FSLCI Forum for Sustainability through Life Cycle Innovation

in collaboration with

RICV Red Iberoamericana de Ciclo de Vida

Workshop Report

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Connecting Expert Communities to Address Marine Litter in Life Cycle Assessment

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Connecting Expert Communities to Address Marine Litter in Life Cycle Assessment

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Introduction

The Forum for Sustainability through Life Cycle Innovation (FSLCI) organized a workshop on the subject of “Connecting Expert Communities to Address Marine Litter in Life Cycle Assessment” in Brussels, Belgium, held 22-23.05.2018.

The invitation-only workshop was organized by FSLCI – the global life cycle community organization - in collaboration with the Red Iberoamericana de Ciclo de Vida (RICV) and was kindly supported by a number of industry stakeholders including Plastics Europe and Braskem.

The workshop in Brussels was organized as a follow-up to the Medellin Declaration on Marine Litter in Life Cycle Assessment and Management. The declaration can be accessed and signed at https://fslci.org/medellindeclaration/ and was launched by FSLCI and RICV last year as a call for action in terms of addressing marine litter in Life Cycle Thinking. The workshop was held to bring together key experts in order to lay the groundwork for the establishment of a community of experts interested in addressing issues associated with marine litter in life cycle assessment (LCA) and management.

Marine litter is a global pollution concern crossing country borders. A study by Jambeck et al. (2015) estimated that 4.8 to 12.7 million tonnes of plastic waste entered the oceans in 2010. They identified the main flows to be linked to insufficient or inefficient waste management planning, littering and consumption behavior. Workshop participants agreed that while estimated numbers vary, it is clear that too much waste enters our environments, including rivers, lakes, seas, and oceans which have turned into the world's biggest landfill, causing environmental, economic, and social damage. Besides plastic, marine litter or debris consists of a range of materials including metal, wood, rubber, glass, and paper. Although the relative proportions of these materials vary from region to region, there is evidence that plastics are by far the most common type of debris in terms of the number of items (60 - 80%) on the sea surface, seafloor, and beaches, making plastic litter the most important waste stream to address (Brack HG, 2015). Regardless of their amount, plastic debris are also a major source of concern because most conventional plastics are not biodegradable. Thus, their durability in the marine environment is estimated in hundreds of years, hence potentially leading to significant accumulation of (especially micro) plastic particles in the marine environment in the future (Barnes et al, 2009).

Plastics in the oceans have a negative effect not only on marine life and ecosystems overall, but they can also have a potential impact on human health, for example through the intake of plastic fragments in seafood or by the consumption of seafood grown under unhealthy conditions. Minimizing these impacts is crucial, as highlighted by the Call for Action “Our

Ocean, Our Future" from last year's UN's Ocean Conference (United Nations, 2017). Apart from the UN, the OECD, European Commission, EPA Network, UNEP and recently the G7 as well as G20 and many other stakeholders have all placed marine litter on their environmental agenda. In addition to the aspirational target for marine litter reduction in the EU's Marine Strategy Framework Directive, regional action plans are under development, with key measures that focus on improved waste management and changes in human behavior that result in the responsible disposal route for end of life materials. More recently, the European Commission (2018) published a proposal to reduce littering of the 10 most found single-use plastic items on European beaches, with measures going from consumer awareness and drastic increase of recycling, extended producer responsibility, to banning the use of plastic for certain product categories.

At the same time, the Medellin Declaration (Sonnemann and Valdivia, 2017) highlighted that currently LCA, as one of the most widely used environmental sustainability assessment tools for greening the economy (UNEP, 2012), is not adequately addressing the impacts on the environment caused by marine debris, such as plastics. It also noted that there do not seem to be any product LCA studies that include the impacts of waste plastic flows and adequately address the challenge of marine litter. Indeed, there is still an overall need to assess marine ecological impacts in marine environments in LCA in a meaningful way (Woods et al, 2006), despite the fact that some attempts have been made in the past linked to fishing activities (Ziegler et al., 2016).

Given the magnitude of the impacts caused by marine debris, plastics and micro plastics in the oceans and as a response to the public concern on these impacts echoed at last year's Ocean Conference, the FSLCI Marine Litter workshop was organized. It convened more than 30 experts with various backgrounds to start a process towards addressing the issue of marine litter within LCA and also to some extent in life cycle management.

Input sources and sinks for marine litter

Participants also discussed the importance of distinguishing between sinks and sources. Sources were understood as a precursor to the material ending up in the marine environment. Thus a source is defined based on the emission into the environment (terrestrial+ marine) and not based on the generation of the particle/item. Sinks were defined as environments, which capture the litter and cause it to remain within that environment.

However, in order to model the differences, a better understanding of the flows between both states is required along with an accepted scientific definition. To this end, it was noted that the terrestrial environment could, for example, be considered either a sink or a source,

depending on whether or not the litter would end up in waterways and, thus, in the marine environment. Equally so, when sediments are disturbed again and redisperse they change their status from sink to source. Thus, a time factor needs to be attached to the definition of sinks.

Participants discussed a broad range of input sources that cause litter to end up in waterways and oceans and thus the marine environment. In general, it was agreed that sources derive from either dissipative use, littering, informal or illegal dumping or unintentional losses of materials. To classify marine litter sources in more detail, inputs were classified based on whether they were land-based or sea-based inputs:

Land-based, in particular urban environments:

- Laundry
- Roads and tire wear
- River Shipping
- Landfills
- Littering
- Mismanaged Waste (open dumps)
- Wastewater and other discharges into rivers

Sea-based, in particular ships:

- Fishing, including packaging, discards and lost fishing gears
- Commercial, Tourism and Leisure and other Shipping activities
- Offshore infrastructure

With regards to the above mentioned list it is important to highlight that one could further distinguish both land based as well as sea-based sources between unintentional leaks e.g. laundry, insufficient infrastructure; e.g. the lack of proper waste management or wastewater treatment and behavioural leaks, such as littering.

Participants further defined sinks in three environmental compartments in line with the USEtox classification system. Due to this classification, it was recognized that biota is present in all of the three environments below:

- Marine Environment:
    - Seafloor/sediments
    - Beaches/mangroves
    - Water column
    - Water surface
    - Ice
    - Biota

- Freshwater Environment (Rivers/Lakes):
    - Sediments
    - Banks
    - Floodplains
    - Biota
- Terrestrial:
    - Soil
    - Biota

Pathways and Mechanisms:

Following an analysis of input sources and sinks, input pathways and mechanisms that lead to marine litter were discussed. The following list also represents an indication of the relevance of the input pathways and mechanisms in order of importance as suggested by workshop participants:

1. Wastewater and other direct discharges into the marine environment
2. Rivers
3. Natural Disasters
4. Wind (Aeolic)
5. Storm drains

The relevance of natural disasters, which is normally not accounted for in LCA, was also discussed. In fact, ongoing research suggests that natural disasters (e.g., flooding, earthquakes and tsunamis) may be a significant source in the million tonnes range of plastic and thus need to be considered.

Which input is most relevant?

In addition to pathways, participants engaged on the question of whether or not marine litter could be traced back to specific products and, thereby, address the littering issue on the product level. Product categories were defined concerning the complexity of their identification:

Easy:

- Pellets
- Whole Products
- Fishing Gear

Medium:

- Product fragments (chemical composition might change over time)
- Microfibers
- Tire and brake dust

Challenging

- Secondary micro plastics (chemical composition can change)

A mass-balance approach was suggested to assess litter, define leakage rates and, thereafter, address the impact side via LCIA. In this context, it was noted that products and product parts are imported and exported on a global level, which would make it difficult to assess product-specific leakage rates. Still, a number of product categories were identified based on their respective sector size. Product categories concerning their share and relevance for marine litter were listed by workshop participants in terms of relevance from top to bottom as follows:

1. Packaging
2. Construction and demolition materials
3. Textiles (microfibers)
4. Transportation (tires)
5. Fishing / Fishing gear
6. Pre-Consumer (pellets)
7. Single-use non-packaging
8. Agriculture
9. Cosmetics and detergents

Participants noted that there are significant regional differences between these product categories and, thus, highlighted that LCA efforts to assess marine litter would need to be regionalized on both inventory and impact assessment level.

Why do products/materials become waste and end up as marine litter in the environment?

In addition to discussing the challenges concerning the inventory side, participants also discussed the main causes of marine litter. It was agreed that the following factors cause products/product parts/materials to end up as marine litter:

- low value of material or product
- lack of proper waste management infrastructures, especially in developing countries
    - informal vs formal
- consumer behavior that leads to products/materials being improperly discarded

- the lack of proper implementation and application of laws, regulations and their governance with regards to end-of-life treatment
- the lack of eco-designed products
- the cost for managing the end-of-life treatment of products/materials
    - internalization vs. externalization
- lack of social responsibility to act as a global community
- lack of (the application of) socio-economic tools to ”nudge/adjust behaviors“

Taking these elements together, participants highlighted two the main drivers for littering: On the one hand market conditions in the countries where the products are used and on the other hand the inefficiency or lack of a proper waste management infrastructure at a given location.

When addressing marine litter in LCA it will be important to capture parameters that enable an assessment of the waste management infrastructure on a regional or local level. Participants also discussed whether parameters to assess product design could be established, which was however considered significantly more complex.

It was also highlighted that an assessment of micro plastic leakage rates would be relatively easy, but that the solution to the problem would be rather complex because of a lack of knowledge on how to address for example the textile shedding issue, as outlined in the recent report by Ross et al. (2017).

In contrast, participants noted that it would be relatively straightforward to address the lack of proper waste management infrastructures from a solutions perspective, although macro plastic leakage rates would be significantly more complex to assess.

Still, participants agreed that there is a need for a satisfying accounting framework concerning marine litter in order to ensure that LCA remains the best approach to assess sustainability impacts from a systems perspective.

Participants also agreed that research projects will need to focus not only on the inventory side to address, how marine litter could be linked to a concrete product. Researchers should also address the impact side by developing characterization factors that could be applied.

Do we need a new Impact Category?

When discussing impact categories concerning marine litter and plastic litter in specific, participants agreed that, a distinction between macro, micro, and nano plastic needs to be made. It was also noted that impacts differ depending on where in the environment and in which size litter occurs and that impacts would not only occur directly but also indirectly. Indirect impacts could be caused, for example, by micro plastics consumed through the food

chain and thus potentially affecting human health. It was also mentioned that macro plastics could cause indirect impacts for example by providing a breeding ground for insects and ticks, which are transmitting malaria and other vector-borne diseases.

It was noted that all three areas of protection that are currently used in LCIA could be applied for the subject of marine litter:

- **Human Health:** In this area of protection it was agreed that uncertain pathways for damage to the human health remain since it is unclear what the actual risks and hazards many of these particles represent to the human body.
- **Ecosystems:** From a conservation perspective, it is important to keep plastic out of fish and other marine organisms. However, in a similar way to human health, much of the potential damage that marine litter could inflict on marine species remains unexplored or highly uncertain.
- **Resources:** Marine litter is extremely complex and expensive to recover. Therefore, it is also a way of consolidating the depletion of resources, since their availability to recycle or reuse is essentially lost. Some participants expressed interest in looking into the development of a monetarization indicator, such as $ cost per kg of litter waste that ends up as marine litter. To this end, the need to avoid double counting was highlighted, as depletion is already accounted for in the production assessment.

In addition to the three types of plastic particle sizes, different types of ecosystem impacts were classified as either chemical, physical or biological impacts which need to be addressed in LCIA:

- **Chemical impacts:** Harmful chemicals present in plastic that can affect human health or animal species. Some of these chemicals include heavy metals, polycyclic aromatic hydrocarbons (PAHs), pesticides and polychlorinated biphenyls (PCBs), which can disrupt important physiological processes of animals causing diseases and reproductive problems.
- **Physical impacts:** Related to size, entanglement, starvation, malnutrition or strangulation of animals
- **Biological impacts:** ecosystem, everything that can be carried up by plastics, can be breeding grounds for species that carry malaria or other species or modify ecosystems balance

Participants agreed that biological and chemical impacts of micro and nano plastics might be covered by toxicity, eutrophication etc. but physical impacts, e.g. materials entering into stomachs, would not be covered and thus needed to be addressed somehow. Participants thus concluded that there is currently a lack of a robust understanding of the whole scope of

final damages that litter is causing in the marine environment but that existing impact categories could probably be used for most impacts caused by micro and nano plastics.

For macro plastic, they highlighted that new impact categories might need to be developed to address impacts not only for macro plastic in the marine environment but also in the terrestrial environment (e.g. on beaches or other coastal environments). In this context, it was highlighted that it would not be clear what current impact categories at midpoint level should address macro plastics. It was discussed that relevant issues include entanglement of animals and e.g. starvation due to a blockage of internal organs. It was also highlighted that effects would be product specific.

Concerning impact categories at the endpoint level, it was suggested to keep conventional endpoints but also highlighted that there is a lack of a solid understanding of cause effects chains concerning marine litter. To this end, it was suggested to look into linking the accumulation of plastics to the degradation of marine biota. This might be inspired by recent developments in the area of water footprint methods.

Finally, participants noted that for corporations and policymakers the development of characterization models to integrate marine litter impacts in an LCA might be of most relevance, so that the final flows of marine litter into the marine environment are accounted for. It was concluded that there is a need to assess potential impacts that are occurring in addition to the final damages that will be generated due to the plastic waste flows within LCA. In order to develop characterization factors, participants started to discuss which parameters are needed and agreed that following parameters are needed for:

Micro plastic

- Shape, Size, and Type of polymer needs to be known
- Persistence and fate in the environment
- Degradation

Macro (and micro) plastic

- Polymer types
- Product groups need to be known.

Which impact pathways do we know?

Concerning midpoints, it was noted that pathways could be similar to the ones of chemicals for nano and micro plastics. In this context, it was highlighted that contaminants on plastics can either decrease or increase toxicity, thereby create additional challenge. Participants also noted that an approach similar to Usetox for the assessment of fading of compounds

could be applied, where micro plastic would be assessed and the effect on chemicals checked afterward.

Participants highlighted that taking a time perspective would be crucial, as macro plastics will eventually degrade to micro and nano plastics and the impact would thus not be seen if an infinite time perspective were to be taken. Furthermore, impacts over time can change and affect different species differently.

Concerning endpoints for macro plastics, it was noted that the issue of visible marine litter and impact on species could be addressed through an economic evaluation. Participants agreed that many of the impact pathways are not well defined and need to be researched with regards to degradation, dissipation, mineralization, creation of sinks, toxicity effects, eutrophication, damage on biota, human health etc.

Where do we need research within Life Cycle Assessment?

Concerning urgent research needs, participants agreed that a lot more research needs to be done in various areas. With regards to ecosystem impacts they prioritized research needs as follows:

	Biological impacts	Physical impacts	Chemical impacts
Micro	high	medium	high & feasible
Macro	high	high	medium

Concerning nano plastics, it was concluded that there is a high uncertainty around all relevant areas, which needs to be addressed in future research. It was also agreed that a lot more research is needed in order to enhance available data concerning:

- Fate, exposure, and effects of (plastic) marine litter
- Impacts on wildlife/biodiversity which is so far not considered in LCA
- Quantification of marine litter flows
- Changes of macro plastics which evolve into micro and nano plastics

Participants also suggested linking with other communities to enhance the understanding of the complexity of the subject, such as with

- experts on toxicology and ecotoxicology,
- marine scientists,
- experts on waste and wastewater treatment and management,
- economists (for economic evaluation)

- social scientists (how to best implement waste management structures)

Going beyond environmental life cycle assessment

They also noted that three potential additional damage categories could be considered as well: socioeconomic assets, cultural heritage and natural heritage (thereby addressing the visibility issue). It was concluded that concerning the cause-effect chain, applying a monetarization-based assessment might be the most feasible approach given the current state of the understanding of the system rather than using ecosystem or human health impacts, though the later might still be developed with more information becoming available over time.

Moreover on the technical side to address the reasons for marine litter, it was reiterated that modeling will need to account for the quality of waste and wastewater treatment and management infrastructures to be reflective of regional and local conditions. In this context, participants noted that even if waste and wastewater treatment and management infrastructure were optimized around the world, some inevitable pathways would remain like road runoff, wind etc. which still needed to be considered over time.

Which countries are most affected

It was noted that the impact of marine litter is global, yet there are significant differences between regions, both from an inventory as well as an impact perspective. To this end, a recent study by Schmidt et al. (2017) highlighted that 10 rivers transport 88 – 95 % of the globally mismanaged plastic waste into the sea, making certain world regions more vulnerable to the effects of marine litter than others. Participants also highlighted that impacts caused by micro plastic are a more relevant issue for developed countries, whereas impacts caused by macro plastics affect emerging and developing economies more due to differences in waste management systems (Boucher and Friot 2017).

To this end, participants reaffirmed the relevance of effective waste and wastewater treatment and management systems and related governanmental regulations and the need to develop or enhance these especially in developing countries, which were also considered to be most vulnerable to the waste generated by new products and the damages due to insufficient wastewater treatment.

Finally, it was noted that not only coastal but also landlocked countries would be affected, for example, due to littering that affects their rivers or major lakes, like for example Lake Titicaca in Peru and Bolivia or regions surrounding the Caspian Sea. In addition, participants noted that countries, which depend on fisheries and extensive aquaculture (national

nutrition demand and export) and coastal tourism (in particular relying on biodiversity such as diving through coral reefs, whale watching etc.) may be most affected.

Conclusions

There is a high urgency to tackle the issue of marine litter

Participants concluded that there is an immediate need to promote and implement science-based decision making across the globe to consider marine litter in the context of resource efficiency. Given the high attention of public opinion and decision makers around the world concerning the issue of marine litter, participants agreed on the urgency of establishing environmental management mechanisms to address pollution from marine litter.

Marine Litter can be addressed in LCA

Workshop participants agreed that LCA provides a robust and consensus-oriented methodological framework, which can be used to include science-based environmental information regarding marine litter in the future. . LCA can integrate different environmental impacts or in an extended application economic and social impacts as well in a holistic picture. LCA can create an overall result to support decision-making purposes. It was also agreed that the methodology needs to be further adapted in order to address the issue of marine litter, but concluded that addressing marine litter within LCA would principally be feasible and meaningful.

Inventory work needs to be region-specific

To address the open issues, participants highlighted the need to develop inventories linked to waste flows that find a sink in water bodies. This inventory task could be achieved in a relatively short timeframe to enable the usage of proxy data within LCA as a quick fix. More time and work would be needed to consider marine litter systematically as a way of dissipative use in LCA, which has been discussed in a recent publication by Zampori and Sala (2017). Participants also highlighted that marine litter needs to be addressed on a regional level within LCA. To this end, linking with watershed experts might help to address the issue from a regional perspective.

Impact assessment needs to follow inventory work

Following the inventory development, existing impact categories would either need to be improved and/or new categories that represent the cause-effect pathways of marine litter environmental impacts would need to be developed. Given the complexity of the issues highlighted throughout this report, this process would require a longer timeframe in order to be scientifically sound and accepted.

More data and research is needed

Workshop participants outlined the need for more research, data, statistics and assessment methods to enhance the understanding of the issue. It was also noted that while beach litter might provide an indication of what is in the sea, it would be too early to draw conclusions in terms of waste flow relevance and importance based on these findings, due to a lack of a scientifically sound assessment method. Concerning LCA, it was also noted that more scenarios for use and end of life modeling are needed to better reflect the complexity of the current end of life flows. Agent-based modeling might be a helpful complementary tool for this endeavor (see Querini & Benetto 2015).

Marine Litter is more than just plastics

Participants highlighted that the issue could be addressed either by focussing on the product (design) level or by focussing on waste infrastructures and management. Participants also emphasized that despite the relevance and share of the plastic fraction within marine litter, marine litter is composed of other relevant components. Participants also noted that apart from LCA, there is a huge challenge to address consumer behavior to decrease littering around the world.

Cross-domain collaboration is required

It was highlighted that a lot of work has already been done, but that there is an ongoing need to collaborate with various expert communities to develop a better understanding of the issues and of the results from an LCA. The need to reach out to non-LCA experts was emphasized and it was suggested to involve stakeholders from other sectors and social sciences in the debate. The easy interpretation of final results is key for better understanding of non-experts and for consumers, to act accordingly to prevent marine litter. To this end, it was noted that the Social LCA process could serve as an example on how to do so. Finally, it was highlighted that more research needs to be funded on this subject in order to foster the development of a better understanding and assessment methods.

FSLCI should facilitate global knowledge sharing

Participants called on the FSLCI to establish a working group of interested experts along with an open platform to facilitate the exchange on marine litter and LCA and enable an overview of global activities on the subject in order to avoid the duplication of efforts. They further suggested to conduct follow-up workshops in various world regions to address the issue on a regional level yet with a global perspective and called for the inclusion of more non-LCA experts into the global dialogue.

References

Barnes DKA., Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments, Philos. Trans. R. Soc. B Biol. Sci. 364: 1985–1998.

Brack HG (2015) Where Have All the Plastics Gone? - Ménage à Trois in the Sea Surface Microlayer, Davistown Museum, http://www.nanotoxinalert.com/microplastics.pdf

Boucher J and Friot D (2017) Primary Microplastics in the Oceans: A Global Evaluation of Sources. Gland, Switzerland: IUCN. 43pp.

European Commission (2018) Single-use plastics: New EU rules to reduce marine litter, Brussels, http://europa.eu/rapid/press-release_IP-18-3927_en.htm

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

Querini F and Benetto, E (2015) Combining Agent-Based Modeling and Life Cycle Assessment for the Evaluation of Mobility Policies, *Environmental Science and Technology*, *49* (3), pp 1744–1751

Ross S, Levenstam Arturin O, Hanning A (2017) Microplastics shedding from polyester fabrics, Kista, http://mistrafuturefashion.com/wp-content/uploads/2017/06/MFF-Report-Microplastics.pdf

Schmidt C, Krauth T, Wagner S (2017) Export of Plastic Debris by Rivers into the Sea, Environmental Science and Technology, 51 (21), pp 12246–12253

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

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

United Nations (2017), Our Ocean, Our Future: Call for Action, New York, https://oceanconference.un.org/callforaction

Woods JS, Veltman K, Huijbregts MA, Verones F, Hertwich EG (201&) Towards a meaningful assessment of marine ecological impacts in life cycle assessment (LCA), Environ Int. 89-90, 48-56

Zampori L and Sara S (2017) Feasibility study to implement resource dissipation in LCA, Brussels, https://ec.europa.eu/jrc/en/publication/feasibility-study-implement-resource-dissipation-lca

Ziegler F, Hornborg S, Green B S, Eigaard O R, Farmery A K, Hammar L, ... & Vázquez-Rowe I (2016), Expanding the concept of sustainable seafood using Life Cycle Assessment. Fish and Fisheries, 17(4), 1073-1093.