Topical Discussion:

Microplastics – Nanoplastics, Life Cycle Analysis and Environmental Risk Assessment

Wednesday, November 15,2022
Pittsburgh, Pennsylvania, US

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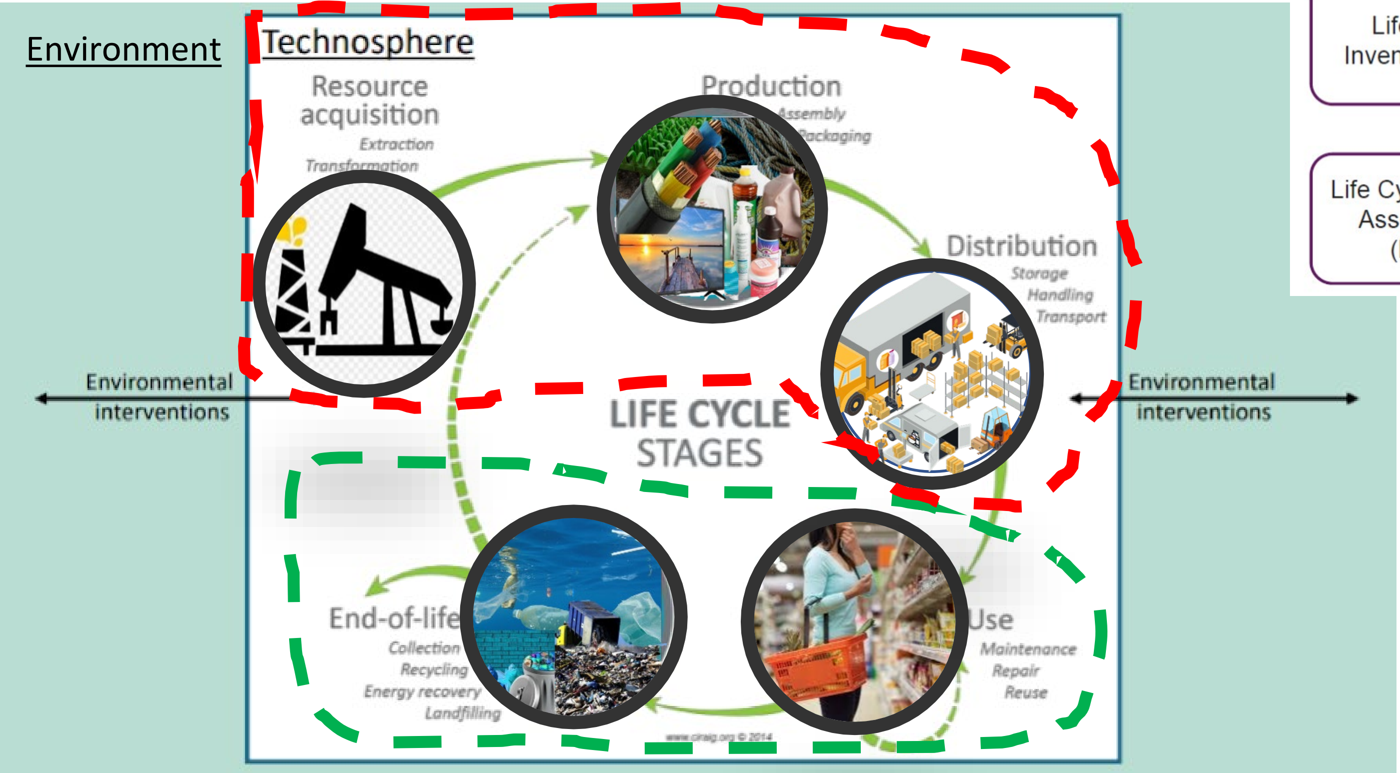
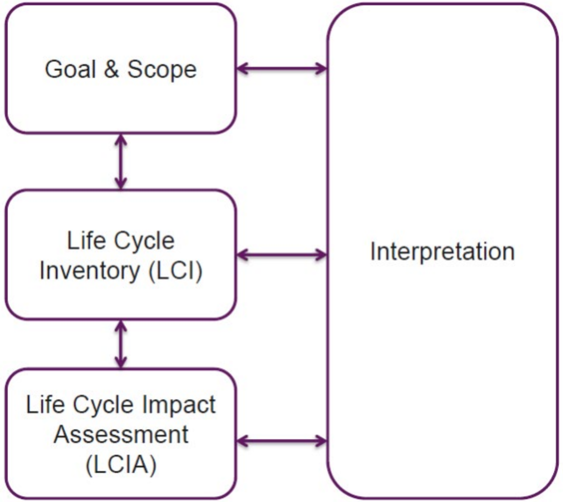
Bridging Innovation and Sustainability

Life Cycle Assessment (LCA)



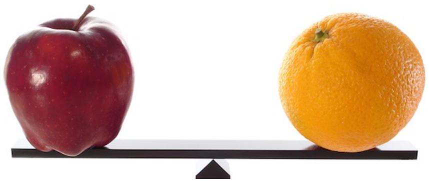
Cradle to grave; Cradle to gate; Gate to cradle

Modified from ciraig.org



ISO 14040

Life Cycle Inventory (LCI) and Life Cycle Impacts Assessment (LCIA)

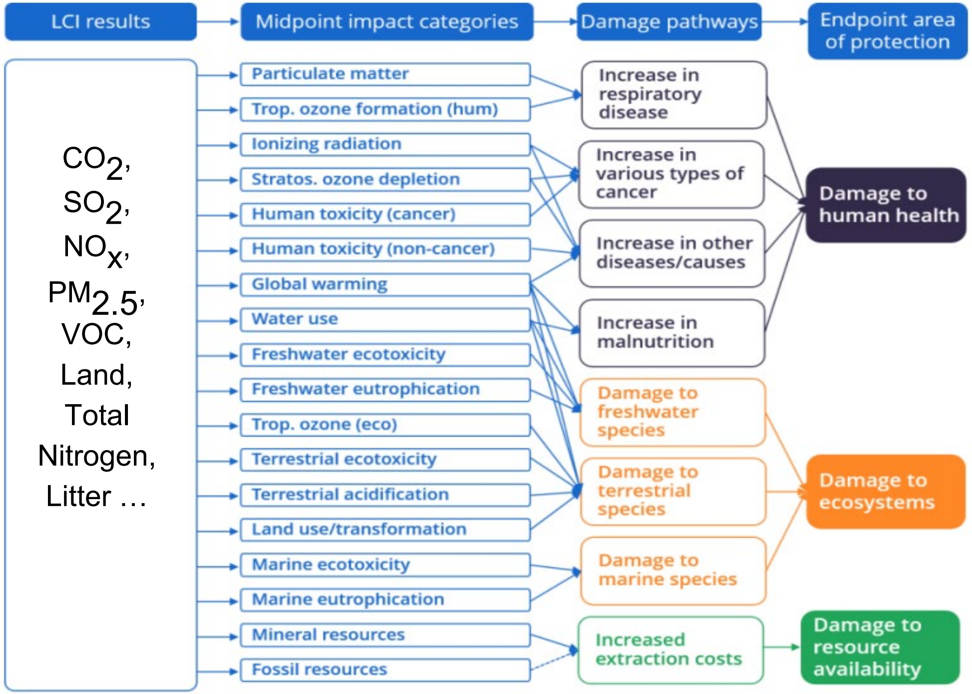


Comparing apples with oranges

Functional Unit

vs.

Chris Koffler. Thinkstep



Modified form ReCiPe

LCIA Characterization Factors (Now Moving from Beer to Microplastic)

Indicator of Damage = Characterization Factor × Environmental Intervention

Plastic Leaked into Environment

Fate Factor (FF) × Exposure Factor(XF) × Effect Factor (EF) = Characterization Factor (CF)

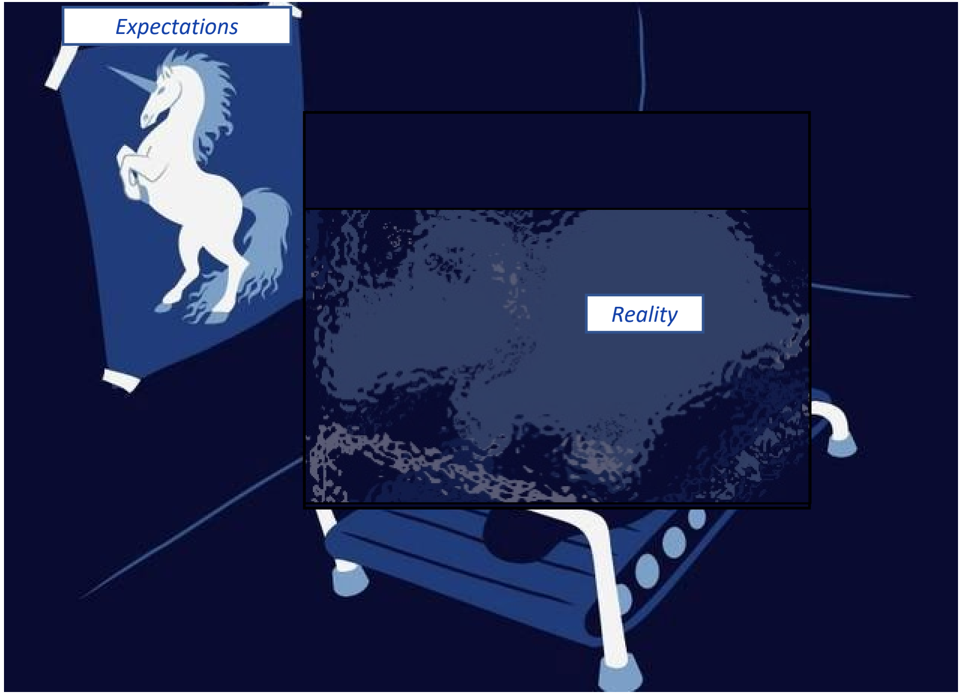
Distribution/ Longevity/Degradation

Interaction with Sensitive Receptors

Consequence s

LCA is not Perfect

Here it is, the reality of LCA!



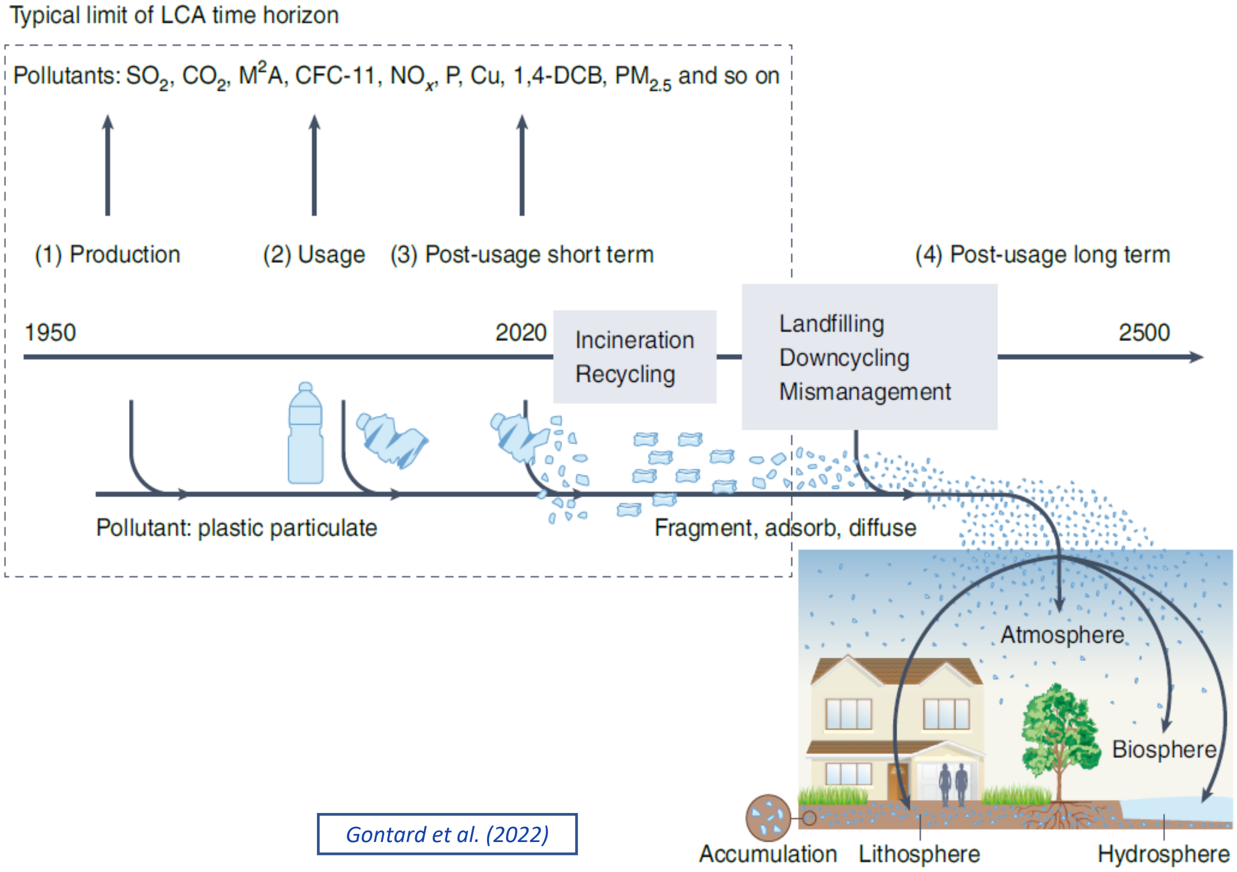
Chris Koffler. Thinkstep

Can do	Can't do
Assess the **potential environmental impacts** of product systems (limited by availability of data and methodology)	Assess all relevant environmental issues Assess any environmental issue
Identify **potential hot-spots and areas of improvement**	Predict actual or precise environmental impacts
Avoid burden shifting and identify unintended consequences	Predict the exceeding of thresholds, safety margins, or risks
Explore scenarios of future changes	Predict market responses to changes in production and consumption

PET Bottle LCA Case Studies Meta Analysis

Plastics & LCA

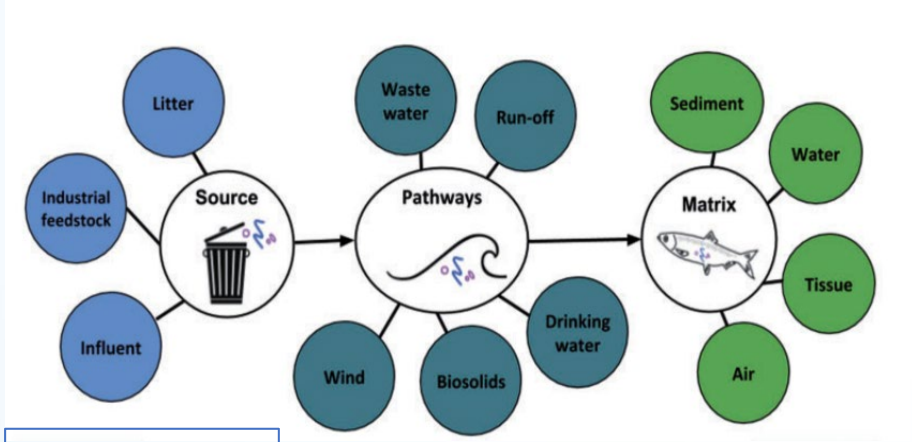
- Limitations with end of life impacts assessment options
- Limited LCI databases
- Time Horizon
- Macro, micro and nano plastic impacts



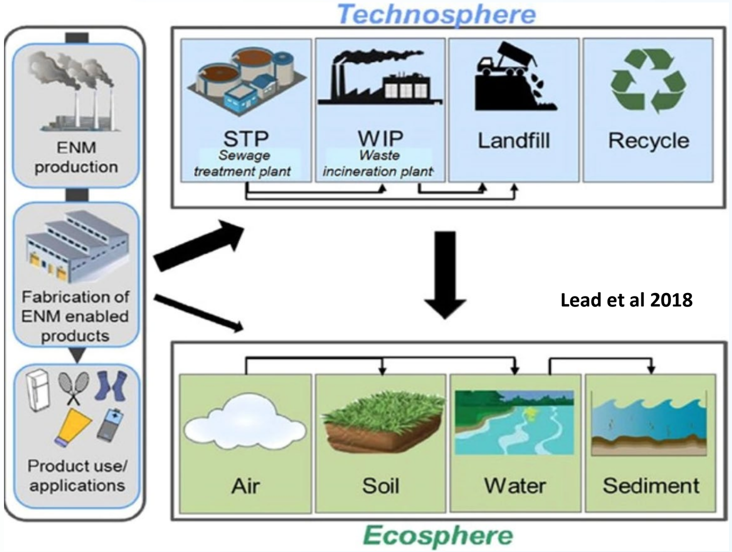
Gontard et al. (2022)

Microplastics and Nanoplastics Research

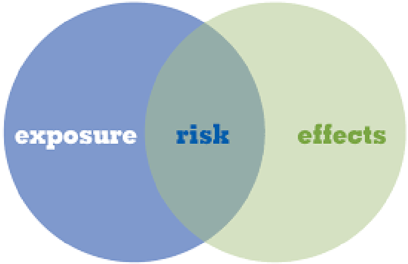
The fields of microplastics and nanoparticle research share challenges along several common threads. Risk assessment from both needs to be integrated with LCA approaches.



Brander et al 2020



Risk Assessment

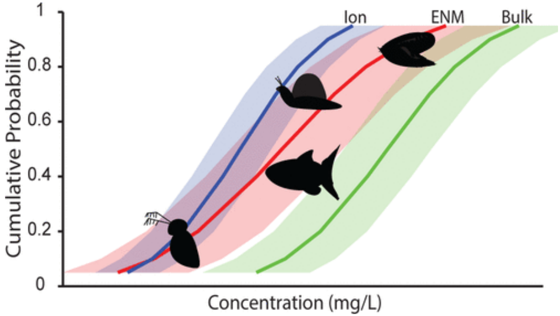


New or shared challenges faced by micro and nanoplastics

- Can we address secondary (degradation, breakdown, fragmentation) products?
- Need for dose-response data for environmentally relevant concentrations or exposure scenarios. But what is environmentally relevant, do we really know?

Lessons learned:

- Need better understanding of mechanisms of action to accurately assess risk
- Better knowledge of smaller size fractions in the environment and their concentrations will improve exposure assessment.



Garner et al 2015, ES&T

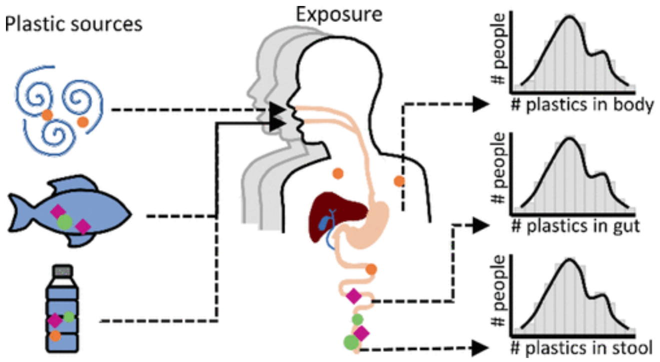
Regulatory concerns

Shared challenges faced by micro and nanoplastics

- Current frameworks e.g. LCA don't microplastic persistence, fragmentation, how to avoid regrettable substitutions?
- Human and environmental exposure widely documented, what next?

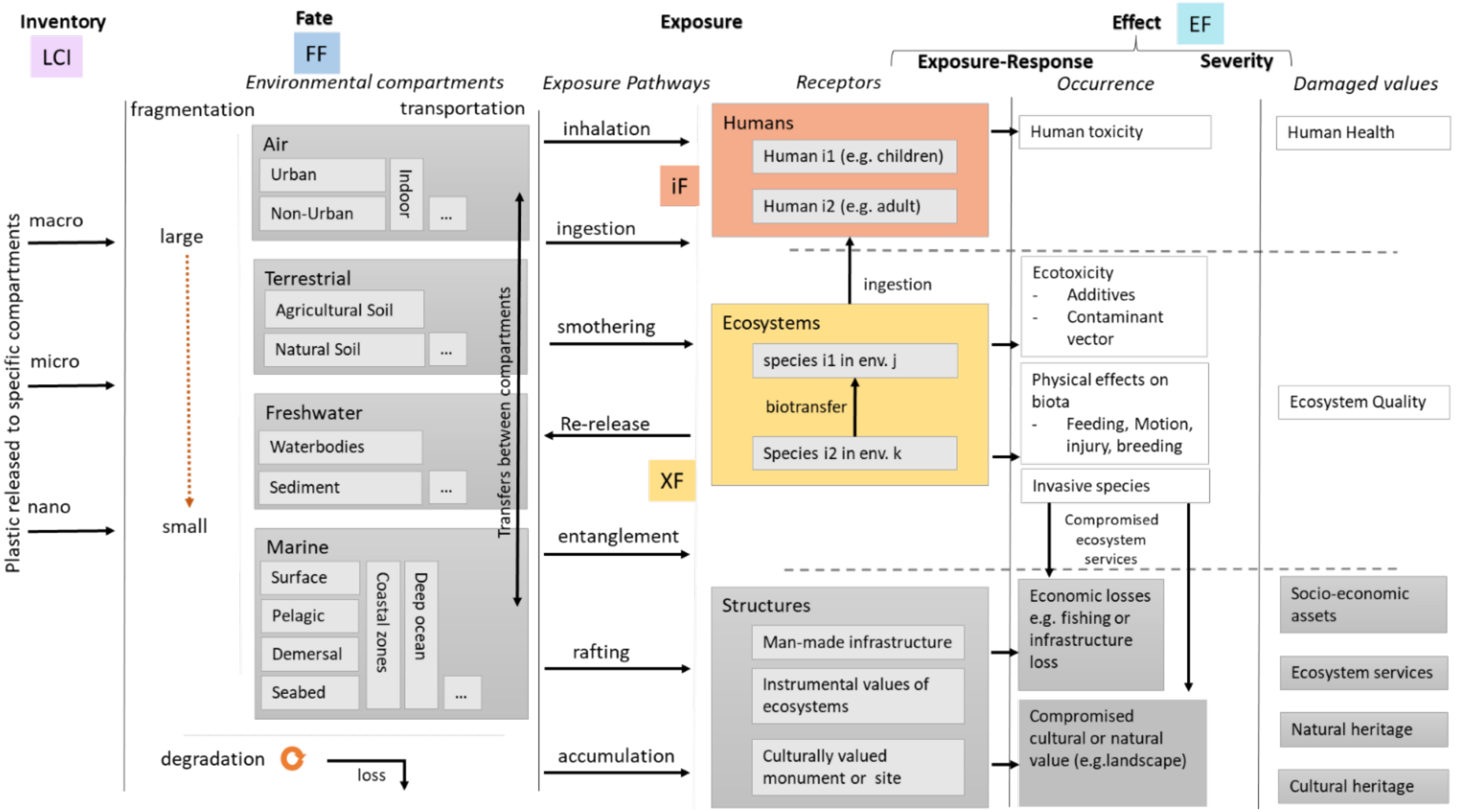
Proposed approaches

- Cap on virgin plastic production recommended by scientists, as well as move to circular economy.
- Is this realistic? How do we use available data on risk combined with LCA to assess different scenarios?



Nor et al. 2021

Integration of plastic litter impacts into LCA



Modified from Woods et al, 2021

The data we need in LCA and ways to get it

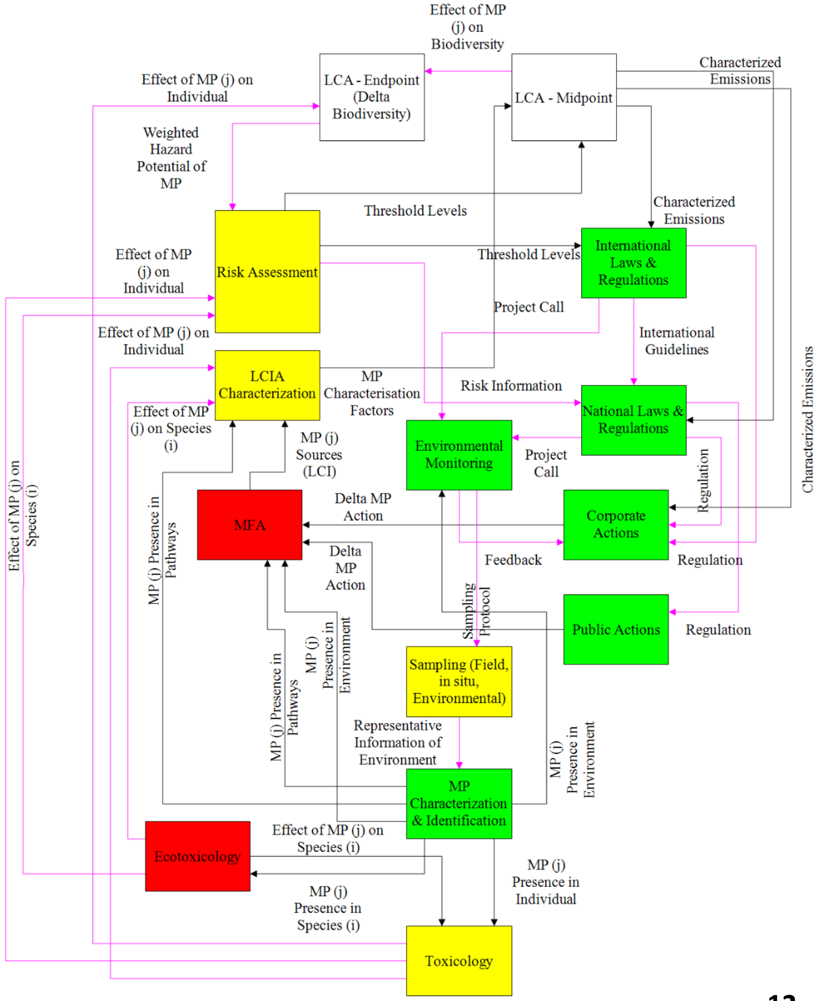
- LCIA use environmental sampling and laboratory toxicity data to calculate characterization factors (CFs) for impacts arising from emissions to the environment.
- This exposure and toxicity data to aid understanding and provision of data that is as useful as it can be across these disciplines.
- LCIA relies on results from sampling and laboratory studies in order to derive fate and effect factors.
- It is vital that the data LCIA experts mine from literature is of relevant detail and quality for the derivation of CFs.

Laboratory	Inventory (LCI)	Fate (FF)	Exposure (iF)	Exposure (XF)	Effect (EF)
Metadata					
1) State of plastic particles		✓	✓	✓	✓
2) Polymer type(s)		✓	✓	✓	✓
3) Additives in polymers		✓	✓	✓	✓
4) Ecotoxicological Information			✓	✓	✓
5) MNP lifetime information		✓			
6) Additional Information: a) NOEC b) LOEC			✓	✓	✓
Data Types					
1) Qualitative:					
a) mass-based dose metric			✓	✓	✓
b) polymeric composition		✓	✓	✓	✓
c) fragmentation		✓	✓	✓	✓
d) morphology		✓	✓	✓	✓
e) colour of particles				✓	✓
f) BIOTA: presence or absence on significant effects			✓	✓	✓
g) BIOTA: direction of effect (induction vs. inhibition)			✓	✓	✓
h) biofouling		✓	✓	✓	✓
i) additives in particles		✓	✓	✓	✓
2) Quantitative:					
a) total mass of particles		✓	✓	✓	✓
b) dimensions		✓	✓	✓	✓
c) mass of particles/size range		✓	✓	✓	✓
d) aspect ratio		✓	✓	✓	✓
e) mass of CO_2, CH_4 & O_2 emissions/mass of plastic tested	✓	✓			
f) mass loss/mass of plastic tested	✓	✓			
g) mass of individual particles		✓	✓	✓	✓
h) % monomers within polymers		✓	✓	✓	✓
i) degradation rate		✓		✓	✓

Askham et al. 2023

LCA’s (synergistic) interaction with Risk Assessment, Ecotoxicology, Toxicology, Material Flow Analysis, etc., etc., etc…

- LCA inherently relies on data from other fields of study, both directly and indirectly.
- LCIA (and the characterisation of MNPs) inherently relies on metadata from a variety of fields, but particularly:
    - Toxicology
    - Ecotoxicology
    - Materials Science
    - Marine Pollution (environmental sampling/monitoring)
    - Etc. (don’t forget about hydrology, sedimentology, oceanography)



Pauna and Askham, 2022

Way Forward

- Which fields of study is do you think LCA is reliant on, how could this change?
- How can an interdisciplinary outlook benefit micro and nanoplastic research in the project planning stages
- Is the quality, quantity, and geographic diversity of data available on MNP hazard and risk to the environment and human health sufficient to improve LCA models globally?
- How do we best validate LCA models, given this is an excellent opportunity for synergistic improvements across relevant disciplines?