Proposed response on the potential options for elements towards an international legally binding instrument

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Date	12 January 2023

Introduction

The International Council of Chemical Associations (ICCA) welcomes the opportunity to provide the following comments to support the INC Secretariat's effort to develop a document of potential options for elements towards an international legally binding instrument.

We support an international agreement to eliminate plastic pollution, while also enabling progress toward a net zero global emission goal and achievement of the Sustainable Development Goals. Our ambition is that 100% of plastic products are reused, recycled, or responsibly disposed of in the case where materials are not yet able to be recycled (e.g., medical waste), supporting a low carbon circular economy without plastic pollution. This will require innovation in product design, expanded access to waste management systems across all countries, deployment of existing, new, and innovative recycling technologies and reuse models, comprehensive life cycle assessment of all materials to better understand the various impacts of choices, including the greenhouse gas (GHG) footprint, and enhanced policies to value secondary raw materials to support a circular economy for plastics.

I. Substantive elements

1. Objective(s)

a) What objective(s) could be set out in the instrument?

Plastic producers recognize the importance of Sustainable Consumption and Production in addition to downstream measures in addressing the issue of plastic pollution. We recognize the urgency to address the issue of plastic pollution and encourage governments to establish intermediate targets to enable progress towards the global agreement objective of eliminating plastic pollution by eliminating plastic leakage to the environment.

ICCA supports the 5 key elements for a Global Framework:

1. Governments commit to eliminate leakage and establish National Action Plans
2. Harmonized definitions and reporting
3. Guidance to improve product design
4. Waste management capacity building and technology deployment
5. Achieve climate goals

Having global objectives that are easy to understand and that ensure clarity on which plastic applications are included provide an opportunity for everyone to contribute. This helps strengthen the social and political will to achieve success and enables governments, the private sector, and others to tailor their own specific actions towards the overarching objective.

2. Core obligations, control measures and voluntary approaches

a) What core obligations, control measures and voluntary approaches would provide a comprehensive approach to addressing plastic pollution, including in the marine environment, throughout the full life cycle in line with the future objective(s) of the instrument?

We call on governments to consider a combination of timebound objectives and targets for the short, medium, and long-term, harmonized definitions and international/global technical standards, standardized monitoring and reporting, guidance on voluntary measures, and other tools to support governments in addressing plastic pollution and accelerating the transition to a circular plastics economy.

- Timebound targets with flexibility to account for regional and national circumstances
    - (Upstream) – To increase use of circular feedstocks for plastic production supported by policy and regulatory incentives for the use of recycled plastic and well-designed EPR or like systems therefore reducing reliance on fossil feedstocks
    - (Midstream) – To establish design principles for circularity for all plastic applications that will be in scope of the instrument and to develop reuse and refill business models and infrastructure
    - (Downstream) – To develop a responsible and achievable plastic collection rate for waste management and access to recycling; and to establish a plastics recycling rate with application specific targets set in annexes, including targets for an inclusive transition of the informal sector
- Additional Measures
    - Globally harmonized definitions
    - Standardized monitoring for measuring and reporting on progress
    - Guidance on the use of voluntary measures to compliment and help scale existing and future voluntary initiatives
    - (Upstream & Downstream) – Recommendation for governments to establish national requirements for Operation Clean Sweep® implementation among all businesses handling plastics pellets, including independent third-party verification auditing
    - (Midstream) – Guidance on the need to demonstrate a reduced environmental footprint and also consider health and safety information to inform governments in

making science-based policy decisions on whether to replace single-use plastics with more durable products or alternative materials

- (Downstream) – Guidance on end-of-waste criteria to create legal certainty that will facilitate transport of sorted plastic waste and recycled plastics and enable investments in plastic recycling

II. Implementation elements

1. Implementation measures

a) How to ensure implementation of the instrument at the national level (e.g., role national action plans contribute to meeting the objectives and obligations of the instrument?)

b) How to ensure effectiveness of the instrument and have efficient national reporting?

c) Please provide any other relevant proposals or priorities here on implementation measures (for example for scientific and technical cooperation and coordination as well as compliance).

The global agreement should include guidance on the following to accelerate national and regional transition to a circular plastics economy with particular emphasis on supporting developing countries.

- Measures to ensure collection, recycling, or responsible management of all plastic products designed for circularity
- Measures to ensure that plastics producers have access to collected plastic waste, enabling producers to accelerate the transition to a circular plastics economy
- Tools to support governments in developing a roadmap for achieving targets through capacity building and best practice sharing
- International funding mechanisms to improve waste management infrastructure in developing countries
- Development of national waste management policies based on the waste hierarchy
    - Help developing countries skip the linear economy waste management and directly install waste management for a circular economy
    - Enforcement of laws to prohibit dumping of waste into the environment
    - Development of laws to prevent loss of recyclable plastics into landfill or incineration
- Market-based funding mechanisms to accelerate deployment of technologies to enable a circular plastics economy, e.g., sorting, recycling.
- International recycling standards and certification programs to promote fair and equitable access to recycling programs and promote a secondary raw material market

2. Means of Implementation

With respect to means of implementation, document UNEP/PP/INC.1/5 covers the following elements: capacity-building, technical assistance, technology transfer on mutually agreed terms and financial assistance.

a) What measures will be required to support the implementation of the instrument?

We recommend development of a capacity building mechanism with a focus on supporting developing countries in their transition to a circular plastics economy to eliminate plastic pollution. Such a mechanism could encourage best practice and knowledge sharing as well as support adoption of standards and specification along the plastics value chain to support circularity.

Capacity building efforts could include among others best practice sharing on implementing:

- EPR or like schemes
- Design for circularity principles
- Life cycle assessments of materials

III. Additional input

Please provide any other relevant proposals or priorities here (for example introductory elements; awareness-raising, education and exchange of information; research; stakeholder engagement; institutional arrangements and final provisions).

Interim technical science working group: To support the INC process, we recommend creating an interim technical science working group that includes industry scientists among others to highlight existing research and answer technical questions from member states.

Stakeholder engagement is critical to a successful, implementable global agreement. The private sector is already transitioning to a circular plastics economy and welcomes the opportunity to work with governments throughout the INC process to accelerate this transformation towards a low carbon circular economy without plastic pollution.

Background information on plastics

- Plastipedia - The Web's Largest Plastics Encyclopedia (extensive information on the history of plastics, additives, applications, chemical recycling, energy, life cycle analysis, plastics processing, pre-processing technologies, polymer types (including biobased / degradables; economics, sustainability, standards, testing techniques, literature & Guides)

Recycling worldwide

- https://www.bpf.co.uk/Sustainability/Plastics_Recycling.aspx

Plastics and their applications flow chart

- Petrochemistry-FlowChart_2019MC_V13-13092019-withoutFolds.pdf (Process of making plastics and how plastics are used in many applications)

Technical standards on plastics recycling and recycled plastics

- DocsRoom - European Commission (Circular Plastics Alliance proposed a set of standards to be developed by the European Standards bodies (see Annex 1))

Chemical Additive Information

- Appendix A - White Paper - Overview of Additives in Plastic
- Appendix B - Review of Wiesinger et al. 2021
- Appendix C - Review of Groh et al. 2019
- Blockchain Pilot Projects
    - Dow blockchain pilot using ChemChain
    - LyondellBasell digital product passport solution prototype
    - Borealis and Covestro Blockchain Project to Trace Plastics in the Supply Chain

Chemical recycling background information

- BPF Chemical Recycling Briefing Paper - August 2022.pdf
- Chemical Recycling Flyer - BPF.pdf
- OnePager_-P-E_Chemical-Recycling_221222.pdf (Overview of current investments in Europe)
- Informe-RQ-2021-ING-A4.pdf (plasticseurope.org) (Overview of the chemical recycling industry in Spain and its potential contribution to the circular economy and climate neutrality)
- Advanced Recycling to Meet Sustainability Goals in the United States
- CSIRO Report on Advanced Recycling

Braskem Circular Economy Project

Plastics Europe Plastics the Facts 2022

- Plastics - the Facts 2022 • Plastics Europe (Analysis of recent data related to plastics production, demand, conversion and end-of-life management in Europe)

Microplastics

- Appendix D – Key Microplastic Health and Environmental Risk Assessment References
- Appendix E – Microplastic State of the Science
- Microplastics Advanced Research and Innovation Initiative (MARII) - International Council of Chemical Associations (ICCA) (icca-chem.org)
- Brigid (PlasticsEurope multimillion-euro, five-year (2022-2026) scientific research project to assess the potential risks to human health from microplastic exposure through ingestion)

Operation Clean Sweep® in Europe

Operation Clean Sweep (OCS) is a voluntary program aimed at improving awareness, promoting best practices and providing guidance tools to support companies from the plastics value chain in the implementation of pellet loss prevention measures.

Global Plastics Alliance

Established in 2011 at the 5th International Marine Debris Conference, the Global Plastics Alliance (GPA) has grown to 75 plastics organizations and allied industry associations in 40 countries worldwide. As voluntary signatories of The Declaration of the Global Plastics Associations for Solutions on Marine Litter, these organizations operate as GPA and execute projects locally and regionally to address the issue of marine debris.

Appendix A - White Paper - Overview of Additives in Plastic

Overview

As part of the global focus on eliminating plastic waste, the chemicals contained within plastics, such as additives, are under increasing focus. While ICCA supports the global effort to eliminate plastic leakage into the environment, we must recognize that plastics, and the chemical additives contained within, are a critical element to achieving the circular economy with the lowest carbon impact.

The focus of this white paper is to provide an overview of the purpose, benefits, and risk-based science related to chemical additives and their uses in plastics. This white paper covers the following areas:

1. Context and societal benefits enabled by plastics and chemical additives
2. Overview of chemical additives' classes, uses, benefits, and concerns
3. Risk based scientific principles applied to chemical additives
4. Regulatory frameworks and existing rigor applied to chemical additives in plastics
5. Sustainability and the circularity economy

Plastics

It is impossible to discuss chemical additives without also emphasizing the benefits enabled by the plastics containing them. Plastics are materials used to make various products essential to modern day life. Plastics[1] are a mixture of one or more polymers with various chemical additives used to impart the desired properties for a particular application. A polymer is made up of linked chemicals molecules called monomers. The polymer becomes a chemically distinct substance from the individual monomer units. Plastics are then made from the resulting polymer through the application of energy (e.g., heat) and incorporation of the desired additives. Once a plastic material is manufactured, chemicals, like trace amounts of the monomers and processing aids used to make the original polymer, may be in the plastic. Plastics contain chemicals—even all "natural" polymers (e.g., latex rubber) and "natural" chemical additives (e.g., essential oil used to repel insects) are 100% composed of chemicals.

Benefits of Plastics:

- Plastic helps make modern life safer, more efficient, and more sustainable.
- Plastic helps enable medical and personal care products to be safe, sanitary, and affordable, so more people have access to life saving products.
- Plastic food packaging keeps food fresher longer and limits food waste that contributes to climate change.
- Plastic makes our cars lighter, and more fuel efficient.

[1] ASTM D883 defines plastic as "a material which contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and at some stage in its manufacture or processing into finished articles can be shaped by flow."

- Modern plastic pipes deliver clean drinking water throughout the world, and gas to heat homes.
- Plastics are a key to our clean energy future for electric cars, solar panels, wind turbines and energy-saving insulation to reduce overall greenhouse gas emissions.[2]

Plastics are critical to meeting the UN sustainable development goals for hunger, health, clean water, and clean energy.[3]To enable these activities, plastics are often formulated with plastic additives.

Additives

Additives are substances intentionally added to plastics to provide a function fit for purpose to provide, improve, modify, or retain plastic properties such as preventing fire, providing flexibility or stability during the plastic life cycle.[4] Additives are included in plastics because without additives, the plastic materials would have limited applications, be brittle, potentially degrade and have a very limited shelf life. Additives are typically classified and categorized by the function or purpose of their use. A joint project between the European Chemicals Agency (ECHA) and industry identified over 400 additives registered under the European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation at more than 100 tonnes.[5] Some of the major categories of additives include the following.

1. *Processing Aids*
    a. Context: Processing aids are not typically considered to be plastic additives but are used in the manufacturing of plastic articles from polymers. Plastic articles are fabricated by melting the polymer power/granules inside a heated tube. The melted polymer can be:
        i. forced through a shaped opening (i.e., extrusion);
        ii. injected into a mold (i.e., injection molding);
        iii. Rolled into sheets; or
        iv. Blown into thin films or bottle shapes.
    b. Purpose: The ease and efficiency of these processes can be improved through the use of processing aids that modify the polymer's melt viscosity, resistance to heat and oxygen, and reduce the temperature at which the polymer becomes a liquid.
    c. Benefits: Modifying the polymer's properties means less energy is needed to manufacture the same article and prevents polymer degradation, leading to less material needing to be used.
2. *Antioxidants and Heat Stabilizers*

[2] Fabiula Danielli Bastos de Sousa. (2021). The role of plastic concerning the sustainable development goals: The literature point of view. Cleaner and Responsible Consumption.
Vol 3.100020.https://doi.org/10.1016/j.clrc.2021.100020.
[3] De Sousa. (2021).
[4] Zweifel, Hans et al. (2009). Plastic Additives Handbook, 6th edition. Chapter 2. ISBN 978-3-446-40801-2.
[5] ECHA. (2018). Mapping exercise – Plastic additives initiative. https://echa.europa.eu/mapping-exercise-plastic-additives-initiative.

a. Context: Most plastics have to be processed at high temperatures (I.e., above 180 degrees Celsius) or are designed to function at a high temperature over the life of the plastic article (e.g., coffee cup). High temperatures can weaken plastic during the manufacturing process and decrease the life span of plastic products.
b. Use: Preventing the breakdown of plastic materials during manufacturing and decreases the amount of materials needed.
c. Benefits: Heat stabilizers and antioxidants are critical components in the recycling process. They both inhibit degradation and re-stabilize post-use plastic waste. These often allow for the end article to have a longer shelf life and prevent the need for additional packaging and prevent spoilage.

3. *Colorants or Pigments*
    a. Context: Pigments are additives that impart color to plastic and are added to the polymer before or during the molding process. They are embedded and therefore cannot wear off the finished product.
    b. Use: Colorants/Pigments are used to protect medicines and materials from light and to improve safety, whether reflective materials for workers /runners / drivers or for color coding wires and switches.
    c. Benefits: Pigments are not only decorative. Many are used to impart critical features to products (e.g., for instance in pipe, different colors of pipe may indicate to the user the type of service or utility, either water, gas, or chemical).
4. *Impact Modifiers*
    a. Context: Many commodity thermoplastics are brittle when unmodified and can easily crack when struck. Impact modifiers increase the impact strength of the plastic articles.
    b. Use: Safety equipment (e.g., automobiles). Impact modifiers allow plastic articles to flex when struck.
    c. Benefit: Increased resilience means plastic articles will not crack as easily and have to be replaced. This reduces the amount of plastic waste by increasing the life span of the plastic article.
5. *Flame Retardants*
    a. Context: Flame retardants increase plastic resistance to ignition, reduce flame spread, suppress smoke formation, and prevent a polymer from dripping.
    b. Use: Electronics, wires and cables, cars and airplanes. Prevents the start or slow the growth of fire and thereby, increasing the safety profile of the plastic.
    c. Benefit: Decreases the likelihood plastic articles will catch fire (e.g. electronics) and if they do catch fire, less smoke generated leads to fewer fatalities due to smoke inhalation.
6. *UV Filters*
    a. Context: UV filters prevent a chemical process (i.e. "photo degradation"), which occurs when ultraviolet radiation coming from the Sun or an artificial light source collapses chemical bonds within a polymer.

b. Use: Polypropylene, Kevlar, and Aramid fibers are particularly susceptible to photodegradation. UV stabilizers are mixed into polymer products before the final shaping or molding to prevent degradation.
c. Benefit: Prevents premature breakdown, chalking, cracking, and changes in color.

7. *Plasticizers*
    a. Context: Plasticizers are added to plastics to improve their flexibility, durability, and elasticity over a broad range of temperatures.
    b. Use: Medical devices and IV bags, automobile equipment, wires and cables, and construction materials.
    c. Benefits: Improved durability and high performance for PVC applications.

Concerns related to additives often center around hazards associated with their intrinsic characteristics and ignore exposure potential and risk.

Risk Based Science:

The terms "hazard" and "risk" are frequently used interchangeably, but they mean very different things. [6,7] These terms, along with other critical terms, are defined as:

- **Hazard** is a chemical's potential ability to cause harm.
- **Exposure** is the amount of and the frequency with which a chemical comes into contact with a person or the environment.
- **Risk** is the likelihood that harm will occur from exposure to a specific hazard. Without exposure to a hazard, there can be no risk.
    - A simplified equation that is often used is: Risk = Hazard x Exposure
- **Risk Assessment** is the formal process of quantifying risk based on known hazards and the amount of exposure.

Additives are chemicals and therefore, they have specific hazards and may be classified if they have the potential to cause a specific effect (e.g., classified as a liver toxin). However, similar to other chemicals, just because an additive is classified for an adverse effect does not mean it will automatically cause the effect. Exposure to the hazardous chemical must be high enough to cause an adverse effect to occur in a person or organism. If there is no exposure or exposure is too low to cause an effect, then there is no risk to a person or to the environment.

[6] Toxicology Education Forum (TEF). (2023). Hazard vs. Risk. https://toxedfoundation.org/hazard-vs-risk/ .
[7] U.S. Environmental Protection Agency (EPA). (2023). Risk Assessment Guidance. https://www.epa.gov/risk/risk-assessment-guidance.

Sufficient exposure to a hazardous chemical is needed to cause an adverse effect. This is a key point missed in several prominent technical reports and papers,[8,9] often cited in discussions of additives used in plastics. These papers incorrectly assume the presence of additives equates to harm or adverse effects. It is only through the use of the risk assessment process that potential risks of a chemical can be identified and then used in a safe manner to protect human health and the environment.

Given the central role of risk assessments in the regulatory decision-making process, it is critical risk assessments conducted for additives are based on a firm scientific foundation and use the following principles:

1. Scientific Standards[10]
    a. **Best Available Science** - Best available science is the "use of supporting studies conducted in accordance with sound and objective science practices, including, when available, peer reviewed science and supporting studies and data collected by accepted methods or best available methods (if the reliability of the method and the nature of the decision justifies use of the data)."
    b. **Weight of Evidence (WOE)** – WOE is defined as "a systematic review method, applied in a fit-for-purpose manner, that uses a preestablished protocol to comprehensively, objectively, transparently, and consistently, identify and evaluate each stream of evidence, including strengths, limitations, and relevance of each study and to integrate evidence as necessary and appropriate based upon strengths, limitations, and relevance."
    c. **Systematic Review** – The goal of using systematic review methods is to "ensure that the review is complete, unbiased, reproducible, and transparent." A systematic review is, "… a scientific investigation that focuses on a specific question and uses explicit, pre-specified scientific methods to identify, select, assess, and summarize the findings of similar but separate studies."[11]
    d. **Data Quality** – A system should be implemented designed to objectively assess the quality of data used for a risk assessment. The data should be disclosed, where possible (e.g., aggregated or summarized data if the raw data is unavailable), if not previously reported in the literature.[12]

[8] Helene Wiesinger, Helene, Zhanyun Wang, and Stefanie Hellweg. (2021). Deep Dive into Plastic Monomers, Additives, and Processing Aids. Environmental Science & Technology. 55: 13. p. 9339-9351. DOI: 10.1021/acs.est.1c00976

[9] Groh et al. (2019). Overview of known plastic packaging-associated chemicals and their hazards. Science of the Total Environment. 651:3253-3268. https://doi.org/10.1016/j.scitotenv.2018.10.015.

[10]

[11] US EPA. (2017). Guidance to Assist Interested Persons in Developing and Submitting Draft Risk Evaluations Under the Toxic Substances Control Act Documents. EPA 740-R17-001. https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/guidance-assist-interested-persons-developing-and-1

[12] See also. US EPA. (2022). Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility and Integrity of Information Disseminated by the Environmental Protection Agency. https://www.epa.gov/quality/guidelines-ensuring-and-maximizing-quality-objectivity-utility-and-integrity-information.

2. Risk Assessment Process[13]
    a. **Scope** – The scoping step of a risk assessment "identifies the hazards, exposures, conditions of use and potentially exposed or susceptible subpopulations that the risk assessor expects to consider in a risk assessment." The scope is developed before the next steps in the process begin.
    b. **Exposure Assessment** – "The exposure assessment evaluates, where relevant, the likely duration, intensity, frequency and number of exposures to human populations (e.g., general population, consumer, worker), including potentially exposed or susceptible subpopulations, and ecological receptors (e.g., aquatic, terrestrial species) for the conditions of use of the chemical substance."
    c. **Hazard Assessment** – "A hazard assessment identifies the types of adverse health or environmental effects or hazards that can be caused by exposure to the chemical substance in question and characterizes the quality and weight of the evidence supporting this identification." It has two parts: the hazard identification and the dose-response (i.e., the dose at which the chemical is causing an adverse effect).
    d. **Risk Characterization** - "…risk characterization integrates information for the preceding components of the risk assessment and synthesizes an overall conclusion about risk that is complete, informative, and useful for decision makers…"

These principles form the scientific bases for modern chemical regulations in many countries.

Regulatory Frameworks

Hazard Identification and Communication Frameworks:

UN's Globally Harmonized System of Classification and Labelling of Chemicals (GHS),[14] is primarily a system of hazard communication for chemical hazards that can be adopted by countries around the world. GHS, and adaptation like the EU's CLP,[15] provide a framework for governments and for industries to identify and classify potentially hazardous substances using a unified system. The chemical industry encourages countries to adopt UN GHS as an important step to enhancing chemical safety regulations across the world.

Chemical Management Regulatory Frameworks:

[13] US EPA. (2017).
[14] UN GHS. (2021). ST/SG/AC.10/30/Rev.9 - GHS Rev.9. https://unece.org/transport/standards/transport/dangerous-goods/ghs-rev9-2021
[15] ECHA. (2017). Guidance on the Application of the CLP Criteria Guidance to Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures. Version 5.0. Section 3.6.3. Classification of mixtures for carcinogenicity. Page 390. https://echa.europa.eu/documents/10162/2324906/clp_en.pdf/58b5dc6d-ac2a-4910-9702-e9e1f5051cc5

Additives are regulated for safety under existing chemical management regulatory frameworks and under several global environmental agreements. Chemical regulatory frameworks are well-established in many developed economies and cover the manufacture, import, processing, distribution, use, and disposal of chemical substances, including additives. Chemical substances include both organic chemical substances (contain carbon) and inorganic chemical substances (do not contain carbon) of a specific chemical identity, which covers all polymers and all chemical additives. These chemical inventory regulatory schemes are used similar to a passport for entry of a substance into a country. In order to obtain this chemical passport, product safety and toxicological data must be submitted to government agencies.

Among the existing regulatory frameworks include TSCA in the US;[16] CEPA in Canada;[17] REACH in the EU;[18] K-REACH in Korea;[19] CSCL (Chemical Substances Control Law) in Japan;[20] and AICIS (Australian Industrial Chemicals Introduction Scheme) in Australia.[21] These frameworks require new chemicals to be reviewed for uses, hazards and safety before they can be manufactured and used to make products and put restrictions on chemical manufacture and use with the approvals.

Chemicals that have been in historic use are subject to many information reporting requirements so regulators can take additional regulatory action if needed. Regulators also perform risk assessments on chemistries, including chemicals added to plastic. For example, the United States is currently undertaking risk assessments on six phthalate esters and four flame retardants, all of which are or were chemical additives in plastics.[22] If the regulator, EPA, finds a significant risk from a particular additive in a product, it is required by law to take regulatory action to reduce the risk.

Regulatory action arising from the results of risk assessments in major economies will drive global markets as regulators prohibit or restrict certain additives from use in plastics, which extends to both the plastic material and any item or product made with the plastic.

Additionally, there are some chemicals used in plastic that are regulated globally through the Stockholm Convention and other multilateral environmental agreements.[23] These chemicals

[16] The Toxic Substances Control Act of 1976. 15 U.S.C. §2601 et seq. (1976). https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act
[17] Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33). https://laws-lois.justice.gc.ca/eng/acts/c-15.31/
[18] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. http://data.europa.eu/eli/reg/2006/1907/oj .
[19] Ministry of Government Legislation Act on the Registration and Evaluation, etc. of Chemical Substances. [cited 2014 Dec 30]. Available from: http://www.law.go.kr/lsInfoP.do?lsiSeq=140402#0000 (Korean)
[20] Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture etc., Act No. 117 of 1973.
[21] Australian Industrial Chemicals Introduction Scheme. https://www.industrialchemicals.gov.au/.
[22] US EPA. (2023). Chemicals Undergoing Risk Evaluation under TSCA. https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/chemicals-undergoing-risk-evaluation-under-tsca
[23] Stockholm Declaration on the Human Environment, in Report of the United Nations Conference on the Human Environment, UN Doc. A/CONF. 48/14, at 2 and Corr. 1 (1972).

are not evaluated specifically based on their use in plastics, but on their overall hazard and risks posed in all applications.

Use Specific Regulatory Frameworks:

Further, beyond chemical management programs, many countries regulate plastics for specific uses. These existing regulations Food contact packaging, and the additives utilized in such packaging, are subject to some of the most stringent – and comprehensive - regulatory frameworks for safety (e.g., European Food Safety Authority (EFSA) and the United States Food and Drug Administration (US FDA)).[24, 25] Food packaging must meet sanitary requirements and meet its performance requirements to protect the safety and integrity of the food. Food must be protected from contamination – bacteria, insects, rodents, dirt. It must hold liquids and wet foods without leaking, and chemically withstand the product type and its contents (e.g., acidic lemon juice), and any physical conditions (transporting, storing, cooking, or microwaving the food in the packaging).

Regulators also specifically evaluate the levels of chemical additives used in the food packaging, taking into account migration of the additives into food. Across the world, materials in contact with food and beverages - packaging, storage and service containers, dinnerware, bottles and cutlery – are subject to specific regulatory frameworks designed to ensure the safety of food and beverages for human consumption.

Food contact regulations:

- *Cover all materials, beyond plastics* – These frameworks cover all materials used in food contact – whether plastics, rubber, paper, ceramics, glass, metal, or other.

- *Broad coverage* – The frameworks thus cover things like cereal bags; water bottles; chip and snack bags; candy wrappers; milk jugs; containers for yogurt; plastic wraps for meats, fish and cheese. This also includes the protective plastic lining inside metal cans and the protective plastic coatings on paper and cardboard. The safety of baby formula and baby foods is generally managed by the food regulatory body as well.

- *Require pre-market approval* – Regulatory bodies require a scientific demonstration of the safety of the material before the material is authorized for use in a particular kind of food packaging in large parts of the chemical market.

- *Considers Exposure* – Considers migration of chemical additives under a range of conditions - the regulatory review takes into account heating and cooling the package (e.g., boiling or microwaving. It specifically reviews the amount of chemical additives that are in the food packaging that move into the food or beverage (migration) to determine that the amounts are so small that they are safe. For example, EU food contact requires manufacturers of intermediate materials (plastics) to include in the declaration of compliance the identity

[24] EFSA. (2022). Food contact material applications: overview and procedure. https://www.efsa.europa.eu/en/applications/foodcontactmaterials
[25] FDA. (2022). Inventory of Food Contact Substances Listed in 21 CFR. https://www.fda.gov/food/packaging-food-contact-substances-fcs/inventory-food-contact-substances-listed-21-cfr

and amount of substances in the intermediate material for which genotoxicity cannot be ruled out and which could be present in amount that could give rise to a migration exceeding 0.15 ppb.[26] For emphasis, ppb can be translated into 1 tsp in an Olympic size swimming pool.

- *Set a high standard for safety* – Food packaging, the safety standards are stringent – for example, "reasonable certainty of no harm" in the United States.

- *Ongoing risk assessments and updates* – Food regulators periodically undertake risk assessments and new reviews of chemical additives.

Beyond food packaging, medical and pharmaceutical uses of plastics are also heavily regulated spaces with additional rigor and product safety toxicological assessments. Several countries also have separate regulations for materials and substances used in children's products.[27]

Sustainability and the Circular Economy

Chemistry will be critical to solving many of the global challenges we face today and meet the goals as described in the UN's 17 Sustainable Development Goals (SDGs). Innovation will be needed to ensure those chemistries, including plastic additives, are more sustainable and enable a circular economy.[28] As governments, industry, and other stakeholders consider how to design and promote more sustainable plastics, there are principles that can guide the assessment and use of plastic additives to enable a circular economy and reduce risk to human health and the environment.

- •*Risk assessment Approaches* - Sustainable chemistry on chemical plastic additive use should reduce potential impacts on human health and the environment with the objective of maximizing societal benefits and overall contributions to sustainable development. Risk assessment approaches, that assess both a chemical's potential hazard and exposure, are necessary to protect the environment and human health while enabling the circular economy.
- *Life Cycle Assessment (LCA) Approaches* – The selection of a plastic additive and its optimal use through the entire value chain, will require the use of a transparent and comparable life cycle assessment approach. LCAs are used to evaluate the environmental impact of a product through its life cycle encompassing extraction and processing of the raw materials, manufacturing, distribution, use, recycling, and final disposal. However, not all LCAs are conducted in a similar manner and a lack of transparency hinders assessors' ability to compare the results. To enable and optimize a circular economy, it is critical LCAs be conducted in a similar manner and they are fully transparent.

[26] EFSA. (2019). Guidance on the use of the threshold of toxicological concern approach in food safety assessment. EFSA J. 17 (6). p. 5708. 10.2903/j.efsa.2019.5708
[27] E.g., U.S. Consumer Product Safety Improvement Act of 2008; EU Toy Safety Directive
[28] United Nations Brundtland Commission. (1987). Definition of 'sustainable chemistry'. http://www.un-documents.net/our-common-future.pdf .

- *Foster Innovation* - Sustainable chemistry should be a process that stimulates innovation across sectors to develop technologies and to design and discover new chemicals, applications of plastics, production processes, and chemical management practices that can provide increased performance and value while meeting the goals of protecting and enhancing human health and the environment. Enabling policies must allow for sufficient time to develop new chemistries, reformulate products, and safely implement them across the value chain.

Conclusion

Additives are an essential component to the use and design of plastic materials. Additives improve resource-efficiency, contribute to sustainable development, and can enable circularity. ICCA recognizes the need for governments, industry, consumers, and other interested stakeholders to understand the hazards and risks of chemicals used in plastics. Risk-based chemical regulations are currently being used to protect health and the environment in many countries and can guide the global discussion on chemicals in plastics as part of the INC process.

Appendix B - Review of Wiesinger et al. 2021

Review of Wiesinger et al. (2021), "Deep Dive into Plastic Monomers, Additives, and Processing Aids"

Summary

The paper by Wiesinger et al. (2021) brings together a number of information sources to start assembling a more complete picture of the use of additives in polymers and plastic.[29] However, this task is extremely complex and time consuming; even the authors note many data sources could not be used because they were not in a format that could be easily accessed and that a great deal of additional work is needed. The publication represents a good first step to understand the global use of additives in plastics.

To understand the chemicals used in plastics and whether they are actually a potential risk to health or environment requires an understanding of chemical regulations and a fundamental understanding of toxicology and risk assessment. There are number of subtleties, like the difference between a chemical that is classified as hazardous and a hazardous chemical that is able to cause harm because of *sufficient* exposure, that are not discussed or acknowledged by the authors. By not fully discussing these key principles, the publication gives an incomplete picture of plastic additives. This review clarifies some of these critical concepts that include:

1. The authors do not identify chemicals that are actually causing harm to health or the environment because they focus on a chemical's hazard potential, rather than its actual risk.
2. Chemicals and additives are more highly regulated than described by the authors.

Only a Risk Assessment can Determine if a Plastic Additive is Causing Harm

The terms "hazard" and "risk" are frequently used interchangeably, but they mean very different things.[30] The Toxicology Education Forum (TEF) produced a short video explaining these concepts.[31] These terms are defined as:

- **Hazard** is a chemical's *potential* ability to cause harm.
- **Exposure** is the amount of and the frequency with which a chemical comes into contact with a person or the environment.
- **Risk** is the likelihood that harm will occur from *exposure* to a specific hazard. Without exposure to a hazard, there can be no risk. A simplified equation that is often used is: **Risk = Hazard x Exposure**

[29] Helene Wiesinger, Helene, Zhanyun Wang, and Stefanie Hellweg. (2021). Deep Dive into Plastic Monomers, Additives, and Processing Aids. Environmental Science & Technology. 55: 13. p. 9339-9351. DOI: 10.1021/acs.est.1c00976

[30] Toxicology Education Forum (TEF). (2023). Hazard vs. Risk. https://toxedfoundation.org/hazard-vs-risk/ .

[31] TEF (2023). What's the difference between a hazard and a risk? https://www.youtube.com/watch?v=Sk88kkuIo6g .

- **Risk Assessment** is the formal process of quantifying risk based on known hazards and the amount of exposure.

With these principles in mind, the Wiesinger et al. publication can be evaluated in a scientific manner.

Key Point: Wiesinger et al. (2021) does not identify chemical additives that are causing harm to health and/or the environment.

- Wiesinger et al. only uses half of the available data, hazard potential, to arrive to the conclusion that "[o]ver 2'400 substances are identified as substances of potential concern."
- The use of the phrase "potential concern" in the publication is misleading. A chemical that is classified as hazardous may be of potential concern *only if there is sufficient exposure*.
- The authors identify these chemicals of potential concern if "they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union."[32]
    - Chemicals identified as hazardous under the EU REACH regulation must develop "safe limits" and ensure that exposure stays under that value for a given use.
    - This means that these hazardous chemicals are both 1) regulated and 2) being used in a manner that poses minimal risk to health and the environment.
    - This point is discussed in more detail in the next section on chemical regulations.

The use of risk, rather than relying on a hazard-based approach, allows regulators and manufacturers to safely use chemicals to benefit society and enable the circular economy.

Key Point: Hazard identification allows regulators and manufacturers to either use chemicals that are less intrinsically hazardous or reduce exposure and thereby reduce or eliminate risk to health or the environment.

- Hazard identification and exposure assessment are critical steps to establishing the safe use of a chemical.
- Some chemicals are essential for a particular use and by identifying the hazards and exposures to a chemical, a regulator or manufacturer can develop solutions that continue to benefit society while minimizing or eliminating risk.

Key Point: Additives are not instantly or completely released from plastic in the environment. This is important to consider when determining an additive's risk.

- The authors correctly note, "…plastics contain many substances that are not chemically bound to the polymer matrix, including unreacted monomers, residual processing aids and additives. These substances *may be released* during the plastic life cycle, resulting in human and environmental exposure."[33] [*emphasis added*].

[32] Wiesinger et al. at 9339.
[33] *Id*. 9339.

- Many additives are not chemically bound (e.g., ionic, covalent) within a polymer, but it is important to note that the laws of thermodynamics always apply.[34,35]
    - Additives will remain in the plastic article so long as there is no thermodynamic driver for their release.
- Manufacturers use the principles of chemical management and hazard communications to ensure that products are used in the correct manner.
    - Migration data and risk assessments are often developed to ensure the additives are not released at levels that could potentially harm human health or the environment.
- There are a number of guidance documents and models that are available to predict the rate and amount an additive might be released by a plastic article.[36,37]

Plastic Additives are Highly Regulated

Plastic additives are more highly regulated than stated by the authors. To determine the regulatory status of an additive, the authors compare the list of identified chemicals to a number of regional regulatory lists.[38] If an additive appears on one or more of these lists, then the authors note it as regulated. However, if a chemical is not on a regulatory list, the authors consider this chemical as "not regulated." This interpretation of the data gives the reader the impression that the vast majority of additives are not regulated. This is a misunderstanding of the current chemical regulations across the globe.

The European Union's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation[39] and Regulation on classification, labelling and packaging of substances

[34] Gouin, T., Roche, N., Lohmann, R. & Hodges, G. (2011). A thermodynamic approach for assessing the environmental exposure of chemicals absorbed to microplastic. Environ. Sci. Technol. 45, 1466–1472.
[35] Gouin, T. (2021). Addressing the importance of microplastic particles as vectors for long- range transport of chemical contaminants: perspective in relation to prioritizing research and regulatory actions. Micropl. Nanopl. 1: 14.
[36] OECD. (2014). Plastic Additives: OECD Emission Scenario Document. .https://www.oecd.org/env/plastic-additives-9789264221291-en.htm .
[37] ECHA. (2020). Describing uses of additives in plastic material for articles and estimating related exposure Practical Guide for Industry. https://echa.europa.eu/documents/10162/17228/expo_plastic_addives_guide_en.pdf/ef63b255-6ea2-5645-a553-9408057eb4fd .
[38] Wiesinger et al. (2021). Page 9341. "Regulatory status in specific regions was assessed by checking the presence of identified substances on various regulatory lists (Sheet S2 in Supporting Information S1)."
[39] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. http://data.europa.eu/eli/reg/2006/1907/oj .

and mixtures (CLP)[40] together form a comprehensive chemical regulatory scheme. While CLP, based off of the UN's Globally Harmonized System of Classification and Labelling of Chemicals (GHS),[41] is focused on hazard identification, REACH requires a manufacturer to develop a "safe limit" for chemicals. It is also important to note that countries may currently adopt UN GHS. This is an important step for nations to establish their own chemical safety regulations and further develop their chemical industries.

Key Point: Chemical hazards are identified and classified under CLP or GHS. Classified chemicals are subject to concentration limits in a mixture depending on the identified hazard.

- GHS is primarily a system of hazard communication for chemical hazards that can be adopted by countries around the world.
- CLP is the EU's adaptation of GHS specifically for EU member countries.
- Under CLP, a substance must be self-classified when it has no harmonized classification in Annex VI to CLP and it presents hazardous properties.
- A mixture of classified and non-classified chemicals is not classified itself unless it contains more than the listed generic concentration limits established by GHS or CLP.[42]
- GHS is widely adopted across the globe and serves as the basis for many countries chemical safety regulations.
- The chemical industry encourages countries to adopt UN GHS as an important step to enhancing chemical safety regulations across the world.

Key Point: Chemicals classified and registered under REACH are subject to regulatory limits that require exposures to be below a safe or acceptable limit.

- A company registering a chemical under REACH is required to provide health and environmental studies designed to identify potential hazards.
    - These studies may not be published in the peer-reviewed literature (e.g., not in SciFinder), but they are often conducted according to rigorous OECD Testing Guidelines.
    - Information on data-rich chemicals may be used to predict hazard potentials for structurally similar, but data-poor chemicals (e.g., read-across principles, QSAR models, etc.). Because these two chemicals have different CAS numbers, the data-rich chemical may be interpreted as being extensively studied while the data-poor chemicals may be incorrectly interpreted as being not adequately studied.

[40] Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006 (Text with EEA relevance)
OJ L 353, 31.12.2008, p. 1–1355. ELI: http://data.europa.eu/eli/reg/2008/1272/oj
[41] UN GHS. (2021). ST/SG/AC.10/30/Rev.9 - GHS Rev.9.
https://unece.org/transport/standards/transport/dangerous-goods/ghs-rev9-2021
[42] ECHA. (2017). Guidance on the Application of the CLP Criteria Guidance to Regulation (EC) No 1272/2008 on classification, labelling and packaging (CLP) of substances and mixtures. Version 5.0. Section 3.6.3. Classification of mixtures for carcinogenicity. Page 390. https://echa.europa.eu/documents/10162/2324906/clp_en.pdf/58b5dc6d-ac2a-4910-9702-e9e1f5051cc5

- If a hazard is identified, and that hazard requires classification under CLP, the company must calculate a safe limit for that chemical.
- These safe limits are called a "Derived No Effect Level" (DNEL) for non-carcinogens, a "Derived Minimal Effect Level" (DMEL) for carcinogens, or a Predicted No Effect Concentration (PNEC) for environmental endpoints.
- DNELs, DMELs, and PNECs are calculated by dividing an observed effect in experimental or modelled data by several conservative adjustment factors (AFs). AFs are used to account for the uncertainty that may or may not be present in the data. This results in a safe limit that has a greater margin of protection for health or the environment
- After the DNEL, DMEL, or PNEC is calculated, a company must assess the exposure potential for each registered application the chemical will be used in (e.g., used in a sprayable, consumer product).
- The exposure potential is compared to the DNEL, DMEL, or PNEC to derive the risk characterization ratio (RCR).
    - RCR = Exposure / DNEL
- If the RCR is below one, this means exposure to the chemical, for that use, is below the safe limit and may be used in a safe manner.
    - RCR < 1 = safe use
- If the RCR is above one, then a company must implement risk management measures (RMMs) or reduce the amount of chemical used in that particular uses until the RCR is recalculated to be below 1.
    - RCR > 1 = potential risk to health or the environment
- This risk based regulatory scheme means that all classified, REACH registered additives are in fact, regulated.
    - Wiesinger et al. incorrectly identifies many of these chemicals as unclassified.

Key Point: Monomers are almost exclusively used as a chemical intermediate, meaning the monomers are used exclusively in a closed system and exposures are *de minimus*. The resulting polymers formed from the reaction and used in plastics are usually not reactive or classified.

- Monomers typically have reactive chemical properties that allow them to form bonds with other chemicals. This is a desired property, and this reactivity means many monomers are classified for adverse effects.
- Monomers are reacted in a closed-loop system to improve the reaction efficiency. Because of this closed-loop system, there is almost no exposure to unreacted monomers.
- While there may be very low residual concentrations of unreacted monomers in the final product, these concentrations are very low. However, if their concentration exceeds the generic concentration limit for the specific hazard (e.g., 0.1% for Cancer Category 1A or 1B) the polymer will be classified accordingly.
- Wiesinger et al. does not acknowledge that the total tonnage for the identified monomers is consumed in the reaction and therefore there is almost no risk to health and the environment.

Key Point: EU REACH and CLP are not the only risk-based regulations deployed in countries across the globe. Additives are already regulated under a number of regulatory frameworks.

- Existing regulatory frameworks include: TSCA in the US;[43] CEPA in Canada;[44] REACH in the EU;[45] K-REACH in Korea;[46] CSCL (Chemical Substances Control Law) in Japan;[47] AICIS (Australian Industrial Chemicals Introduction Scheme) in Australia,[48] and globally under the Stockholm Convention.
    - These frameworks require new chemicals to be reviewed for uses, hazards and safety before they can be manufactured and used to make products and put restrictions on chemical manufacture and use with the approvals.
- Beyond chemical management programs, many countries regulate plastics for specific uses. Food contact packaging, and the additives utilized in such packaging, are subject to some of the most stringent – and comprehensive - regulatory frameworks for safety.[49,50]
- Other applications, like medical devices and toys, may also regulate plastics additives.

Conclusions

The publication by Wiesinger et al. is a first step in identifying chemicals that are potentially used in plastic-related applications and how they are regulated. However, given the large volume of data available, the paper only focuses on whether 1) a chemical is hazardous and 2) if it appears on a regulatory list. This approach does not take into account that non-classified additives do not appear on such lists, and it does not identify the myriad of chemical regulations that use a risk-based assessment method to determine how a chemical can be used safely. When these risk-based regulations are accounted for, it becomes apparent that most plastic additives are regulated under one or more country chemical management scheme.

The use of additives in plastic applications is necessary to provide, improve, modify, or retain plastic properties. Because of their widespread use, additives are regulated under a number of risk-based regulatory instruments. Risk-based regulations ensure plastic additives are used in a safe manner that protects human health and the environment for the benefit of society.

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[43] The Toxic Substances Control Act of 1976. 15 U.S.C. §2601 et seq. (1976). https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act

[44] Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33). https://laws-lois.justice.gc.ca/eng/acts/c-15.31/

[45] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. http://data.europa.eu/eli/reg/2006/1907/oj .

[46] Ministry of Government Legislation Act on the Registration and Evaluation, etc. of Chemical Substances. [cited 2014 Dec 30]. Available from: http://www.law.go.kr/lsInfoP.do?lsiSeq=140402#0000 (Korean)

[47]Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture etc., Act No. 117 of 1973.

[48] Australian Industrial Chemicals Introduction Scheme. https://www.industrialchemicals.gov.au/.

[49] EFSA. (2022). Food contact material applications: overview and procedure. https://www.efsa.europa.eu/en/applications/foodcontactmaterials

[50] FDA. (2022). Inventory of Food Contact Substances Listed in 21 CFR. https://www.fda.gov/food/packaging-food-contact-substances-fcs/inventory-food-contact-substances-listed-21-cfr

Appendix C - Review of Groh et al. 2019

RE: Review of Groh et al., 2019: Overview of known plastic packaging-associated chemicals and their hazards

Summary

Using a hazard only approach, Groh et al., (2019) compiled a database of 906 chemicals "likely" and 3377 chemicals "possibly" associated with plastic packaging.[51] Of the 906 chemicals likely associated with plastic packaging, 148 chemicals were identified as of high concern (i.e. PBTs, vPvBs, EDCs, environmental hazards and human health hazards). However, on closer analysis, there are a number of critical issues with the methods used to assemble this list. These issues include:

1. The use of a hazard only based approach does not actually identify chemical additives that are causing harm to health or the environment;
2. Plastic additives are more highly regulated than represented in the paper;
3. There is a great deal more health and safety data publicly available for plastic additives than noted by the authors and large data gaps do not exist;
4. The citations the authors use to identify EDCs do not actually identify EDCs and a more detailed analysis reports much fewer potential EDCs.

Key Point: Groh et al. does not identify chemical additives that are causing harm to health and/or the environment.

- For a chemical to cause harm to health or the environment, a chemical must be hazardous (i.e., have the ability to cause harm) and there must be sufficient exposure to the chemical to cause the harmful effect.
    - Risk is the likelihood that harm will occur from exposure to a specific hazard.
    - Without exposure to a hazard, there can be no risk.
- A significant deficit in the methods used by Groh et al. is it is focused on a *hazard only* approach and does not give any consideration of the potential for exposure.
    - Exposure potential of additives may be due to the concentrations associated with plastic production, their polymerization/reaction during the production process, or their ability to leach or migrate out the plastic.
- By focusing only on hazard, the authors describe an unrealistic extreme characterization of the hazard potential of plastic products and raise concerns for population-wide human effects without adequate data to support their conclusions.
- A lack of available information is the primary reason used by the authors to justify the hazard-only approach. However, as is described in the next key point, the authors did not use the data available in existing regulations.

[51] Groh, Ksenia et al. (2019). Overview of known plastic packaging-associated chemicals and their hazards. Science of The Total Environment. Volume 651:2. Pages 3253-3268. https://doi.org/10.1016/j.scitotenv.2018.10.015

Key Point: Plastic additives used in food packaging are more highly regulated than stated by the authors.

- There are a number of regulations enforced across the globe the authors do not discuss.
- Plastic packaging used in food contact applications adhere to some of the most stringent food contact regulations, i.e., strict safety migration limits, stringent risk management, exposure and migration are mitigated to within safe limits, which ensures that plastic packaging products for food contact pose no risk to consumers.[52,53]
- There are additional chemical regulatory frameworks that include: TSCA in the US;[54] CEPA in Canada;[55] REACH in the EU;[56] K-REACH in Korea;[57] CSCL (Chemical Substances Control Law) in Japan;[58] and AICIS (Australian Industrial Chemicals Introduction Scheme) in Australia.[59]
    i) These frameworks require new chemicals to be reviewed for uses, hazards, exposures, and safety (i.e., risk) before they can be manufactured and used to make products and put restrictions on chemical manufacture and use with the approvals.

Key Point: Under the EU REACH regulation, all registered chemicals are required to submit basic data on health and the environment. The lack of CLP classification for a chemical does not mean there is no hazard information available.

- The authors interpret the lack of CLP classification to mean there is no hazard information available, i.e. significant data gaps exist for hazard information on chemicals likely associated with plastics packaging.
- However, CLP is a hazard classification scheme, which means, only when a chemical is hazardous, it will have a CLP classification. And when a chemical is non-hazardous, it will not have a CLP classification.
    - For example, water is identified in the paper as associated with plastic packaging and does not have CLP classification. It is because water is non-hazardous.
- In addition to the harmonized CLP classification noted by the authors, self-classification is performed by industry as a part of the REACH dossier for every chemical registered

[52] EFSA. (2022). Food contact material applications: overview and procedure. https://www.efsa.europa.eu/en/applications/foodcontactmaterials
[53] FDA. (2022). Inventory of Food Contact Substances Listed in 21 CFR. https://www.fda.gov/food/packaging-food-contact-substances-fcs/inventory-food-contact-substances-listed-21-cfr
[54] The Toxic Substances Control Act of 1976. 15 U.S.C. §2601 et seq. (1976). https://www.epa.gov/laws-regulations/summary-toxic-substances-control-act
[55] Canadian Environmental Protection Act, 1999 (S.C. 1999, c. 33). https://laws-lois.justice.gc.ca/eng/acts/c-15.31/
[56] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC. http://data.europa.eu/eli/reg/2006/1907/oj .
[57] Ministry of Government Legislation Act on the Registration and Evaluation, etc. of Chemical Substances. [cited 2014 Dec 30]. Available from: http://www.law.go.kr/lsInfoP.do?lsiSeq=140402#0000 (Korean)
[58]Act on the Evaluation of Chemical Substances and Regulation of Their Manufacture etc., Act No. 117 of 1973.
[59] Australian Industrial Chemicals Introduction Scheme. https://www.industrialchemicals.gov.au/.

and is publicly accessible through ECHA portal. The publication failed to include these or even mention these classifications.

- It is incorrect for this paper to indicate that data from *in silico* prediction, *in vitro* tests or peer-reviewed literature may not be used in CLP classification. *In vitro*, *in silico* and peer-reviewed literature data are all included in the CLP classification scheme.
    - The adequacy, reliability, validity and relevance of the data play an important role in the consideration in the final assessment.
- One final point regarding CLP not discussed was that a harmonized classification often defines concentration limits in products based on the human health endpoint. This has consequences beyond the general impact on classification of the chemical but also influences the classification for formulations containing this product.

Key Point: PBT assessments are a multi-step process that uses different types of data and a weight of the evidence approach to determine if classification, and risk management measures, are appropriate.

- There are three levels for PBT assessment: screening, PBT assessment and identification, and regulatory decision (e.g., SVHC identification).
- The screening level usually utilizes in silico methods. However, because each in silico methods has its own applicability domain, reliability and conservatism, screening level assessment is intended to prioritize information for further assessment. Screen level assessment is not intended nor appropriate for ultimate determination of PBT properties.
- The next level (PBT assessment and identification), higher tier information (e.g., environmental fate simulation studies, in vivo bioaccumulation or field studies, etc.) is reviewed in a weight of evidence approach against PBT criteria. PBT chemicals are subject to a risk assessment within Chemical Safety Report under REACH, and the risk assessment informs on risk management.
- Finally, once a chemical goes through regulatory process and listed as SVHC under REACH, risk management is often closer to a ban or a severe restriction of use.

Key Point: The paper incorrectly identifies a number of chemicals as endocrine disrupting chemicals (EDCs) due to a misinterpretation of the available information.

- In section 4.2, the authors characterize the UNEP report on EDCs (UNEP, 2018) as a list of "EDCs or potential EDCs identified by at least one robust stakeholder."[60] However, the UNEP report on EDCs is actually a compilation of publicly available "initiatives" that list potential endocrine disrupting compounds. These "initiatives" to identify EDCs originated from a wide variety of sources.
- When comparing these "initiatives", the UNEP report on EDCs indicated a large variation in the compilation of potential EDCs, including the following points taken directly from the report:
    - "The intended purpose of individual initiatives as well as the criteria used to identify (or include) chemicals as EDCs or potential EDCs vary considerably."

[60] UNEP (2018). Overview Report I: Worldwide Initiatives to Identify Endocrine Disrupting Chemicals (EDCs) and Potential EDCs International Panel on Chemical Pollution (IPCP).

  - "Some initiatives have already been heavily developed and publicized, whereas others are planned or currently in earlier development stages."
  - "No commonly accepted criteria for the identification of EDCs are yet available, however, recently the European Commission accepted criteria for the identifications of EDCs in plant protection products (Commission Regulation (EU) 2018/605)."
- Aside from the limitations recognized in the UNEP Report on EDC, there are other notable limitations to these "initiatives" including:
  - The criteria used to compile these "initiatives" are variable and unlikely to meet regulatory standards as the chemical initiatives were compiled prior to adoption of the EU endocrine criteria. Furthermore, there are differences across the "initiatives" in chemical selection criteria, methods for chemical inclusion, requirements for data robustness, etc.
  - There is no standardized approach to evaluate data quality, endocrine mode-of-action, impact of systemic toxicity, etc., which are critical to an EDC evaluation.
  - *These* "initiatives" *do not require a Weight-of-evidence (WOE) analysis* to include or exclude substances, but WOE is a critical step in the determination of endocrine disrupting potential (see OECD Guidance Document 150).[61]
- The authors' classification of the UN report as containing "EDCs or potential EDCs identified by at least on robust stakeholder" mischaracterizes the reliability of these "initiatives" and gives the impression that these compounds have undergone a rigorous regulatory evaluation for endocrine disruptor potential, which is not accurate.

Key Point: The number of EDCs identified by ECHA is approximately half the number stated by the paper.

- The European Chemicals Agency (ECHA) is conducting regulatory reviews to determine whether compounds meet the endocrine disruptor criteria.
- A review of the chemicals highlighted in the Groh et al. (2019) as EDCs found 17 of the 32 chemicals have not been identified as EDCs by ECHA.[62]
- The chemicals identified by Groh et al. were included in a table in the UNEP Report on EDCs (2018) with the footnote:

  "The chemicals which appear in this table *have not been identified* as known or suspected EDCs as part of a regulatory review which considers and weighs all available evidence, engages external peer review and is open and responsive to public review and comment." [*emphasis added*].
- Another chemical included in Groh et al. (2019) is di-undecyl phthalate (CAS 3648-40-0; note the CAS should be 3648-20-0). This chemical has not been identified as an EDC by ECHA.
- Of the 14 remaining chemicals, ten chemicals are forms of nonyl and octyl-phenol and four are phthalates, which have been identified as EDCs by ECHA.

[61] OECD (2018), *Revised Guidance Document 150 on Standardised Test Guidelines for Evaluating Chemicals for Endocrine Disruption*, OECD Series on Testing and Assessment, No. 150, OECD Publishing, Paris, https://doi.org/10.1787/9789264304741-en.

[62] https://edlists.org/the-ed-lists/list-i-substances-identified-as-endocrine-disruptors-by-the-eu?page=0 .

- The authors did not discuss the incidence of these materials in food packaging or that food packaging is reviewed for safety by the Food and Drug Administration in the US, which conducts a safety review before new materials are allowed on the market.

Chemicals not Identified as EDCs by ECHA

Chemical Name	CAS
Ziram	137-30-4
Thiram	137-26-8
Triclosan	3380-34-5
Methylparaben	99-76-3
Ethylparaben	120-47-8
Propylparaben; propyl 4-hydroxybenzoate	94-13-3
Triphenyl phosphate	115-86-6
Dicyclohexyl phthalate (DCHP)	84-61-7
Dihexyl phthalate (DHP)	84-75-3
Diethyl phthalate (DEP)	84-66-2
Dioctyl phthalate	117-84-0
Diisodecyl phthalate (DiDP)	68515-49-1 / 26761-40-0
Butylated hydroxytoluene (BHT)	128-37-0
Tert.-Butylhydroxyanisole (BHA); tert-butyl-4-methoxyphenol	25013-16-5
Benzophenone-1; 2,4-Dihydroxybenzophenone; Resbenzophenone	131-56-6
Benzophenone-2; 2,2',4,4'-tetrahydroxybenzophenone	131-55-5
Benzophenone-3; Oxybenzone	131-57-7
Diundecyl phthalate (DuDP), branched and linear	3648-20-2
Diundecyl phthalate (DuDP), branched and linear	3648-20-2

Compounds Identified as EDCs by ECHA

Benzyl butyl phthalate; BBP	85-68-7	EU REACH SVHC
Dibutyl phthalate; DBP	84-74-2	EU REACH SVHC

Bis(2-ethylhexyl) phthalate; DEHP	117-81-7	EU REACH SVHC
Diisobutyl phthalate; DIBP	84-69-5	EU REACH SVHC
4-Nonylphenol, branched and linear	84852-15-3/ 26543-97-5/ 104-40-5/ 17404-66-9/ 30784-30-6/ 52427-13-1/ 186825-36-5/ 142731-63-3/ 90481-04-2**/ 25154-52-3**/ Others not specified	EU REACH SVHC
4-(1,1,3,3-tetramethylbutyl)phenol	140-66-9	EU REACH SVHC
4-Nonylphenol, branched and linear, ethoxylated	104-35-8/7311-27-5/ 14409-72-4/ 20427-84-3/ 26027-38-3/ 27942-27-4/ 34166-38-6/ 37205-87-1/ 127087-87-0/ 156609-10-8/ 68412-54-4**/ 9016-45-9**/ Others not specified	EU REACH SVHC

Appendix D – Key Microplastic Health and Environmental Risk Assessment References

Key Microplastic Health and Environmental Risk Assessment References

Authoritative Reports – Key Summaries by Regulatory or Global Scientific Bodies

1. World Health Organization (WHO). (2022). Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. 30 August 2022. ISBN: 978-92-4-005460-8. https://www.who.int/publications/i/item/9789240054608
    - Importance
        - The WHO report was authored by independent experts in microplastics and systematically reviewed the most recent data on microplastics and their potential to affect human health.
    - Key Findings
        - "A key observation is that MP are ubiquitous in the environment and have been detected in environmental media with direct relevance for human exposure, including air, dust, water, food and beverages."
        - "The weight of the scientific evidence provided by current data on adverse effects of NMP on human health is low, because of substantial limitations of the available information."
        - "The assessment scores indicated that the available data are of only very limited use for assessing the risk of NMP to human health."
        - "Little is known about the adverse effects of MP-associated biofilms, although the available data provide no evidence of a risk to human health."
        - "It is therefore not currently possible to characterize or quantify the potential role of NMP in the transport of chemicals."
        - "It is generally recommended that standard methods be developed and adopted to ensure that the research community can reduce uncertainties, strengthen overall scientific understanding and provide more robust data for assessing the risks of exposure to NMP to humans."

2. World Health Organization (WHO). (2019). Microplastics in drinking-water. ISBN: 978-92-4-151619-8. https://www.who.int/publications/i/item/9789241516198
    - Importance
        - The WHO assembled a panel of independent experts to systematically review the peer reviewed literature to determine the potential effects of microplastics to human health.
    - Key Findings
        - "Based on the limited evidence available, chemicals and biofilms associated with microplastics in drinking-water pose a low concern for human health. Although there is insufficient information to draw firm conclusions on the toxicity related to the physical hazard of plastic particles, particularly for the nano-size particles, no reliable information suggests it is a concern."

- "However, optimized wastewater (and drinking-water) treatment can effectively remove most microplastics from the effluent. For the significant proportion of the population that is not covered by adequate sewage treatment, microbial pathogens and other chemicals will be a greater human health concern than microplastics."
- "To better assess the human health risks and inform management actions, researchers should undertake targeted, well-designed and quality-controlled investigative studies…"

3. Science Advice for Policy by European Academies (SAPEA). (2019). A Scientific Perspective on Microplastics in Nature and Society. Berlin: SAPEA. https://doi.org/10.26356/microplastics
    - Importance
        - Science Advice for Policy by European Academies (SAPEA) brought together expertise from over 100 academies and learned societies in over 40 countries across Europe to assess the potential environmental hazards of microplastics.
    - Key Findings
        - "The SAPEA working group concludes that a lot is already known about nano- and microplastics, and more knowledge is being acquired, but some of the evidence remains uncertain and it is by its nature, complex…"
        - "They conclude that there is a need for improved quality and international harmonization of the methods used to assess exposure, fates and effects of NMPs on biota and humans."
        - "The working group concludes from this evidence that, while ecological risks are very rare at present for NMPs (plastics of sizes below 5mm), there are at least some locations in coastal waters and sediments where ecological risks might currently exist."
        - "If future emissions to the environment remain constant, or increase, the ecological risks may be widespread within a century."

4. U.S. Interagency Marine Debris Coordinating Committee (US IMDCC). (2022). Draft Report on Microfiber Pollution. https://marinedebris.noaa.gov/interagency-marine-debris-coordinating-committee-reports/report-microfiber-pollution
    - Importance
        - The U.S. Environmental Protection Agency's (EPA) and the National Oceanic
        - and Atmospheric Administration's (NOAA) assessed the state of the science on microfibers to assess the potential effects microfibers have on the environment and recommendations for reducing microfiber pollution.
    - Key Findings
        - "Though there is currently insufficient data on human exposure and hazards associated with microfibers to perform meaningful human risk assessments for microfibers or microplastics, it is widely accepted that humans are exposed to microplastics via ingestion and inhalation…"
        - "Though research confirms that humans and a diverse range of aquatic and terrestrial organisms are exposed to microfiber pollution, the impacts of

microfiber pollution on environmental and human health are largely unknown."
    - "Though the public health and environmental impacts of microfiber pollution are largely unknown, there is evidence that organisms might experience physical, chemical, and/or biological impacts as a result of exposure to microfibers…"
    - "Microfibers are a highly complex and diverse type of contaminant and research on the subject is particularly challenging due to a lack of standard definitions and research methods, which make comparisons across studies difficult."

5. European Food Safety Authority (2016). EFSA Journal 2016;14(6):4501. DOI: https://doi.org/10.2903/j.efsa.2016.450
    - Importance
        - The EFSA Panel for Contaminants in the Food Chain was asked to deliver a statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood by the German Federal Institute for Risk Assessment (BfR).
    - Key Findings
        - "Based on a conservative estimate the presence of microplastics in seafood would have a small effect on the overall exposure to additives or contaminants."
        - "…however, toxicity data for nanoplastics are essentially lacking for human risk assessment and it is not yet possible to extrapolate data from one nanomaterial to the other."

6. European Food Safety Authority (2021). EFSA Journal 2021;18(8):EN-6815. DOI: https://efsa.onlinelibrary.wiley.com/doi/pdf/10.2903/sp.efsa.2021.EN-6815
    - Importance
        - An online colloquium was organized by EFSA to bring researchers, risk assessors and risk managers together to understand the current state of play and ongoing research in micro- and nano- plastics and to facilitate the assessment of the risks of micro and nano- plastics to human health.
    - Key Findings
        - "However, it is clear from the large list of uncertainties presented that further efforts are needed to generate the data necessary for a comprehensive human health risk assessment."

7. Environment and Climate Change Canada and Health Canada. (2020). ISBN 978-0-660-35897-0.
Cat. No.: En14-424/2020E-PDF. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html
    - Importance
        - Environment and Climate Change Canada and Health Canada summarized the "current state of the science regarding the potential impacts of plastic

pollution on the environment and human health, as well as to guide future research and inform decision-making on plastic pollution in Canada."

- Key Findings
  - "The evidence for potential effects of microplastic pollution on environmental receptors is less clear and sometimes contradictory, and further research is required."
  - "The current literature on the human health effects of microplastics is limited, although a concern for human health has not been identified at this time."

Peer Reviewed Science Key Findings

Key Finding: **The available data indicates there is minimal risk to health and to environmental organisms at current microplastic exposure levels. Scientists agree higher quality data is needed to accurately evaluate the potential risk from microplastics.**

- WHO (2022). See above.
- WHO (2019). See above.
- SAPEA (2019). See above.
- US IMDCC (2022). See above.
- EFSA (2016). See above.
- EFSA (2021). See above.
- de Ruijter VN et al. (2020). Quality criteria for microplastic effect studies in the context of risk assessment: a critical review. Environ. Sci. Technol. 54: 11692–11705. https://doi.org/10.1021/acs.est.0c03057
  - The authors evaluated the quality of 105 aquatic biota microplastic studies using 20 objective criteria and then conducted a weight of evidence analysis with respect to demonstrated effect mechanisms.
  - Author quote: "On average, studies scored 44.6% (range 20–77.5%) of the maximum score. No study scored positively on all criteria, reconfirming the urgent need for better quality assurance. Most urgent recommendations for improvement relate to avoiding and verifying background contamination, and to improving the environmental relevance of exposure conditions… [w]hen accounting for the quality of the studies according to our assessment, three of these mechanisms remained. These are inhibition of food assimilation and/or decreased nutritional value of food, internal physical damage, and external physical damage. We recommend that risk assessment addresses these mechanisms with higher priority."
- Gouin, T., Ellis-Hutchings R., Thornton Hampton, L., Lemieux C., Wright S. (2022). Screening and prioritization of nano- and microplastic particle toxicity studies for evaluating human health risks – development and application of a toxicity study assessment tool. Microplast nanoplast. 2(1):2. https://doi.org/10.1186/s43591-021-00023-x.
  - The authors developed object criteria to evaluate the quality of 74 microplastic studies relevant to human health in order to determine which studies could be used to inform a risk assessment.

- Author Quote: "A total of 74 studies representing either inhalation or oral exposure pathways were identified and evaluated… Using [the approach detailed in the study] we identify 10 oral ingestion and 2 inhalation studies that score at least 1 against all critical criteria… several key observations for strengthening future effects studies are identified, these include a need for the generation and access to standard reference materials representative of human exposure to NMPs for use in toxicity test systems and/or the improved characterization and verification of test particle characteristics, and the adoption of study design guidance, such as recommended by OECD, when conducting either in vivo inhalation or oral ingestion toxicity tests."

- Bucci, K et al. (2020). What is known and unknown about the effects of plastic pollution: a meta- analysis and systematic review. Ecol Appl. 30(2):e02044. https://doi.org/10.1002/eap.2044
  - Author Quote: "We also assessed the environmental relevancy of experimental studies by comparing the doses used in each exposure to the concentrations and sizes of microplastics found in the environment. We determined that only 17% of the concentrations used in experimental studies have been found in nature, and that 80% of particle sizes used in experiments fall below the size range of the majority of environmental sampling. Based on our systematic review and meta-analysis, we make a call for future work that recognizes the complexity of microplastics and designs tests to better understand how different types, sizes, shapes, doses, and exposure durations affect wildlife. We also call for more ecologically and environmentally relevant studies, particularly in freshwater and terrestrial environments."
- Burns and Boxall. (2018). Microplastics in the aquatic environment: Evidence for or against adverse impacts and major knowledge gaps. Environmental Toxicology and Chemistry. 37:11. pp. 2776–2796. https://doi.org/10.1002/etc.4268
  - Author Quote: "Concentrations [of microplastics] detected are orders of magnitude lower than those reported to affect endpoints such as biochemistry, feeding, reproduction, growth, tissue inflammation and mortality in organisms. The evidence for microplastics acting as a vector for hydrophobic organic compounds to accumulate in organisms is also weak. The available data therefore suggest that these materials are not causing harm to the environment. There is, however, a mismatch between the particle types, size ranges, and concentrations of microplastics used in laboratory tests and those measured in the environment."
- Nor, N., et. al. (2021). Lifetime Accumulation of Microplastic in Children and Adults. Environ. Sci. Technol. 55:8. pp. 5084–5096. https://doi.org/10.1021/acs.est.0c07384

- The authors developed a lifetime exposure model for children and adults using a probabilistic model. The authors calculate a typical scenario and a "worst-case" scenario.
- For comparison, The US EPA Exposure Factors Handbook recommended values for daily soil and dust ingestion is 30 – 90 mg/day, soil ingestion alone is 10-40 mg/day, dust (indoor + outdoor) alone is 20-50 mg/day, depending on age groups.
    - US EPA. (2017). Update for Chapter 5 of the Exposure Factors Handbook. EPA/600/R-17/384F. https://www.epa.gov/expobox/exposure-factors-handbook-chapter-5.
- Author Quote: "A recent report by the World Wildlife Fund (WWF) claimed that humans consume up to 5 g of plastic (one credit card) every week (~700 mg/capita/day) from a subset of our intake media (Figure 2C). Their estimation is above the 99th percentile of our distribution and hence, does not represent the intake of an average person." [Internal references omitted].

Key Finding: **Results from microplastic research need to be carefully considered because it is difficult to replicate results between labs and there is a high risk of sample contamination.**

- Belz, S. et. al. (2021). Current status of the quantification of microplastics in water - Results of a JRC/BAM inter-laboratory comparison study on PET in water. EUR 30799 EN, Publications Office of the European Union, Luxembourg. ISBN 978-92-76-40958-8. JRC125383. https://doi.org/10.2760/6228
    - The European Commission's Joint Research Centre (JRC) and German Federal Institute for Materials Research and Testing (BAM) organized almost 100 independent labs to conduct an inter-laboratory comparison (ILC) study. The ILC investigated the reproducibility of methods used for the analysis of microplastics and how microplastics reference materials might be developed.
    - Author Quote: "…[T]he scatter of measurement results is very high, revealing a substantial lack of inter-laboratory reproducibility that seems to be largely independent of the analysis technique applied. This is a severe problem for the comparability of measurement results generated by different laboratories… This unsatisfactory situation, which presumably would be worse for more complex matrices than (clean) water, hampers the further development of the scientific field and prevents the generation of reliable data on occurrence and distribution of microplastics in all kinds of matrices such as environmental water, air, soil or food."
- Cordula W., et. al. (2020). When Good Intentions Go Bad—False Positive Microplastic Detection Caused by Disposable Gloves. Environmental Science & Technology 2020 54 (19): 12164-12172. https://doi.org/10.1021/acs.est.0c03742
    - Overestimation of microplastic particles can occur using common lab techniques and equipment.

        - Author Quote: "There appeared to be polyethylene (PE) in almost all investigated glove leachates and with all applied methods. Closer investigations revealed that the leachates contained long-chain compounds such as stearates or fatty acids, which were falsely identified as PE by the applied analytical methods… It became clear that stearates and sodium dodecyl sulfates can cause substantial overestimation of PE."
    - Gerhard, M., et. al. (2021). Can the presence of additives result in false positive errors for microplastics in infant feeding bottles? Food Additives & Contaminants: Part A. https://doi.org/10.1080/19440049.2021.1989498
        - The authors demonstrate that commonly used techniques to "count" microplastics result in false positives, leading authors to mistakenly report the release of millions of microplastics.
        - Author Quote: "In recent years, it has been shown that food contact materials can be a potential source of microplastics (MP). Recently, it was reported that more than 16 million polypropylene (PP) particles L−1 may be released from infant feeding bottles (IFBs) made of PP… [Analysis] showed that these differences may be the result of migration and precipitation of additives such as fatty acid esters, often used as release agents in bottle production. These observations, that migrating additives could result in false positive errors for MP, indicate the need for critical consideration when polymers have been subjected to heat."

Key Finding: **The microplastic vector effect (i.e., exposure to plastic-associated chemicals) is unlikely to increase the chemical risk of an organism when exposed to microplastics in nature.**

- Koelmans, A.A., Diepens, N.J., Mohamed Nor, N.H. (2022). Weight of Evidence for the Microplastic Vector Effect in the Context of Chemical Risk Assessment. In: Bank, M.S. (eds) Microplastic in the Environment: Pattern and Process. Environmental Contamination Remediation and Management. Springer, Cham. https://doi.org/10.1007/978-3-030-78627-4_6
    - The authors evaluated 61 publications using study quality criteria and conducted a systematic review.
    - Author quote: "We demonstrate that several studies did not meet the standards for their conclusions on the MP vector effect to stand, whereas others provided overwhelming evidence that the vector effect is unlikely to affect chemical risks under present natural conditions."
- Nor, N., et. al. (2021). Lifetime Accumulation of Microplastic in Children and Adults. Environ. Sci. Technol. 55:8. pp. 5084–5096. https://doi.org/10.1021/acs.est.0c07384
    - Using sophisticated models, the authors demonstrate that microplastic ingestion does not appreciably increase the concentration of chemicals associated with (e.g., additives or adsorbed to the surface) microplastics.
    - Author Quote: "With our integrated and more realistic chemical modeling approach, we demonstrate that at the 50th percentile of the chemical concentrations leached, the change in the tissue concentrations for the four chemicals is negligible. This also confirms our model assumption that chemical leaching from MP would not substantially affect the background

chemical concentration in the gut originating from food…These results illustrate that the proportion of chemical exposure from MP intake to total dietary intake, which has usually been used to evaluate the role of the vector effect, is insufficient to inform us about the eventual chemical change in the body, due to the differences in biodistribution processes for different chemicals." [References Omitted]

Key Finding: **Microplastics do not bioaccumulate and are not biomagnified (e.g., concentrate) in the food web.**

- Gouin T. (2020). Toward an Improved Understanding of the Ingestion and Trophic Transfer of Microplastic Particles: Critical Review and Implications for Future Research. Environ Toxicol Chem. 2020 May;39(6):1119-1137. https://doi.org/10.1002/etc.4718
  - The author reviewed information on the ingestion of plastic debris of varying sizes from >800 species representing approximately 87 000 individual organisms, for which plastic debris and microplastic particles have been observed in ~20%.
  - Author quote: "A general observation is that although strong evidence exists for the biological ingestion of microplastic particles, they do not bioaccumulate and do not appear to be subject to biomagnification as a result of trophic transfer through food webs, with >99% of observations from field-based studies reporting that microplastic particles are located within the gastrointestinal tract."

Appendix E – Microplastic State of the Science

State of the Science for Microplastic Hazard and Risk Assessment
January 2023

I. Introduction

Plastic debris in the environment is of increasing interest to the public, scientists, and policy makers. Microplastic particles are one subset of plastic debris primarily characterized as having a size of less than 5 millimeters (5mm) down to 1 micrometer (1µm); plastic particles smaller than this size are typically termed nanoplastic particles. Together, these particles may also be called NMPs (nano-, micro- plastics). Microplastic particles can either result from the discharge of plastic materials originally manufactured at that size (primary microplastics) or from the degradation of larger plastic debris (secondary microplastics). Primary microplastics, like pre-production plastic pellets (i.e., nurdles), have been the subject of voluntary industry programs to prevent microplastic materials from entering the environment.[63] Other forms of primary microplastic particles were the subject of some of the first regulations regarding microplastics.

One of the first actions voluntarily taken by companies to address concerns about microbeads (primary microplastics) and their presence in water bodies was to phase-out of microbeads in beauty products. This was done in the U.S. in 2014, followed by a similar action in Europe in 2015. A number of regulatory agencies across the globe have also issued bans or restrictions on intentionally added plastic microbeads in rinse-off cosmetics, like face scrubs.[64] These bans were implemented not because there was a risk to human health, but rather out of a concern that current technologies could not remove the microplastics from wastewater and they would end up in the environment. Indeed, a subsequent study by the World Health Organization (WHO) concluded there was no risks to human health from microplastics in drinking water[65] and additional research indicates over 90% of microplastics are already removed from drinking water with today's technology.[66] The WHO also concluded the weight of the scientific evidence provided by current data on adverse effects of microplastics on human health from ingestion or inhalation exposure is low.[67] However, the WHO also concluded the current state of the literature has substantial limitations and encourages researchers to conduct higher

[63] Operation Clean Sweep. https://www.opcleansweep.org/
[64] US Microbead-Free Waters Act of 2015. https://www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs#:~:text=The%20Microbead%2DFree%20Waters%20Act%20of%202015%20prohibits%20the%20manufacturing,)%20drugs%2C%20such%20as%20toothpastes.
[65] Microplastics in drinking-water. Geneva: World Health Organization; 2019. License: CC BY-NC-SA 3.0 IGO.
[66] Iyare PU et al. (2020). Microplastics removal in wastewater treatment plants: a critical review. Environ. Sci.: Water Res. Technol. 6:2664-2675. DOI: 10.1039/D0EW00397B
[67] World Health Organization (WHO). (2022). Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. 30 August 2022. ISBN: 978-92-4-005460-8. https://www.who.int/publications/i/item/9789240054608

quality studies. Microplastics also continue to be a subject of interest to scientists and policy makers due to their widespread distribution.

The science around microplastic particles is rapidly evolving and poses several challenges for scientists, company product stewardship programs, and regulators. The movement of microplastics in the environment is complex. Due in part to the increasing sophistication of analytical chemistry instrumentation, scientists are able to detect extremely low levels of microplastics in environmental media. These advanced instrumentation studies have shown that microplastic particles appear to be ubiquitous in the environment and their presence has been reported in remote areas of the globe,[68] in food,[69] and potentially in human tissues[70] in studies with varying scientific veracity. However, the mere presence of microplastics does not necessarily mean they are hazardous or present an unacceptable risk to the environment or to human health.

National regulatory agencies should implement a science-based system to assess the risk of microplastics. A science- and risk-based system is necessary to better understand the potential risks from microplastics and are needed to address significant risks where they exist. Indeed, the benefit of a risk-based approach is that safe levels of microplastics can be identified. Several critical measures are needed to ensure that regulators have access to high quality data, including:

- Adoption of a standardized definition for microplastics.
- Development and adoption of standardized and validated analytical methods to accurately measure microplastics in various environmental media.
- Development and use of scientifically robust hazard screening and testing methods, including quality assurance and quality control criteria for hazard testing, and reference materials.
- Adoption of a risk assessment framework that addresses the complexities of microplastics, hazards and exposures.

II. Definition of Microplastic

The United Nations Environment Assembly (UNEA) resolution 2/11 defines microplastics as "plastic particles less than 5 millimeters in diameter, including nano-sized particles."[71]
However, there is currently no global regulatory definition of plastic. A single definition should be adopted to allow the drafting and implementation of appropriate national and regional regulations for microplastics. The adoption of a definition of plastics, based on those, for example, developed by the ASTM and ISO organizations, would help prevent ambiguity between scientists and regulators.

[68] Alex R. Aves et al. (2022). The Cryosphere. 16: 2127–2145. https://doi.org/10.5194/tc-16-2127-2022
[69] Kwon JH et al. (2020). Microplastics in Food: A Review on Analytical Methods and Challenges. Int J Environ Res Public Health. 17(18):6710. Doi: 10.3390/ijerph17186710.
[70] Yan Z et al. (2022). Environ. Sci. Technol. 56:1, 414–421. https://doi.org/10.1021/acs.est.1c03924
[71] United Nations Environment Assembly resolution 2/11, "Marine litter and microplastics", para. 1.

The voluntary, consensus-driven technical standards and methods developed by ASTM and ISO are considered to be the gold standard among scientists globally. The definition for microplastic is comprised of two parts: a definition for plastic and one for particle size. ASTM's definition for *plastic*[72] distinguishes plastic particles from other types of polymers, like dyed wool.

In addition to recognizing the absolute size range of microplastics, it is encouraged to adopt a definition that denotes a threshold for reliable detection using high-throughput technologies. Most technologies are incapable of reliably detecting microplastics smaller than 5µm, a limitation acknowledged by the broader scientific community.[73] The denotation of a technically feasible lower size limit would allow regulators to effectively develop and implement regulations.

III. Standardized and Validated Methods and Relevant Test Materials

The development and adoption of standardized analytical methods, test methods, quality assurance and quality control criteria, and reference and test materials would ensure quality data from research projects is comparable and able to be replicated across laboratories and studies. Microplastic reference materials that represent the wide range of sizes, shapes, composition, and state of weathering are a critical step needed to start determining any potential risk of microplastics to health or the environment. For example, most laboratory based microplastic research use polystyrene ('PS') beads because they are easily obtained and can be generated in a range of sizes. However, the PS beads used in these experiments have surface modifications that are not representative of the types of PS used in manufacturing and found in the environment[74] and PS microplastics are a relatively minor component of the total amount of microplastics in the environment.[75] Therefore it is highly questionable whether test results using PS beads can be applied to other microplastic types or shapes.

Quality data helps inform environment and health risk assessments necessary to drive public policy. The lack of standardized and validated analytical methods can also lead to conflicting results, making it difficult to compare results across labs. In addition to draft methods currently in development at the ASTM and ISO, others such as the state of California worked with a number of stakeholders to develop two techniques and a protocol to quantify microplastics in drinking water. The use of these new standardized methods, including Raman spectroscopy[76] infrared

[72] ASTM D883 defines plastic as "a material which contains as an essential ingredient one or more organic polymeric substances of large molecular weight, is solid in its finished state, and at some stage in its manufacture or processing into finished articles can be shaped by flow."
[73] Frias JPGL, Roisin Nash. (2019). Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin.138:145-147. https://doi.org/10.1016/j.marpolbul.2018.11.022.
[74] Erickson, B. (2022). Getting a grip on microplastics' risks. C&EN. Volume 100, Issue 19.
[75] Ryberg, M et al. (2018). Mapping of global plastic value chain and plastic losses to the environment: with a particular focus on marine environment. United Nations Environment Programme. Table 17.
[76] Southern California Coastal Water Research Project Authority. (2021). Standard Operating Procedures for Extraction and Measurement by Raman Spectroscopy of Microplastic Particles in Drinking Water. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/microplastics/mcrplstcs_raman.pdf

spectroscopy,[77] and the use of protocols that incorporate more traditional visualization techniques, will allow environmental laboratories to conduct tests to identify microplastic amount, size and composition.[78] The results of these tests will be comparable with other labs following the same protocols.

IV. Risk Assessment Framework for Microplastics in the Environment

Scientists have only begun to assess the potential health and environmental effects of microplastics. Multiple authoritative organizations assessed the current state of the science; all conclude there are no adverse effects from microplastics to health or the environment with the available evidence.[79,80,81,82,83,84] These reports also state that the current body of evidence is relatively poor and further research is necessary to be able to conduct a more comprehensive risk assessment.

Microplastics are a complex mixture of sizes, shapes, and compositions. When a microplastic particle interacts with the surrounding environment, it may begin to be modified by a process referred to as weathering. Such modifications can be complex, and may impact fate, transport, uptake and responses. Compared to the virgin microplastic particles used to date in many laboratory experiments, these environmentally relevant microplastics may have different physical and chemical (e.g., physicochemical) properties that can influence both hazards and risks. Therefore, it is imperative that virgin and weathered microplastics be appropriately characterized: this will improve extrapolations. A risk assessment framework, such as the one developed by Koelmans et al. (2022), that can assess for these physicochemical variables without making artificial categories is critical for determining what property of a microplastics may pose a risk to health or the environment.[85]

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[77] Southern California Coastal Water Research Project Authority. (2021). Standard Operating Procedures for Extraction and Measurement by Infrared Spectroscopy of Microplastic Particles in Drinking Water. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/microplastics/mcrplstcs_ir.pdf

[78] Science Advice for Policy by European Academies (SAPEA). (2019). A Scientific Perspective on Microplastics in Nature and Society. Berlin: SAPEA. https://doi.org/10.26356/microplastics

[79] World Health Organization (WHO). (2022). Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health. 30 August 2022. ISBN: 978-92-4-005460-8. https://www.who.int/publications/i/item/9789240054608

[80] World Health Organization (WHO). (2019). Microplastics in drinking-water. ISBN: 978-92-4-151619-8. https://www.who.int/publications/i/item/9789241516198

[81] Environment and Climate Change Canada and Health Canada. (2020). ISBN 978-0-660-35897-0. Cat. No.: En14-424/2020E-PDF. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html

[82] U.S. Interagency Marine Debris Coordinating Committee (US IMDCC). (2022). Draft Report on Microfiber Pollution. https://marinedebris.noaa.gov/interagency-marine-debris-coordinating-committee-reports/report-microfiber-pollution.

[83] European Food Safety Authority (2016). EFSA Journal 2016;14(6):4501. DOI: https://doi.org/10.2903/j.efsa.2016.450

[84] U.S. EPA. (2017). Microplastics Expert Workshop Report. Trash Free Waters Dialogue Meeting. Convened June 28-29, 2017. https://www.epa.gov/sites/default/files/2018-03/documents/microplastics_expert_workshop_report_final_12-4-17.pdf

[85] Koelmans, AA et al. (2022). Risk assessment of microplastic particles. Nat Rev Mater. 7:138–152. https://doi.org/10.1038/s41578-021-00411-y

V. Physical Characteristics

Microplastic particles have a number of physical properties that will influence their toxicity potential in the environment or to human health. The size, shape, density, surface characteristics, and quantity of microplastics may all play a role in potential microplastic toxicity. This is especially true for aquatic organisms which have been more extensively studied than other organisms.

The observed effects of microplastics on environmental organisms are primarily driven by physical effects. A weight of evidence analysis was conducted to determine probable effect mechanisms that elicit an adverse effect.[86,87] The analysis identified the four most relevant effect mechanisms, which included: food dilution (inhibited food assimilation or decreased nutritional value); internal physical damage; external physical damage; and with much lower certainty, oxidative stress.[88] These mechanisms should be considered when assessing the potential risks of microplastic particles to environmental organisms.

However, published studies on the ecotoxicological effects of microplastics report conflicting observations, even for the same endpoint in the same species.[89] Furthermore, the quality of ecological effects studies is limited. As such, the weight of evidence for ecological effects is very limited.[90] These limitations could be addressed by developing and using standard approaches for testing the effects of microplastics on environmental organisms, using environmentally relevant testing materials, with appropriate quality assurance and quality control criteria, and developing an understanding of the impact of shape, size and chemical composition on ecotoxicological effects.

There is even less reliable information regarding the potential risks of microplastic exposure to human health. In one recent study, the authors evaluated 74 studies using a microplastic toxicity screening assessment tool they developed to compare *in vivo* and *in vitro* studies against quality assurance and quality control (QA/QC) criteria.[91] The majority of these studies used monodisperse particles that were predominately spheres (~60% or 43/74) and consisted of polystyrene (~46% or 34/74). Particle sizes are observed to be similar for both *in vivo* and *in vitro* effect studies, with the median particle size tested observed to be 2.2 μm and 0.5 μm, respectively. After comparing these

[86] Bucci, K et al. (2020). What is known and unknown about the effects of plastic pollution: a meta- analysis and systematic review. Ecol. Appl. 30: e02044.
[87] de Ruijter VN et al. (2020). Quality criteria for microplastic effect studies in the context of risk assessment: a critical review. Environ. Sci. Technol. 54: 11692–11705.
[88] de Ruijter VN et al. (2020).
[89] Environment and Climate Change Canada and Health Canada. (2020). Science assessment of plastic pollution - Canada.ca. https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/science-assessment-plastic-pollution.html
[90] de Ruijter, VN. (2020).
[91] Gouin, T et al. (2022) Screening and prioritization of nano- and microplastic particle toxicity studies for evaluating human health risks – development and application of a toxicity study assessment tool. Micropl.&Nanopl. 2:2. https://doi.org/10.1186/s43591-021-00023-x

studies to the QA/QC criteria, only 10 ingestion and 2 inhalation studies met the inclusion criteria to be deemed suitable for use in a tier 2 – expert elicitation assessment. Given most of these studies used microplastic particles (i.e., a single type, size, and shape) that are not representative of the heterogenous mixtures found in the environment, it is challenging to extrapolate the experimental results into a measurement for potential human health risks.

VI. Chemical Characteristics

In addition to the potential physical hazards and risks of microplastic particles, some additives in microplastics can impart toxicological effects if exposure is high enough. Additives are often used to impart desirable traits to the plastic article being manufactured. Additives may change the flexibility of the plastic, help resist UV degradation, or assist with heat stabilization. Some additives in plastic products may slowly desorb into the environment as plastic items age and fragment, when equilibrium and kinetics allow.[92] Likewise, microplastics may adsorb pollutants that have higher fugacity in the ambient environment until chemical equilibrium is reached.

The microplastic vector hypothesis states that the desorption of chemicals from microplastics after the particle is ingested leads to increased exposure to these chemicals and poses a risk to that organism(s). Observations of the vector hypothesis are largely experimental design artifacts caused by ignoring simultaneous exposure to the same chemicals through other media and caused by using an unrealistic chemical concentration gradient between plastic and biological receptors.[93, 94] However, the contribution of microplastics-absorbed chemicals to the overall chemical exposure to the environment is typically insignificant, due to other major exposure routes (e.g., water, naturally occurring organic matter, etc.). As a result, the vector effect on pollutants already in the environment is unlikely.[95] In light of the chemical equilibration with the surrounding environment, the microplastic vector effect is not thought to be a major risk component in most habitats.[96]

Many plastic additives have already been assessed for potential risk to human health by multiple regulatory agencies. Plastic materials used in food contact have been extensively studied and assessed by the European Food Safety Authority (EFSA) and the United States Food and Drug Administration (US FDA).[97, 98] The European Chemicals Agency (ECHA) completed a high-level

[92] Hermabessiere, L et al. (2017). Occurrence and effects of plastic additives on marine environments and organisms: a review. Chemosphere. 182: 781–793.
[93] Redondo-Hasselerharm PE et al. (2018). Microplastic effect thresholds for freshwater benthic macroinvertebrates. Environ. Sci. Technol. 52, 2278–2286.
[94] Capolupo M et al. (2020). Chemical composition and ecotoxicity of plastic and car tire rubber leachates to aquatic organisms. Water Res. 169, 115270.
[95] Koelmans AA et al. (2022). Weight of Evidence for the Microplastic Vector Effect in the Context of Chemical Risk Assessment. In: Bank, M.S. (eds) Microplastic in the Environment: Pattern and Process. Environmental Contamination Remediation and Management. Springer, Cham. https://doi.org/10.1007/978-3-030-78627-4_6
[96] Burns, EE & Boxall, ABA. (2018). Microplastics in the aquatic environment: evidence for or against adverse impacts and major knowledge gaps. Environ. Toxicol. Chem. 37, 2776–2796.
[97] EFSA. (2022). Food contact material applications: overview and procedure. https://www.efsa.europa.eu/en/applications/foodcontactmaterials
[98] FDA. (2022). Inventory of Food Contact Substances Listed in 21 CFR. https://www.fda.gov/food/packaging-food-contact-substances-fcs/inventory-food-contact-substances-listed-21-cfr

assessment of over 400 additives in plastics used in high volumes in the EU in 2018.[99] Under the EU's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) program, any chemical manufactured or imported into the EU must be assessed for potential risk to human health. Given the small amount of microplastic materials humans are exposed to and the corresponding low concentrations of additives, it is unlikely that there is a risk to human health posed by the chemical characteristics of microplastics.

VII. Risk Assessment Framework

In the peer reviewed publication *Toward the Development and Application of an Environmental Risk Assessment Framework for Microplastic*, [100] Gouin et al. proposed a conceptual environmental risk assessment framework for microplastic particles, discussed challenges with implementation, and then identified and prioritized major research needs to apply risk-based tools for microplastics. Subsequently, Koelmans et al. (2022) proposed a risk assessment framework that accounts for the complexities of microplastics described above and can be applied to questions regarding human health and ecotoxicity.[101] The new framework incorporates three new elements:

- Use of probability density functions to account for an environmentally realistic continuum of microplastic particle characteristics.
- Use of QA/QC screening methods to evaluate whether exposure and effect data are fit for purpose.
- Use of a calculation framework to assess exposure to plastic-associated chemicals through all relevant effect pathways.

The proposed framework uses a stepwise process to assess each potential adverse effect from microplastic exposure, summarized by the following steps:

1. Problem formulation: identify all factors critical to a specific risk assessment and consider the purpose of the assessment, scope and depth of the necessary analysis, analytical approach, available resources and outcomes, and overall risk management goals.
2. Hazard Identification: examine whether a stressor has the potential to cause harm to humans and / or ecological systems, and if so, under what circumstances, including consideration of intensity and duration of exposures.
3. Exposure assessment: examine what is known about the frequency, timing, duration and levels of contact of environmental microplastics with the receptor.[102]
4. Dose metric for the mechanism of effect or mode of action: evaluate the plausible mechanisms of effect or modes of action(s) (e.g., food dilution, internal damage, etc.) for any adverse effects observed. Once the plausible mechanisms causing an effect are

[99] ECHA. (2018). Plastics Additive Initiative. https://echa.europa.eu/plastic-additives-initiative
[100] Gouin et al. (2019). Toward the Development and Application of an Environmental Risk Assessment Framework for Microplastic. Environmental Toxicology and Chemistry, 2019;38:2087–2100. https://setac.onlinelibrary.wiley.com/doi/epdf/10.1002/etc.4529.
[101] Koelmans, AA et al. (2022). Risk assessment of microplastic particles. Nat Rev Mater. 7:138–152. https://doi.org/10.1038/s41578-021-00411-y
[102] An ecological receptor is a specific ecological community, population, or individual organism.

identified, a relevant dose metric should be selected for that effect. For example, the volume of inert microplastic particles in the digestive system may be a relevant dose metric for a food dilution mechanism in some aquatic species. In cases of high levels of exposure, environmentally realistic mixtures of particles may cause effects through multiple mechanisms, so there may be a need to develop multiple relevant dose metrics.

5. Risk Characterization: perform separately for each effect mechanism. Risk characterization includes two major components: risk estimation; and risk description.
    a. Risk estimation integrates knowledge of hazards with measured or modeled levels of exposure. The estimated or measured exposure level for each receptor (plant or animal population, community, or ecosystem) of concern can be compared to point of departure hazard levels[103] applicable to each receptor to estimate the likelihood of expected adverse effects, if any.
    b. Risk description provides information important for interpreting risk results. EPA's Risk Characterization Guidelines state, "the goal of risk characterization is to clearly communicate the key findings and their strengths and limitations so its use in decision making can be put into context with the other information critical to evaluating options for rules, regulations and negotiated agreements (e.g., economics, social values, public perception, policies, etc.). [104] This includes: whether harmful effects are expected on the plants and animals of concern; relevant qualitative comparisons; and how uncertainties (data gaps and natural variation) might affect the assessment.

Once the risk characterization is completed for each effect mechanism, the risk assessor can decide what risk value is most appropriate based on the problem formulation.

VIII. Conclusion

Microplastics in the environment are of increasing interest to the public, scientists and policy makers. The science evaluating the presence and potential hazards and risks of microplastics is rapidly evolving. Through the use of new technologies, standardized methods and materials, more rigorous scientific research and new risk assessment frameworks, scientists, company product stewardship programs, and regulators will have the tools and knowledge necessary to actualize risk-based decision making to enhance human health environmental protection.

[103] EPA's Definition of Point of Departure: The dose-response point that marks the beginning of a low-dose extrapolation. This point can be the lower bound on dose for an estimated incidence or a change in response level from a dose-response model (BMD), or a NOAEL or LOAEL for an observed incidence, or change in level of response.
https://sor.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=IRIS%20Glossary#formTop.

[104] https://www.epa.gov/sites/default/files/2015-10/documents/osp_risk_characterization_handbook_2000.pdf