharmaceuticals in biota and plastics. This included three ultrasonic extraction methods and two QuEChERS methods.***

*Ultrasonic extraction in acetonitrile with a microcentrifuge step then concentration by Bond Elut Carbon SPE resulted in best recovery across most compounds.*

<sup>120</sup> <https://www.mdpi.com/2304-8158/14/6/958>

<sup>121</sup> <https://analyticalsciencejournals.onlinelibrary.wiley.com/doi/full/10.1002/jssc.70084>

*Of the 21 compounds trialed, 16 were efficiently quantified.*

*Five common extraction methods were trialed for the extraction and quantification of 21 pesticides, PFAS, and pharmaceuticals in fish tissues and plastics from marine environments.*

***Of these 21 compounds, 16 were efficiently quantified using LC-MS.*** *All compounds unable to be quantified using the LC-MS method were pharmaceuticals (three estrogens, one antibiotic, and one drug for the treatment of hypertension).*

*The five trials had varying results across matrices and compounds of interest, with Trial 2 comprising of ultrasonic extraction with an ACN solvent, a microcentrifuge step to remove lipids and proteins, followed by SPE using Bond Elut Carbon cartridges (Agilent Technologies, USA) outperforming the other methods.*

*This analytical method was then successfully applied for the detection of target compounds from fish and plastics collected along the Adelaide metropolitan coastline (South Australia) and can be used more broadly to determine the presence of contaminants in marine environments across a range of matrices.*

- **Food packaging solutions in the post-per- and polyfluoroalkyl substances (PFAS) and microplastics era: A review of functions, materials, and bio-based alternatives<sup>122</sup> – December 2024**

***The pervasive use of PFAS and the emergence of microplastics in FPMs present significant environmental and health challenges that necessitate urgent attention.***

*PFAS, due to their strong carbon–fluorine bonds, are highly resistant to degradation, leading to bioaccumulation and adverse health effects in humans and wildlife.*

*Microplastics, generated from the degradation of conventional plastics, pose risks through ingestion and potential toxicity. Addressing these issues requires a fundamental shift in the materials and strategies used in FP.*

*This review has highlighted the potential of sustainable and renewable materials, such as plant-derived polysaccharides (cellulose, hemicellulose, starch, gums, and mucilage), proteins, waxes, and recycled or upcycled materials, to replace traditional, harmful FPMs.*

*These bio-based materials offer inherent biodegradability and non-toxicity, reducing environmental persistence and health risks associated with PFAS and microplastics. They also provide functional properties suitable for FP, such as mechanical strength, barrier properties, and the ability to form films and coatings.*

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<sup>122</sup> <https://ift.onlinelibrary.wiley.com/doi/full/10.1111/1541-4337.70079>

- **Microplastics, nanoplastics, and plastic chemicals: applying the key characteristics of metabolism disrupting agents shows reason for concern**<sup>123</sup> – Jan 2026

*The review specifically evaluates compounds such as perfluorooctanoic acid (PFOA), bisphenol-S (BPS), and diisonyl phthalate (DINP), as well as emerging evidence relating to microplastics and nanoplastics (MNPs).*

*Results*

***Evidence shows that exposure to chemicals derived from plastics, including PFOA, BPA substitutes (eg, BPS) and phthalate substitutes, is linked to metabolic dysfunction, obesity, diabetes, and MASLD.***

*BPS and DINP exhibit properties consistent with metabolism-disrupting agents, suggesting they are “regrettable substitutes.”*                      ***Rising exposure to chemicals in plastics poses significant risks to metabolic health.***

*Identifying metabolic disruptors among thousands of plastic-associated chemicals is urgently needed.*

*Increasing awareness and promoting the use of safer, inert, and reusable materials are essential steps to reduce health risks associated with plastic-derived pollutants and support more sustainable consumption.*

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<sup>123</sup> <https://academic.oup.com/enendo/article/2/1/wkag001/8457957>

## Legal Issues

- **U.S. Supreme Court decides to hear climate case against ExxonMobil and Suncor Entities**  
**Court will consider companies' bid for immunity from damages claims after Colorado localities' win in state supreme court<sup>124</sup> – 23 Feb 2026**

*The United States Supreme Court has decided to review a Colorado Supreme Court decision allowing Boulder County and the City of Boulder's lawsuit against ExxonMobil and two Suncor entities to proceed.*

*The communities filed this lawsuit years ago, alleging that the oil companies' actions have greatly contributed to an altered climate that harms the communities.*

*The rising costs of dealing with the climate crisis led these communities to take legal action so that the costs do not fall on taxpayers alone.*

- **Texas sues Dow, claiming "habitual" pollution violations at Gulf Coast chemical plant<sup>125</sup> – 18 Feb 2026**

*The Texas Attorney General's office filed a lawsuit Friday against Dow Chemical Co., North America's largest chemical manufacturer, describing hundreds of water pollution violations from its industrial complex on the rural Gulf Coast in Seadrift.*

*Members of Wilson's nonprofit, San Antonio Bay Estuarine Waterkeeper, spent the past year collecting evidence of Dow's chronic plastic pollution into local waterways.*

*"It's just everywhere you look," Wilson, 78, said in early February as she ducked through brush on the banks of the Victoria Barge Canal, pointing out the millions of plastic pellets that had mixed with the sediment over decades.*

*"It is unbelievable." On a wooded embankment of dredging spoils from the 1950s, she kicked her sneakers through spots where the earth appeared to be made of plastic. She's seen it flowing from the wastewater outfalls at Dow's plant, she said.*

- **Hawaii's Lawsuit Against Oil Companies Alleges "Harm to Public Trust Resources"<sup>126</sup> – June 2025 –**

*Hawaii's suit is part of a trend in environmental litigation.*

*Over the past eight years, at least 10 states and a dozen more cities have filed [complaints similar](#) to Hawaii's, claiming companies have harmed public trust resources.*

*These suits target fossil fuel companies, plastic producers, and manufacturers of PFAS — so-called forever chemicals, specifically per- and polyfluoroalkyl substances — on behalf of citizens.*

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<sup>124</sup> <https://bouldercounty.gov/news/u-s-supreme-court-decides-to-hear-climate-case-against-exxonmobil-and-suncor-entities/>

<sup>125</sup> <https://www.texastribune.org/2026/02/18/texas-lawsuit-dow-chemical-plant-pollution-seadrift-paxton/>

<sup>126</sup> <https://statecourtreport.org/our-work/analysis-opinion/hawaiis-lawsuit-against-oil-companies-alleges-harm-public-trust-resources>

- **Big Oil Accountability Lawsuits<sup>127</sup>** - Communities across the U.S. are taking Big Oil to court to hold these corporations accountable for their deception and make polluters pay.



- **Plastic Bag Manufacturers Investigation Concludes: Attorney General Bonta Announces Settlement, Files Lawsuit<sup>128</sup>** - State of California, Department of Justice– October 2025

*SAN FRANCISCO – Concluding his statewide investigation into plastic bag producers and whether the plastic bags they have sold in California are recyclable in this state, as required under state law, California Attorney General Rob Bonta today announced a settlement with four plastic bag producers, Revolution Sustainable Solutions LLC (Revolution), Metro Poly Corp. (Metro Poly), PreZero US Packaging LLC (PreZero), and Advance Polybag, Inc. (API), resolving alleged violations of Senate Bill (SB) 270, the Environmental Marketing Claims Act (EMCA), False Advertising Law (FAL), and Unfair Competition Law (UCL), stemming from the unlawful sale of non-recyclable plastic bags in California.*

**The Attorney General today also announced a lawsuit against Novolex Holdings LLC, Intoplast Group Corp., and Mettler Packaging LLC alleging violations of the same laws and seeking monetary penalties, disgorgement, and injunctive relief.**

*“At the California Department of Justice, we have been unwavering in our commitment to exposing illegal actions at the root of the plastic pollution crisis — not just the environmental harm, but corporate legal violations driving it,” said Attorney General Bonta.*

<sup>127</sup> <https://climateintegrity.org/lawsuits>

<sup>128</sup> [https://oag.ca.gov/news/press-releases/plastic-bag-manufacturers-investigation-concludes-attorney-general-bonta?fbclid=IwdGRjCAnivYNleHRuA2F1bQIxMQABHnDIC-PlsV-STIOqZLAUlk0TsnZrVjm0Cq4vG5ULNOTT7FUrF4hfa57baaY5\\_aem\\_IKNJU3dPtnL3nM24Yslv1g](https://oag.ca.gov/news/press-releases/plastic-bag-manufacturers-investigation-concludes-attorney-general-bonta?fbclid=IwdGRjCAnivYNleHRuA2F1bQIxMQABHnDIC-PlsV-STIOqZLAUlk0TsnZrVjm0Cq4vG5ULNOTT7FUrF4hfa57baaY5_aem_IKNJU3dPtnL3nM24Yslv1g)

*“Through our investigation, we are bringing to light how powerful companies have broken the law and prioritized profits over our environment.*

*The seven manufacturers at issue here have provided billions of plastic bags used by California grocery retailers and have certified that these bags meet recyclability requirements as required by SB 270.*

*However, despite the manufacturers' claims and widespread consumer belief, these plastic bags do not, in fact, appear to generally be recyclable, let alone "recyclable in the state," as SB 270 requires.*

*The Attorney General is responsible for the enforcement of California's laws, including SB 270 and the state's unfair competition, false advertising, and misleading environmental marketing laws.*

### **Settlement**

*In November 2022, Attorney General Bonta launched an investigation into producers of plastic bags over concerns that their recyclability claims are misleading. **The Attorney General sent demand letters requiring producers to substantiate their claims that their bags are recyclable, including evidence supporting self-certifications of the bags' recyclability, use of the “chasing arrows” symbol, and explicit and implicit claims relating to recyclability.***

*As part of today's settlement, Revolution, Metro Poly, PreZero, and API have agreed to halt plastic bag sales in California and collectively pay \$1,753,000, which includes \$1,115,750 in civil penalties and \$636,250 in attorneys' fees and costs.*

**Copies of the settlements, which are subject to court approval, can be found [here](#), [here](#), and [here](#).**<sup>129 130 131</sup>

THE PEOPLE OF THE STATE OF CALIFORNIA, Plaintiff, v. REVOLUTION CONSUMER SOLUTIONS (CA), LLC; METRO POLY CORP.; PREZERO US PACKAGING, LLC; ADVANCE POLYBAG, INC., Defendants<sup>132</sup>. -

*4. SB 270 squarely places responsibility on producers of plastic carryout bags to ensure that the plastic carryout bags sold in California comply with SB 270's requirements. (Pub. Resources Code, § 42281.5.)*

*Further, the statute prohibits producers from selling or distributing plastic carryout bags in California without obtaining certification from third-party certification entities indicating that the plastic carryout bags are compliant with SB 270's requirements. (Ibid.)*

*Producers are also required to submit these certifications in proofs of certification to CalRecycle, demonstrating the producers' and their bags' compliance with the statute. (Ibid.)<sup>7</sup>.*

*Despite their awareness that the plastic carryout bags are not recyclable in California, Defendants have continued to mislead and deceive Californians about the recyclability of Defendants' plastic carryout bags. On each plastic carryout bag each Defendant has sold in California, and in media and other marketing materials that have reached California, Defendants have represented that their plastic carryout bags are recyclable, when in truth they are not recyclable*

<sup>129</sup> <https://oag.ca.gov/system/files/attachments/press-docs/2025-10-17%20-%20Complaint%20-%20Settlement.pdf%5B1%5D.pdf>

<sup>130</sup> <https://oag.ca.gov/system/files/attachments/press-docs/Final%20Stipulation%20re%20Judgment%2010.16.2025%5B1%5D.pdf>

<sup>131</sup> [https://oag.ca.gov/system/files/attachments/press-docs/Proposed\\_Judgment%20on%20Consent%20Final%5B1%5D.pdf](https://oag.ca.gov/system/files/attachments/press-docs/Proposed_Judgment%20on%20Consent%20Final%5B1%5D.pdf)

<sup>132</sup> <https://oag.ca.gov/system/files/attachments/press-docs/2025-10-17%20-%20Complaint%20-%20Settlement.pdf%5B1%5D.pdf>

- **Exxon Mobil Sues California Over Looming Climate Disclosure Rules<sup>133</sup>** - Wall Street Journal – October 2025

*Exxon Mobil Sues California Over Looming Climate Disclosure Rules*

*Oil giant says the Golden State’s requirements rely on a framework that unduly blames big companies such as itself for climate change*

***Exxon Mobil says rules requiring it to disclose climate risks infringe on the company’s right to free speech.***

***The oil-and-gas giant made the argument in a suit filed Friday against the state of California, which is rolling out requirements for businesses to report their climate risks as well as greenhouse gas emissions. The climate risk reporting rule will come into effect in a matter of weeks.***

*Exxon Mobil asked the court to halt the rules, arguing that they would violate free speech protections by forcing the business to use frameworks that put “disproportionate blame on large companies” such as the energy producer itself.*

*A spokesperson for the California Department of Justice said the reporting rules “are about transparency.”*

***“ExxonMobil might want to continue keeping the public in the dark, but we’re ready to litigate vigorously in court to ensure the public’s access to these important facts.”***

- **EPA sued over allowing Chevron to convert plastic to fuel<sup>134</sup>** - WLOX, Biloxi, MS – April 2023

**The Cherokee Concerned Citizens are suing the EPA over allowing Chevron to convert used, recyclable plastic waste into renewed fuels and gases.**

*It’s a process tested at Chevron’s Pascagoula Refinery.*

***With support from environmental law firm, the neighbors are now petitioning the U.S. Court of Appeals to review the EPA’s 2022 consent order authorizing Chevron to use pyrolysis oil.***

***That’s the process of heating recyclable plastic waste down to reusable gas and fuel, 18 chemicals Chevron has been authorized to convert and sell since last November.***

*She points to the EPA’s own consent order greenlighting Chevron’s request, signed by Madison Le, Director of EPA’s “New Chemicals Division.”*

*It’s attached to the filed petition and made public.*

*While WLOX did not find that estimate in the agency’s document, it does show a few things like the EPA determines the chemicals it approves may present an “unreasonable” health or environmental risk, with data on the risks involved lacking.*

*Still, the agency points to a few like skin, eye and respiratory irritation, pneumonia, as well as toxicities ranging from systemic, genetic, carcinogenic and reproductive development.*

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<sup>133</sup> <https://www.wsj.com/articles/exxon-mobil-sues-california-over-looming-climate-disclosure-rules-048929f0>

<sup>134</sup> <https://www.wlox.com/2023/04/12/epa-sued-over-allowing-chevron-convert-plastic-fuel/>

***Out of the 18 chemicals, the EPA finds 11 to be “highly hazardous”, while seven are considered “a moderate environmental hazard”.***

*Chevron said, in part, “the claim is based on EPA’s initial risk screening, which was taken out of context and doesn’t reflect how it would actually be done given the processes and safeguards we use every day at the refinery to ensure we do everything safely or not at all. The EPA’s initial screening is very conservative and doesn’t represent actual risk to our community or employees.”*

***“If Chevron, or EPA more importantly, felt that there was inadequate information to characterize the risk, it should have ordered more testing,” O’Brien said.***

***“The estimate that we have is cancer risk to up to one in four people.***

*That’s the basis for the agency’s decision, and that’s the number that the community in Pascagoula is grappling with today.”*

- **What Lies Ahead for Advanced Plastics Recycling Industry After EPA Withdrawal of Proposed TSCA**

**SNURs?**<sup>135</sup> – Latham & Watkins – August 2025

***On April 7, 2023, Cherokee Concerned Citizens, a community group in Pascagoula, Miss., filed suit in the US Court of Appeals for the District of Columbia Circuit alleging that the Order would allow use of the five chemicals as fuels and that such use would pose a significantly increased cancer risk as compared with current fuels.<sup>10</sup>***

***The lawsuit was placed on hold toward the end of the Biden administration, when EPA moved for a voluntary remand, stating that it intended to withdraw the Order.***

*After remand was granted, EPA withdrew the Order on December 18, 2024. In doing so, EPA stated that the large fuel production company that signed the Order had not yet commenced manufacture of the five chemicals.*

***The case remains in abeyance, and what actions EPA now decides to take after its withdrawal of the proposed SNURs and the Order will dictate the future of the case.***

*On April 7, 2023, Cherokee Concerned Citizens, a community group in Pascagoula, Miss., filed suit in the US Court of Appeals for the District of Columbia Circuit for review of the August 25, 2022 5(e) Order. Cherokee Concerned Citizens v. EPA (No. 23-1096).*

*The groups filing this lawsuit alleged that the 5 chemicals covered by the August 25, 2022 5(e) order would be used as fuels which would pose a significantly increased cancer risk as compared with current fuels.*

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<sup>135</sup> <https://www.globalelr.com/2025/08/what-lies-ahead-for-advanced-plastics-recycling-industry-after-epa-withdrawal-of-proposed-tsca-snurs/>

- **April 28, 2022, California Attorney General Rob Bonta announced that a subpoena had been issued to ExxonMobil to determine whether the fossil fuel giant had lied to the public about both the negative effects of plastics and the success of plastic recycling<sup>136</sup>**

*Attorney General Bonta Sues ExxonMobil for Deceiving the Public on Recyclability of Plastic Products*

***Regarding this, the following was made from the “United States District Court – Northern District of California” by Chief United States District Judge Richard Seeborg on 24 February 2025 –***

***VI.CONCLUSION For the reasons explained above, California’s case against Exxon is remanded to the state court from whence it came; neither maritime, federal enclave, nor federal officer jurisdiction applies to its claims.***

***Excerpts from this ruling are<sup>137</sup>:***

- *Page 8 - Exxon highlights that the state’s complaint asserts damages to California’s “waterways” and their “shorelines,” see Complaint ¶ 60—a vast expanse which necessarily must include a few federal enclaves. Exxon also points to the complaint’s description of pollution in Monterey Bay, a recognized federal enclave, as proof that such jurisdiction exists. See id. ¶ 360. Plaintiffs urge the court to reject this argument, given that the complaint expressly disclaims injuries arising on federal lands, which would include federal enclaves, and that it does not seek any relief relating to such injuries. Id. n.1.*

***Exxon’s argument is misguided, to say the least.***

*Even as it concedes that the complaint disclaims injuries or relief on all federal lands, Exxon nevertheless contends that, because some California waterways have been deemed federal enclaves in other contexts, California’s claims necessarily have a federal enclave locus.*

- ***Page 9 - In making this doomed argument, Exxon strives to distinguish San Mateo II and Honolulu***—two cases where the Ninth Circuit roundly rejected fossil fuel defendants’ arguments for federal enclave jurisdiction in similar pollution-related claims—by highlighting the way those defendants argued for conduct-based enclave jurisdiction, rather than the injury-based enclave jurisdiction Exxon raises here. This distinction makes no difference.

- *Exxon’s argument for federal officer jurisdiction revolves around rubber. Because the United States government contracted with Exxon’s predecessors to produce rubber for World War II-era military use, the company claims the existence of “a causal nexus between its actions, taken pursuant to a federal officer’s directions, and [the] plaintiff’s claims. San Mateo II, 32 F.4th at 755.*

***This claim verges on the fanciful. Rubber is not the product at issue in the complaint— plastic is.***

<sup>136</sup> <https://oag.ca.gov/news/press-releases/attorney-general-bonta-sues-exxonmobil-deceiving-public-recyclability-plastic>

<sup>137</sup> [https://oag.ca.gov/system/files/attachments/press-docs/Complaint\\_People%20v.%20Exxon%20Mobil%20et%20al.pdf](https://oag.ca.gov/system/files/attachments/press-docs/Complaint_People%20v.%20Exxon%20Mobil%20et%20al.pdf)

- Page 10 - **What Defendant appears to sidestep, however, is that the claims in this case are not about pollution in the abstract; they concern Exxon’s allegedly self-interested and deceptive promotion of plastics recycling programs that it knew would fail to prevent the current pollution crisis.**
- Page 10 - **Putting the self-congratulations for winning the war to one side, this argument misses the boat entirely.**
- **Page 10** - *Even if it were possible to look past the severe disconnect in Defendant’s premise, its argument for federal officer jurisdiction would still flunk the merits. First, nothing suggests that “the challenged acts occurred because of what [Exxon] w[as] asked to do by the government.” See Goncalves v. Rady Children’s Hospital. San Diego, 865 F.3d 1237, 1245 (9th Cir. 2017) (internal quotation marks omitted).*  
**There could not be a wider mismatch between the purported federal directions regarding synthetic rubber production and the deceptive conduct California raises in its complaint.**
- Page 10 - **As for the colorable federal defense showing necessary to a federal officer removal, Exxon likewise falls flat.** It suggests that a federal contractor immunity defense as to California’s plastics-related claims is viable because the federal government specified the details of its wartime synthetic rubber production.
- As just explained, however, that argument fails to track the complaint’s actual claims, which involve deception about plastic, not the production of rubber. At bottom, and much like its arguments for federal enclave jurisdiction, **Exxon’s asserted rationale for federal officer jurisdiction is completely baseless.**
- **Page 11** - *At oral argument, Exxon’s counsel argued that California waived argument about the saving to suitors clause by not raising it until the reply brief. For support, counsel cited Morris v. Princess Cruises, Inc., where the Ninth Circuit noted that “a state plaintiff may waive the improper removal of a savings clause claim.” 236 F.3d 1061, 1069 (2001). In that case, however, the state plaintiff “fail[ed] to seek remand . . . of claims falling within the court’s admiralty jurisdiction.” Id. Quite the opposite occurred here, where—assuming that such jurisdiction exists—California does seek remand.*

## Currently the “People v. Exxon Mobil Corp” is still in court<sup>138</sup>

### People v. Exxon Mobil Corp. [↗](#)

3:24-cv-07594 N.D. Cal. 4 entries

Filing Date	Type	Action Taken	Document	Summary
11/03/2025	Motion	Motion filed by Exxon Mobil Corporation for stay pending appeal of remand order.	<a href="#">View</a>	–
11/03/2025	Appeal	Notice of appeal filed by defendant.	<a href="#">View</a>	–
24/02/2025	Decision	California's motion to remand granted.	<a href="#">View</a>	The federal district court remanded to state court the State of California's lawsuit regarding Exxon Mobil Corporation's (ExxonMobil's) contributions to “ever-increasing plastic pollution.” The court denied a motion to remand a similar lawsuit brought by environmental groups. Both the State and the environmental organizations' lawsuits include allegations that ExxonMobil misled the public about the greenhouse gas reduction benefits of “advanced recycling.” In California's case, the court rejected ExxonMobil's contention that federal enclave jurisdiction existed “[s]imply because plastic pollution touches on federal enclaves” along California's “waterways” and “shorelines,” as well as the contention that there was federal officer jurisdiction based on the U.S. government's World War II-era contracts with ExxonMobil predecessors to produce rubber. The court also rejected ExxonMobil's assertion of admiralty or maritime jurisdiction as a basis for federal jurisdiction both because such jurisdiction requires an independent basis for jurisdiction and also because it would be inapplicable.
09/12/2024	Motion	Motion to remand filed by People of the State of California.	<a href="#">View</a>	–

- **EPA will withdraw approval of Chevron plastic-based fuels likely to cause cancer<sup>139</sup>** - US Environmental

Protection Agency - The Guardian - 30 September 2024

***An investigation by ProPublica and the Guardian revealed that the EPA had calculated that one of the chemicals intended to serve as jet fuel was expected to cause cancer in one in four people exposed over their lifetime.***

***The risk from another of the plastic-based chemicals, an additive to marine fuel, was more than 1m times higher than the agency usually considers acceptable –***

***so high that everyone exposed over a lifetime would be expected to develop cancer, according to a document obtained through a public records request.***

*The EPA had failed to note the sky-high cancer risk from the marine fuel additive in the agency's document approving the chemicals' production. When ProPublica asked why, the EPA said it had “inadvertently” omitted it.*

*As ProPublica and the Guardian noted last year, making fuel from plastic is in some ways worse for the climate than simply creating it directly from coal, oil or gas.*

*That's because nearly all plastic is derived from fossil fuels, and additional fossil fuels are used to generate the heat that turns discarded plastic into fuels.*

<sup>138</sup> <https://www.climatecasechart.com/collections/people-v-exxon-mobil-corp-97d57a>

<sup>139</sup> <https://www.theguardian.com/environment/2024/sep/30/epa-withdraws-approval-chevron-fuels-causing-cancer>

- **Society left holding the (plastic) bag: A transnational analysis of the impact of plastic litigation on environmental justice<sup>140</sup>** – June 2025

*Finally, the discussion of the contributions of litigation to environmental justice must be understood in the context of the shared responsibility for the plastic pollution crisis.*

*On the one hand, this article rests on the abundantly documented assumption that the plastics industry is primarily responsible for the plastic pollution crisis. [29](#)*

*Two main categories of corporate actors are identified to this effect by the Centre for International Environmental Law: a handful of large resin production companies such as ExxonMobil and fast moving consumer goods companies such as Coca-Cola and PepsiCo. [30](#)*

*Over the past 50 years, the plastics industry has attempted to mislead society into believing that individual consumers were to blame for plastic pollution in an effort to evade regulation.*

***This misleading narrative is unfair for three main reasons: (a) much of the pollution happens before plastics reach the individual consumers; (b) most consumers have little to no control over the packaging the products they purchase are delivered to them in; and (c) even correctly disposed of plastics that are marketed as recyclable are not always recycled because of economic and technical limitations. [31](#)***

*As of 2021, only 10% of the collected plastic waste was being recycled. [32](#) On the other hand, this article also relies on the assumption that public authorities and in particular regulatory bodies can share some of the responsibility for the environmental injustices arising from plastic pollution while not being directly responsible for the plastic pollution crisis in itself.*

*This responsibility primarily stems from the failure of governments to enact legislation to effectively address the crisis and the failure of regulatory bodies to implement existing regulations to prevent environmental injustices from arising. [33](#)*

*Litigation can provide a channel through which communities affected by plastic pollution can seek to participate in political decisions by influencing legislation to prevent the harm arising from it.*

*Such influence on policymakers can be direct, through a court order, or indirect, by raising awareness of plastic pollution.*

*For example, by petitioning the Delhi High Court claimants were able to challenge the city's waste management strategy, which was allowing for vast amounts of plastic waste to accumulate in nature and public spaces. [34](#)*

*Not only did litigation offer claimants a pathway through which they could participate, but, because of the binding power of the court, it also meant their participation had to be effectively considered by the local authorities.*

*In this sense, their participation had a very concrete impact on environmental decision-making: the High Court ordered the Delhi Government to ban plastic bags in certain locations. [35](#)*

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<sup>140</sup> <https://onlinelibrary.wiley.com/doi/full/10.1111/reel.70009>

## 2.2 Enforcing legislation

*By using litigation as a channel for participation, claimants can seek the fair application of existing laws and regulations. Such claims can be directed against regulatory bodies falling short of their established obligations or corporations that breach such regulations.*

*Furthermore, this process can also offer a pathway for citizens to produce information to support their claims. Therefore, litigation advances two of the three ‘forms’ of procedural justice discussed earlier [40](#): information production and participation in decision-making.*

*Firstly, claimants can rely on litigation to ensure the thorough implementation of plastic regulation policies.*

*For example, in 2021, 52 petitioners including youth, artisanal fishermen and waste pickers, all of whom were directly affected by excessive plastic pollution, filed a petition to the Supreme Court of the Philippines against the National Solid Waste Management Commission for failing to implement the Ecological Solid Waste Management Act of 2000. [41](#)*

*As a result, the Supreme Court issued a writ of Kalikasan and a writ of continuing mandamus.*

*The former asserts the public body's obligation to protect the environment and the latter requires it to comply with the 20-year-old legislation.*

*Therefore, through litigation, claimants were able to impact political decision-making by forcing the implementation of an existing legislation.*

*Secondly, claimants can also rely on litigation to challenge the decision of regulatory bodies to enable corporations to engage in activities which would result in plastic pollution.*

*For example, in *Rise St. James v Louisiana Department of Environmental Quality*, [42](#) the local community relied on the Clean Air Act to challenge a regulatory authority's decision to grant Formosa air pollution permits for the construction of a plastic manufacturing complex worth \$9.4 billion.*

- **Plastic Pollution and the Human Right to a Healthy Environment in Cameroon: A Legal Appraisal<sup>141</sup>** – January 2026 –

*This chapter examines the connection between plastic pollution and the enjoyment of the human right to a healthy environment in Cameroon.*

*It analyses the Constitution of Cameroon and relevant environmental and human rights legal instruments to determine whether the law addresses the implications of plastic pollution for the enjoyment of the human right to a healthy environment in Cameroon.*

*The analysis is complemented by a doctrinal review of secondary data to substantiate the arguments.*

***The chapter concludes that the level of legal attention given to plastic pollution and the threat it poses to the full realisation of the human right to a healthy environment in Cameroon is inadequate.***

<sup>141</sup> [https://link.springer.com/chapter/10.1007/978-3-032-01532-7\\_16](https://link.springer.com/chapter/10.1007/978-3-032-01532-7_16)

- A Fraying Patchwork Quilt: International Law and Plastic Patchwork Quilt: International Law and Plastic Pollution<sup>142</sup> – 2023

*Presently, no global agreement exists to prevent plastic litter and microplastics from entering the environment in general and, specifically, the marine environment or to provide a lifecycle approach to the management of plastics, which would align with the circular economy framework.*

*Rather, each convention seeks to resolve its own cooperation challenge with plastic pollution, at best, an afterthought.<sup>312</sup>*

*Calls for a new international instrument focused on marine pollution have become more frequent and are currently being considered at the United Nations level as the global community seeks to create a global plastics treaty encompassing both plastic production and waste by 2025.<sup>313</sup>*

***As this paper has demonstrated, the need to better address the issue of plastic requires more than the current “patchwork quilt” approach that has risen piecemeal over time and has proven to be ineffective in managing ongoing global plastic pollution.***

***Given the scope and impact of international plastic pollution, it is clearly time for a more comprehensive and efficacious global response to the issue.***

*That concern will be analyzed more comprehensively in the forthcoming article, *Many Miles to Go Before We Sleep: The Long Road to Creating a Comprehensive Global Plastics Treaty*, to be published in the next issue of the *Villanova Environmental Law Journal*.*

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<sup>142</sup> <https://digitalcommons.law.villanova.edu/cgi/viewcontent.cgi?article=1467&context=elj>

## Standards (inc Greenwashing)

- **Consultation outcome - Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach<sup>143</sup> - UK Government - Updated 30 October 2024**

**Subject of this consultation** - This consultation explores the application of a mass balance approach to determine the amount of chemically recycled plastic in a plastic packaging component for the purposes of the Plastic Packaging Tax (PPT). It seeks views on whether a mass balance approach should be accepted as a way of allocating recycled plastic content to packaging, and, if so, the controls and standards that should be adopted to ensure the integrity of the tax.

**Scope of this consultation** - HM Revenue and Customs (HMRC) is consulting on the impacts of chemical recycling for plastics and the potential use of a mass balance approach to account for chemically recycled content for PPT.

Adopting a mass balance approach for the purposes of PPT would be a departure from the current accounting requirement, which requires the calculation to be based on the actual amount of recycled plastic in the packaging component.

Allowing a mass balance approach could help create the right economic incentives for businesses to use chemically recycled plastic in packaging, making it possible to demonstrate this type of packaging potentially meets the 30% recycled plastic threshold. In turn, this could help drive investment in chemical recycling infrastructure and increase the overall share of recycled plastic material in circulation.

**Mechanical recycling is the most energy efficient method of recycling plastic.**

**However, the quality of the outputs is highly dependent on the material being recycled.**

**Subject to a few exceptions, it is difficult to mechanically recycle plastic to a high enough quality to meet legal requirements for certain contact sensitive applications such as packaging for food and medicines.**

- **Protecting the health of European citizens against chemical threats - A large-scale project sought to harmonise human biomonitoring for harmful chemicals across the EU<sup>144</sup> – 2022**

To establish a baseline of evidence for chemical threats across the European Union, the EU-funded HBM4EU (opens in new window) project carried out a large-scale human biomonitoring (HBM) programme.

“HBM4EU sought to shed light on the question of just how much humans are exposed to selected chemicals and chemical groups, and analyse the cumulative and aggregate exposure,” adds Kolossa, project coordinator.

“Overall, effective use of the HBM data through the project leads to an improved chemical risk assessment in the EU,” she says. As exposure levels for different substances varied across the continent, this demonstrated that an EU-wide sustainable HBM system is urgently needed.

Yet HBM4EU’s full potential can only be reached if it finds a sustainable form within an EU policy directive such as REACH, the team explains.

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<sup>143</sup> <https://www.gov.uk/government/consultations/plastic-packaging-tax-chemical-recycling-and-adoption-of-a-mass-balance-approach/plastic-packaging-tax-chemical-recycling-and-adoption-of-a-mass-balance-approach>

<sup>144</sup> <https://cordis.europa.eu/article/id/442456-protecting-the-health-of-european-citizens-against-chemical-threats>

- **Consultation outcome - Plastic Packaging Tax - chemical recycling and adoption of a mass balance approach<sup>145</sup>** – UK Government - Updated 30 October 2024

### **Scope of this consultation**

*HM Revenue and Customs (HMRC) is consulting on the impacts of chemical recycling for plastics and the potential use of a mass balance approach to account for chemically recycled content for PPT.*

*Adopting a mass balance approach for the purposes of PPT would be a departure from the current accounting requirement, which requires the calculation to be based on the actual amount of recycled plastic in the packaging component. Allowing a mass balance approach could help create the right economic incentives for businesses to use chemically recycled plastic in packaging, making it possible to demonstrate this type of packaging potentially meets the 30% recycled plastic threshold. In turn, this could help drive investment in chemical recycling infrastructure and increase the overall share of recycled plastic material in circulation.*

***Mechanical recycling is the most energy efficient method of recycling plastic.***

***However, the quality of the outputs is highly dependent on the material being recycled.***

***Subject to a few exceptions, it is difficult to mechanically recycle plastic to a high enough quality to meet legal requirements for certain contact sensitive applications such as packaging for food and medicines.***

*In very simple terms, if 10% of the inputs to a process are recycled feedstock, a mass balance approach can be used to either designate 10% of the outputs as being from 100% sustainable sources, 20% of the outputs as being 50% from sustainable sources, or any other combination as long as the volume of outputs allocated to sustainable inputs do not exceed the total amount of sustainable inputs.*

*Plastic packaging which contains at least 30% recycled plastic is not subject to PPT. Under the current legislation, calculations of recycled content must reflect the actual amount of recycled plastic in packaging. Due to the nature of chemical recycling it is not possible for businesses to evidence actual recycled content. This means that packaging which contains chemically recycled plastic is subject to the tax. PPT therefore does not currently provide the intended price incentive to use more chemically recycled plastic in packaging.*

***Mechanical processes also degrade the polymer over time lowering the quality of recycled material.***

***As a result, mechanically recycled plastic will almost always be of a lower quality than virgin material.***

***This can make it difficult to use mechanically recycled plastic content in some contact sensitive applications.***

*It is vital that the public has confidence in claims made about the recycled plastic in packaging. A mass balance approach can be challenging in this respect, as an individual item may not physically include the recycled content which it claims to have, although may contain traces of recycled plastic*

*It will be important to be able to explain how packaging which is claimed to include 30% recycled plastic may not actually do so because of the way that the mass balance approach works. Explaining this clearly and transparently will be important to avoid consumers questioning other claims about recycling and environmental credentials.*

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<sup>145</sup> <https://www.gov.uk/government/consultations/plastic-packaging-tax-chemical-recycling-and-adoption-of-a-mass-balance-approach/plastic-packaging-tax-chemical-recycling-and-adoption-of-a-mass-balance-approach>

- **EU Commission packaging waste<sup>146</sup> – European Commission - 2025**

*The European Union is eager to increase the production of recycled food contact materials (FCMs) as a part of its Circular Economy Action Plan and the new Packaging and Packaging Waste Regulation (PPWR). To further this goal without compromising consumer safety, legislation is actively reformed, as is evident from several recent regulations.*

***Most notably, Regulation (EU) 2022/1616 established the basic framework for using recycled plastic in food contact materials, with clarifications to purity requirements later introduced by Regulation (EU) 2025/351.***

- **An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling<sup>147</sup>.** - University of Leeds, Woodhouse Lane, Leeds, United Kingdom - POPs Environmental Consulting, Schwäbisch Gmünd, Germany – February 2018

*Despite how useful these additives are in the functionality of polymer products, their potential to contaminate soil, air, water and food is widely documented in literature and described herein.*

***Whereas in the Global North plastics production, use and recycling is regulated to varying degrees, in many developing countries plastic recycling is often not controlled by an appropriate regulatory framework, and environmental protection is poorly enforced, resulting in significant contamination of the ambient environment in areas where plastic is recycled [19].***

- **Unregulated PET imports jeopardize EU circular economy, warns Plastics Recyclers Europe<sup>148</sup> – Recycling Today** - February 2024

*According to Plastics Recyclers Europe (PRE), **the plastics recycling market in Europe was destabilized throughout 2023, which saw prices for recyclates decrease by up to 50 percent through October, while cheap imports from outside of the EU increased significantly.***

***The Brussels-based association says this is creating an unbalanced market with serious environmental consequences. This trend plus the EU's declining competitiveness and the lack of a level playing field are accelerating the EU's de-industrialization, PRE adds.***

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<sup>146</sup> [https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste\\_en](https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste_en)

<sup>147</sup> <https://www.sciencedirect.com/science/article/pii/S030438941730763X>

<sup>148</sup> <https://www.recyclingtoday.com/news/pre-warns-recycled-plastic-imports-threaten-eu-industry/#:~:text=Imports%20to%20the%20EU%20increased,is%20fading%20its%20initial%20optimism>

While PRE says the **Packaging and Packaging Waste Regulation (PPWR)** is meant to enhance circularity by harmonizing practices across EU member states, addressing EU waste effectively and creating a market for recycled products, the policy direction taken in the trilogues is fading its initial optimism.

**Allowing non-EU plastic to contribute to the targets for packages produced and filled in the EU while not having any reliable control and verification mechanisms implemented would negatively impact a shrinking and threatened market, the association says.**

In a December 2023 news release, the association calls for European action to be focused on accelerating the transition toward circular plastics by addressing systemic barriers, promoting the enhancement of harmonized collection systems across the EU, **establishing realistic recycling targets and recycled content targets and taking decisive action to combat greenwashing by promoting transparency and establishing a level playing field for all products, including imported ones, through the implementation of reliable verification and certification systems.**

- **Plastics recycled content requirements - Environment Working Paper No.236 – OECD<sup>149</sup> - May 24**

Proponents of government policies (e.g., regulation) that would require the use of a minimum share of recycled content in products and packaging argue that these policies would strengthen secondary plastics markets by stimulating both: 1. a separate demand for post-consumer recycled (PCR) content, and 2. investment to improve quality and quantity of PCR supply. Governments are beginning to use a myriad of policy tools that will require businesses to use a minimum share of PCR in their products and packaging. Most of these policies are forthcoming. Prominent examples include: • **Targets: at least twelve OECD Member Countries<sup>1</sup> have agreed to a national target for recycled content either for plastics or a relevant sector.**

Challenges include: • **Obtaining supply of quality recycled content-- Food-grade material is particularly challenging to acquire.**

Exemptions from recycled content requirements can help to address sanitary or safety concerns but should be balanced against the fact that they reduce the reach and impact of the policies.

**Verification of recycled content claims by firms will be key to ensuring that these policies do not simply instigate an exercise in 'green washing.' Key to this issue are the methods used to track the movement of the secondary materials through the supply chain.**

Several governments with recycled content requirements are currently developing rules and regulations for their enforcement, but monitoring and verification of self-reporting can help to check for compliance (Table 4.2). Limited resources are likely to be a barrier to monitoring and enforcement efforts. To overcome this barrier, governments can assign responsibility for monitoring to producers.

**For example, the New Jersey law gives the state authority to conduct a random sample each year at cost to the manufacturers (State of New Jersey, 2022[53]).**

<sup>149</sup> [https://one.oecd.org/document/ENV/WKP\(2024\)6/en/pdf](https://one.oecd.org/document/ENV/WKP(2024)6/en/pdf)

- **COMMENTS ON THE FTC GUIDES FOR THE USE OF ENVIRONMENTAL MARKETING CLAIMS** - Green Guides

Review, Matter No. P954501<sup>150</sup> - Submitted by the Center for Climate Integrity - April 2023 – page 21

B. The vast majority of plastic has not been “recyclable” for decades, and labeling it “recyclable” is a deceptive practice.

The nature and characteristics of plastics makes them difficult if not impossible to recycle. Although the industry breaks plastics down into seven broad categories of resin, identified by the industry’s “Resin Identification Codes” illustrated below, there are actually thousands of different plastics, each with its own composition and characteristics.<sup>151</sup> The vast majority of these plastics cannot be recycled.



**Page 24 - The chasing arrows symbol was co-opted by the Plastics Industry Association in 1988 and incorporated into the RIC as part of the industry’s “major program of unprecedented proportions to reverse [the] fast-moving tidal wave of growing negative public perception” of plastic.<sup>153</sup> The symbol is printed on nearly all plastic products, regardless of their recyclability.**

**In July 2022, CCI conducted focus groups in Cleveland, Ohio, Houston, Texas, and Bakersfield, California,<sup>154</sup> to assess consumers’ knowledge about plastic recycling and the impact of recycling marketing on consumers.**

When asked what consumers understood about the recyclability of products imprinted with the industry’s RIC codes, almost all believed that the products were recyclable due to the presence of the chasing arrows. Participant responses included:

- **“Anything that has this symbol you can recycle.” - Cleveland<sup>155</sup>**
- **“The three arrows, I know it’s recycle [sic].” - Bakersfield<sup>156</sup>**
- **“The arrow icon, isn’t that just the universal symbol for recycling?” - Houston<sup>157</sup>**
- **Do you assume most of these are recyclable? “Yes.” - Houston<sup>158</sup>**

- **COMMENTS ON THE FTC GUIDES FOR THE USE OF ENVIRONMENTAL MARKETING CLAIMS<sup>151</sup>**

Green Guides Review, Matter No. P954501 - Submitted by the Center for Climate Integrity - April 2023

**Paltering is intended to deceive consumers and therefore must be identified as a deceptive practice. Companies use paltering to promote themselves and their products as more environmentally friendly and less environmentally damaging than they really are.**

<sup>150</sup> [https://climateintegrity.org/uploads/media/2023\\_April\\_CCI\\_Green\\_Guides\\_Comments\\_Final.pdf](https://climateintegrity.org/uploads/media/2023_April_CCI_Green_Guides_Comments_Final.pdf)

<sup>151</sup> [https://climateintegrity.org/uploads/media/2023\\_April\\_CCI\\_Green\\_Guides\\_Comments\\_Final.pdf](https://climateintegrity.org/uploads/media/2023_April_CCI_Green_Guides_Comments_Final.pdf)

Also known as “lying by telling the truth,” paltering is the use of truthful statements that create an overall false or misleading impression.<sup>21</sup>

Paltering is a distinct form of deception that differs from lying by omission (passively omitting relevant information).<sup>22</sup> Although there are similarities between the two, lying by omission is defined by passively avoiding the truth, while paltering is defined by actively telling selective truths.<sup>23</sup> Paltering is widespread yet difficult for consumers to identify if they are not familiar with the science or technology underlying a claim.

Harvard researchers have found that paltering “may promote conflict fueled by self-serving interpretations,” where the palterers “focus on the veracity of their statements (‘I told the truth’), whereas their targets focus on the misleading impression palterers convey (‘I was misled’).”<sup>24</sup>

**Without explicit guidance from the FTC, companies will continue to palter, justifying their deceptive claims as sound because they aren’t outright lies – and consumers will continue to be misled and unable to make informed decisions.**

Climate journalist Emily Atkin described and illustrated the ways in which fossil fuel companies have used paltering in practice: This is what oil and gas companies do in their advertisements.

Technically, they tell the truth—they’re investing in greener, cleaner technology.

But the investments are small, the technology is unproven, and their companies are overall failing to reduce their emissions.

The selective truth they choose is designed to create a false impression, so everyone gets off their back about climate change.

**Atkin uses an ExxonMobil advertisement,<sup>25</sup> as an example: The ad claims the oil giant is “advancing climate solutions” by investing in carbon capture technology.**

**And technically, Exxon is investing in carbon capture, which is a climate solution. But this truth is incredibly selective. Because overall, Exxon is doing far more to worsen the climate crisis than to solve it.**

**The company is still refusing to slow down fossil fuel production—in fact, it plans to expand its oil and gas business.<sup>26</sup>**

Todd Rogers et al., *Artful Paltering: The Risks and Rewards of Using Truthful Statements to Mislead Others*, 112 *PERSONALITY & SOC. PSYCHOL.* 456, 456 (2017). 22 *Id.* 23 - Emily Atkin, *Big Oil’s Favorite Way to Lie: Paltering*, *HEATED* (Apr. 6, 2023), <https://heated.world/p/big-oils-favorite-way-to-lie-paltering>. 24 Rogers, *supra* note 21 at 456. 25 Emily Atkin (@emorewee), Twitter (Nov. 17, 2022), <https://twitter.com/emorwee/status/1460998705734197264>. 26 Atkin, *supra* note 23.