FSLCI Forum for Sustainability through Life Cycle Innovation

in collaboration with

Fraunhofer UMSICHT

université de BORDEAUX

Workshop Report

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Linking the Life Cycle Inventory and Impact Assessment of Marine Litter and Plastic Emissions

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Virtual Workshop

Linking the Life Cycle Inventory and Impact Assessment of Marine Litter and Plastic Emissions

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Introduction

The Forum for Sustainability through Life Cycle Innovation (FSLCI), the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT and the Université de Bordeaux organized a joint workshop on the subject of "Linking the Life Cycle Inventory and Impact Assessment of Marine Litter and Plastic Emissions" on 18th March 2020. The workshop was initially meant to take place in Bordeaux, France, but then was hosted as a virtual workshop due to the global spread of Covid-19 and the inability to travel.

The objective of the workshop was to bring together a number of interested stakeholders to discuss and identify key issues that still need to be addressed with regards to the inclusion of marine litter into Life Cycle Assessment (LCA), especially with regards to the link from inventory to impact assessment.

In 2017, the Medellin Declaration on Marine Litter in Life Cycle Assessment and Management (Sonnemann & Valdivia, 2017)[1] highlighted that currently life cycle assessment (LCA), as one of the most widely used sustainability assessment tools for greening the economy (UNEP, 2012)[2], is not adequately addressing the impacts on the environment generated due to marine debris, such as plastics and microplastics. Ever since the launch of the Medellin Declaration, several projects have been launched to work on various aspects of integrating marine litter and plastic emissions into life cycle assessment. Projects are, however, currently mostly focused on either the inventory or the impact assessment side.

The workshop was thus meant to focus on the link between life cycle inventory and life cycle impact assessment of marine litter and plastic emissions. During the first part of the workshop, participants focused on the question of how to integrate marine litter and plastic

[1] Sonnemann G and Valdivia S (2017) Medellin Declaration on Marine Litter in Life Cycle Assessment and Management, Int J Life Cycle Assess (2017) 22:1637–1639

[2] UNEP (2012) Greening the Economy Through Life Cycle Thinking, Paris, http://www.unep.fr/shared/publications/pdf/DTIx1536xPA-GreeningEconomythroughLifeCycleThinking.pdf

emissions' life cycle inventory flows into LCA software, while the second part of the workshop focused on discussion around the modeling of a fate factor.

During the workshop, which brought together around 30 stakeholders from a range of different disciplines, a number of participants presented ongoing projects and activities which address marine litter from various perspectives. Following these presentations, interactive sessions were organized where participants split into smaller groups to discuss key issues around marine litter. On the following pages, this workshop report summarizes outcomes of those group discussions along the questions that were developed by the workshop organizers to guide the discussions. The workshop report does not seek to provide a scientific report on the status of marine litter in LCA but summarizes the perspectives and insights presented by the participants of the workshop.

Inventory

Are there differences between micro- and macroplastics for life cycle inventory?

Participants agreed that there is a clear difference between impacts caused by micro- and macroplastic. Hence, a differentiation on inventory level is needed. From an economic perspective it was noted that, while macroplastic has a potential value for recollection, this is not the case for microplastic.

It was also noted that different sources would be responsible for emitting macro- or microplastics into the environment, which would need to be reflected in inventory data. It was suggested to focus on sources with high emission rates, which were identified in studies from Jambeck et al. (2015)[3], the Plastic Leak project (2020) [4], and others.

[3] Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady, Narayan AR, Lavender Law K (2015) Plastic Waste inputs from land into the ocean, Science, 347(6223): 768-771
[4] Quantis, 2020, The Plastic Leak Project, https://quantis-intl.com/strategy/collaborative-initiatives/plastic-leak-project/

Participants also highlighted a need to better understand and address emissions. In this context, microplastic emissions from the textile (fibers) or the chemical sector (pellets) were highlighted along with a need to also better assess emissions from waste and wastewater treatment plants for both macro- and microplastic.

Generally, it was agreed that the differences between micro and macroplastic with regards to inventory need to be taken into consideration.

Which attributes need to be considered?

With regards to possible attributes which need to be considered from an inventory perspective, participants noted the following:

- Size of the plastic
- Shape of the plastic and risk of entanglement
- Polymer type (including specification of rigid vs. foam)
- Degree and types of additives
- Degree and type of fillers and reinforcement substances

It was agreed that including various attributes within the inventory would be crucial to enable proper impact assessment afterward. In this context, the risk of entanglement was, for example, highlighted for marine life. It was also noted that rigid plastic would behave, for example, differently than foam, and thus the density of the emitted plastic object might need to be addressed as well. Participants also mentioned that the degree and types of additives would be relevant with regards to toxicity.

In order to apply a practical approach, the use of an equivalence factor was suggested. Workshop participants, however, also cautioned that even though LCIA requirements should inform life cycle inventory data needs, a pre-judgment on data needs and data availability would be necessary with a prioritization based on realistic availability of data. In this context, it was also noted that a high amount of data would not only require a significant amount of computational software capacity but might also cause software users to be overburdened with the number of environmental flows.

Finally, it was outlined that, for example, the Plastic Leak project (2020) would currently differentiate between three sizes of macroplastics (small, medium, and large) and noted that for microplastic, only one category was considered. To this end, a more detailed differentiation might become relevant when new knowledge about possible impacts of different sizes of microplastic will become known.

Which level of detail do we need for differentiating different inventory flows? Which inventory flows can be grouped?

Participants noted the need for a good level of detail of inventory data especially given the requirements of the impact assessment, yet agreed that it would be better to start with a rather low level of detail and then fill data gaps in the future, in order to enable the modeling of inventory flows already now.

Participants agreed that initially, decision-makers need to be the target audience, which would require a lower degree of detail than the scientific community. To this end, it was noted that climate scientists also initially used simplified data but managed to create a global discussion and movement on the subject. Whereas the biodiversity community was still discussing more detailed questions, yet failed to generate an equal momentum.

Do we need regionalized inventory flows/processes? If yes, at which level of detail?

Concerning the need for regionalized inventory flow and process data and the corresponding level of detail, participants noted that challenges are mainly related to consumption and end-of-life stages. Tire abrasion was referenced as an example. Databases, as well as LCA software, would, however, currently focus predominantly on production processes and thus were mostly not suited in a way that would allow for the regionalization of data. Still, participants strongly argued in favor of addressing data regionalization in the future, given the significant regional differences. In this context, factors such as the number of rivers, access to the sea, etc. would be of high importance for fate modeling as well as factors such as other environmental conditions such as average regional temperatures. Furthermore, it was highlighted that a better understanding of

waste and wastewater treatment and infrastructure would be important, which is currently not adequately reflected in LCA models.

How to calculate the initial release rate into an environmental compartment?

For the life cycle inventory, exclusively the initial release rates of plastics into environmental compartments are needed. However, different methods to calculate leakage rates exist.

In the case of macroplastic, leakage rates exist that are based on beach accounting. Workshop participants agreed that these numbers might be a pragmatic starting point, although they do not cover all relevant macroplastic emissions. In addition, these beach counts do not reflect the initial release rates into environmental compartments since they already include the fate of the items found at the beach. Apart from beach accountings Chitaka & von Blottnitz (2019)[5] and other authors such as Jambeck et al. (2015)[6] tried to estimate the leakage into the sea based on regional conditions (access to the sea, etc.) and the local waste generation and management. However, these are only very vague estimations and they do not reflect the initial release rates into environmental compartments. The Plastic Leak project (2020) has proposed to calculate the loss rate (initial release) of macroplastics based on direct emissions, littering, and mismanaged waste, which were derived from country-specific World Bank data for waste management. In a second step, considering the value of the plastic emission (small, medium, high value) and the size (small, medium, large), they estimate recollection rates and the initial release rates into the compartments ocean and freshwater as well as terrestrial environment. Although the data goes along with high uncertainty, they provide initial release rates into an environmental compartment. Fraunhofer UMSICHT has proposed to estimate the initial release rates of macroplastics into environmental compartments based on estimations made by street cleaning companies to answer the question how many waste remains in nature after cleaning. However, there exist several approaches addressing loss rates, initial

[5] Chitaka, TY and von Blottnitz, H (2019) Accumulation and characteristics of plastic debris along five beaches in Cape Town. Mar. Pollut. Bull. 138, 451–457

[6] Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, Andrady, Narayan AR, Lavender Law K (2015) Plastic Waste inputs from land into the ocean, Science, 347(6223): 768-771

release rates, and leakage rates. For the life cycle inventory exclusively, numbers referring to the initial release rates, which are environmental compartment-specific, are thus still required.

Microplastics need to be treated differently. Microplastics can be either directly released during their planned use (intended microplastics, e.g. exfoliating body scrub) or be released during the use stage by abrasion or weathering (e.g. tire wear). Microplastic emissions might also occur at the end-of-life stage by for instance shredding processes. In addition, microplastic might occur from the degradation of macroplastics (secondary microplastic), which is not considered within life cycle inventories because it is a fate issue. Loss rates can be estimated, for example, by abrasion or weathering experiments in combination with consumption patterns. In order to estimate the initial release into the environment, different pathways such as the wastewater, air, or direct pathway (direct plastic emissions into the sea, e.g., by fishers) have to be taken into account in combination with retention factors, e.g., realized by wastewater treatment. This approach taken by the Plastic Leak project (2020) was referenced as a good starting point for further calculations.

Impact Assessment

What are the differences between micro- and macroplastics?

With regards to differences between micro- and macroplastics for impact modeling, participants agreed that there are significant differences that include, for example, but are not limited to, the following factors that need to be considered:

Microplastics:

- behavior in sub-compartments
- aggregation of material
- interacting with marine life
- movement due to ocean currents and wind
- properties and behavior related to environmental exposure

Macroplastics:

- animals on land and in water and their exposure
    - role in transporting to other compartments
    - Impossible to track animal behavior
- marine debris
    - fishing gear which is designed to entangle
    - other wastes that attract and entangle animals or cause blockages
- function factor

Which steps should be considered by the fate modeling?

Concerning fate modeling, it was noted that even if the same flows were to be existent, fate modeling might still be different due to regional differences. Hence, the importance of regionalized life cycle inventory flows was again emphasized to enable fate modeling factors for specific regions. Participants cautioned that such a requirement might then also lead to many inventory flows; thus, prioritization would be necessary. To this end, it was questioned which fate modeling parameters would be needed to make the link with the elementary inventory flows into the different environmental compartments. With regards to possible parameters that allow the characterization of plastics, the work of Kooi & Koelmans (2019)[7] was referenced, who have identified continuous probability distributions for size, shape, and density. In this context, it was also questioned how to incorporate best food web/interception of animals affecting fate into the discussion.

Generally, it was agreed that there is a considerable data gap when it comes to fate modeling and that empirical bottom-up data is needed. In this context, the work of the MarILCA project[8] was referenced, which is coordinating several research projects around the world that have been set up to contribute to the development of a global impact modeling framework of marine litter in LCA.

[7] Kooi M and Koelmans AA (2019) Simplifying microplastic via continuous probability distributions for size, shape, and density. Environmental Science & Technology Letters 6 (9) 551-557
[8] MarILCA project, https://marilca.org

Participants also agreed on the need to work together with other disciplines during method development. In this context, it was noted that collaboration with the risk assessment and environmental toxicology community would be important. It was also noted that a stronger focus on research of macroplastics would be important, given that much work was currently focusing on microplastics.

How can we address redistribution between compartments?

Participants also agreed that inventory data modeling should stop at the point of assessing emission routes into the different compartments, whereas fate modeling would then also need to focus on all environmental compartments, including redistribution. In this context, it was noted that the ability of fate modeling would be depended on available inventory data and acknowledged that the quality and quantity of available data would currently be rather limited. It was thus suggested to move forward with a pragmatic approach starting with data that was available and then refine it over time.

In a first step, the most relevant compartments to be considered need to be defined (sea, river, soil, etc.) and linked to inventory data. Redistribution would strongly depend on regional conditions and thus differ to a high degree, pointing again to the need for regionalized data.

Participants also highlighted the lack of fate data, which would be needed to better address the issue of redistribution between environmental compartments. Regionalized inventory data and fate data will need to be gathered by measurements and extrapolations. To this end, participants also pointed to the need for a better understanding of residence time within compartments, which would be crucial for fate modeling. However, given that lack of overall data, participants noted that the issue of residency time might need to be addressed at a later point in time of method development and noted that data might be able to be developed by working with markers. In addition, the general issue that accidents and catastrophes are not and will not be reflected within LCA methodology, in the way it is currently defined, was highlighted since it could play a role with regards to redistribution.

Participants thus outlined the relevance of defining transfer factors, yet highlighted the challenge of finding reliable factors, given the local dependencies. The need for probabilistic models for both littering behavior and transfer factors was discussed and whether it would be better to have factors or min/max scenarios. It was noted that min/max per compartment might be more accessible than one factor, including probabilities, given the high uncertainty caused by the lack of data. If data on the materials' ability to fly, its weight, or dimensions were available, a transfer factor could be modeled.

It was thus suggested to launch a new project which measures the redistribution between compartments. Such measured data could then be extrapolated to develop transfer factors, which would then need to be verified by additional measurements in various regions. In this context, markers could be used to determine the residence time in different compartments. However, the residence time is also linked to the topic of degradation which is addressed by the following question.

How can we consider degradation?

Participants discussed the importance of identifying processes that cause degradation and then develop specific degradation rates. Beyond the issue of degradation, participants also discussed the issue of retaining emissions in specific compartments, which could also affect their fate. To calculate retention rates as part of inventory modeling, participants suggested to take into account:

- waste management models
- wastewater models
- technologies
- use scenarios

Modelling degradation as part of fate modeling was considered a bit more challenging given the lack of data. In this context the role of additives was highlighted again given their effect on the stability of plastics and thus the speed of degradation. In addition to additives, the exposure to chemicals and other degradation factors, including physical factors such as temperature would need to be considered. In this context, it was noted that the current

data basis is quite broad and that standardization of methodologies is needed, which helps to measure degradation in the environment (sea, river, soil).

Participants agreed that there is a lack of methodology in measuring degradation in environmental conditions and that standardization of measurements is needed so that data on degradation can be compared and used for modeling purposes. In this context, it was noted that such a methodology is currently just available for bio-plastic degradation and thus would need to be also developed for non-bio-based plastic emissions.

How to consider toxic metabolites?

Participants highlighted that plastics represent to a large degree polymers with their additives and that the latter would always need to be considered when assessing degradation and weight loss to ensure that the math balance is closed. In this context, the importance of data availability and sample quality was again highlighted. It was also noted that additives should be addressed, e.g., for their toxicity.

Assessing the release of additives was considered to be easier than those of metabolites, where actual knowledge and data is missing. Hence, one would need to actually measure the release of metabolites and then apply extrapolation. In this context, it was also noted that the absorption of toxic substances would also represent a challenge, given its unclear impact.

Key messages

In summary, workshop participants highlighted several key messages that should be addressed by the various stakeholders needed to create an impact and address the issue of marine litter within LCA. Participants agreed that:

- there is a need to differentiate between micro- and macroplastics also on inventory level given the differences in impact modeling
- end-of-life modeling needs to be enhanced and a better understanding of solid waste and wastewater treatment and infrastructure is needed

- regionalized inventory data is of utmost importance in order to develop accurate assessments
- data on initial release and leakage rates need to be linked, or translated, into ISO-conform life cycle inventory data for different environmental compartments
- the life cycle community needs to agree on where to draw the line between inventory and impact assessment modeling with regards to the fate
- degradation rates should be modeled as part of impact assessment (as a part of the fate factor)
- impacts can be caused by emissions of plastic litter into any environmental compartment
- one big challenge is to define transfer factors between different compartments in LCIA as well as emissions' (speed of) degradability
- a standardized approach to address degradability is needed for all plastics, which is specified for different environmental compartments and, e.g., typical soils and not just industrial composting
- the degradation rate should be defined based on a surface degradation rate which is independent of the shape of the investigated product

In general, participants highlighted that there is a huge urgency to act. Decision-makers in industry and governments are challenging the global scientific community to provide guidance. This guidance is needed urgently, yet method development takes time. Still, the various presentations during the workshop showed that the global life cycle community is actively working on addressing the subject, yet scientifically sound method development needs time due to the complexity and scale of the issue and the current lack of data on the losses of plastics into the environment and on their fate, exposure and toxicity.