Land-Based Solutions for Plastics in the Sea

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D9.5 Support for plastic leaks LCA methodology development

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4	LABORATORIO IBERICO INTERNACIONAL DE NANOTECNOLOGIA	INL	PORTUGAL	RTO
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Executive summary:	This deliverable (D9.5), conducted within the LABPLAS project, evaluates methodologies for assessing plastic leakage impacts in Life Cycle Assessment (LCA). By means of a literature review, along with the analysis conducted on T5.5 (*Comparative LCA: biopolymers vs conventional fossil-based alternative for a model biopolymer vs a conventional plastic*), but particularly on D5.6 (*LCA methodology resulting from Subtask 5.5.1*), and expert consultations via questionnaires; key gaps were identified, particularly regarding microplastic formation and its environmental effects. Findings highlight a limited availability of primary data on microplastic degradation, fragmentation and toxicity, as well as a lack of consideration of additive effects and long-term accumulation dynamics. Likewise, while marine environments are the most studied, freshwater and terrestrial compartments remain largely overlooked. Expert consultations reinforced these findings and emphasized additional challenges, such as the absence of standardized impact categories, limited inventory data on plastic emissions and the slow integration of microplastic modelling into LCA software. The LABPLAS project addresses some of these gaps by generating primary data on microplastic distribution, toxicity and biodegradability in both aquatic and terrestrial systems. Despite these efforts, integrating such data into LCA remains challenging due to the need to

	develop specific Characterization Factors (CFs) and the limitations of conventional LCA methodologies in capturing temporal dynamics. To improve plastic leakage assessments, further experimental studies on degradation mechanisms and additive effects are needed. Additionally, integrating CFs into LCA software should be prioritized. While more precise methodologies are under development, existing scientific approaches can provide preliminary assessments. By harmonizing primary data with advanced modelling techniques, LCA can offer a more comprehensive evaluation of plastic pollution impacts, contributing to sustainable decision-making.

Version	Date	Comments
1.0	27/03/2025	First version
2.0	09/04/2025	Final revised version

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ABBREVIATIONS AND ACRONYMS

Abbreviation / Acronym	Description
CF	Characterisation factor
D	Deliverable
EF	Effect Factor
EoL	End-of-Life
EU	European Union
FF	Fate Factor
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LDPE	Low-Density Polyethylene
MFA	Material Flow Analysis
PE	Polyethylene
PHA	Polyhydroxyalkanoates
PLA	Polylactic acid
PLP	Plastic Leak Project
PP	Polypropylene
SMNP	Small, Micro- and Nano-Plastics
T	Task
WP	Work Package
XF	Exposure Factor

1 INTRODUCTION

Nowadays, it is estimated that about 5,250 billion plastic particles are floating on the surface of the seas and oceans around the world. Once in the ocean, these particles fragment into smaller ones and move with the currents and ocean gyres before washing up on the coastline. They are hardly removed from the ocean, so proactive action regarding research on plastic alternatives and strategies to prevent plastic from entering the environment should be taken promptly. Despite the research increasing, there is still a lack of suitable and validated analytical methods for the detection and quantification of Small Micro- and Nano-Plastics (SMNP) evidencing a huge obstacle for large-scale monitoring.

In this sense, LABPLAS is a 48-month project whose vision is to create capacities to evaluate rapidly and precisely the interactions of plastics with the environmental compartments and natural cycles leading to the development of effective mitigation and elimination measures, as well as making management decisions. It will assess reliable identification methods for more accurate assessment of the abundance, distribution and toxicity determination of SMNP in the environment. It will also develop practical computational tools that should facilitate the mapping of plastic-impacted hotspots and promote scientifically sound plastic governance.

This document corresponds to D9.5. (*Support for plastics leaks methodology development resulting from T9.4*) of the LABPLAS project. The structure of this document starts first with a comprehensive review of methodologies for assessing the impacts of plastic leakage into the environment (**Literature review**). Gaps in the current approaches are identified through both the methodology developed in D5.6 (*LCA methodology resulting from Subtask 5.5.1*) of T5.5 (*Comparative LCA: biopolymers vs conventional fossil-based alternative for a model biopolymer vs a conventional plastic*) and a thorough review of the scientific literature. Additionally, this is complemented by the opinion of experts in the field (**Discussion with experts**) who were contacted through questionnaires (**Annex I**. Questionnaire), to share the identification of gaps and proposal of strategies. Consequently, based on the findings, recommendations can be made to improve the methodology for assessing the potential impacts of plastic leakage in Life Cycle Assessment (LCA) (**Conclusions and recommendations**).

2 LITERATURE REVIEW

2.1 Identification of gaps in the developed methodologies

Microplastics originate from both primary and secondary sources. Primary microplastics are particles intentionally manufactured and added to consumer products, such as microbeads in face scrubs. In contrast, secondary microplastics are by-products of the breakdown of larger plastic items, or macroplastics, which can occur through processes such as abrasion, photodegradation, oxidation, and digestion. Over time, these larger plastic items fragment into microplastics (<1 mm) and eventually nanoplastics (<1 µm), all while retaining the durability and stability of the original polymer. These fragments can be released into the environment at various stages, such as during transportation spills, from wastewater treatment facilities, waste management operations, or as a result of improper End-of-Life (EoL) management as littering (Xayachak et al., 2024).

Once plastics are released into the environment, tracking them becomes increasingly challenging as they are dispersed by wind and water currents, leading to widespread distribution and further fragmentation. As a result, plastic particles of all sizes have been detected in a variety of natural environments, from terrestrial landscapes, and rivers, up to the deep ocean (Sabate & Kendall, 2024).

Plastic particles, particularly non-biodegradable ones, can persist in the environment for hundreds of years, leading to significant ecological disruption and posing serious risks to human health. These impacts range from physical hazards, such as entanglement risks for animals, to potential toxicity. Notably, the toxic effects are not only linked to the original composition of plastic materials but also to their physicochemical properties, which enable microplastics to act as carriers for harmful compounds, transferring these toxins from the environment to living organisms. Organisms can be exposed to microplastics through various routes, including ingestion, inhalation and dermal contact (Xayachak et al., 2024).

Despite growing research on microplastics, comprehensive data mapping on the release of plastics across product value chains is still limited. However, initial estimates can be made using established methodologies, such as the Plastic Leakage Project (PLP) guidelines (Quantis & EA, 2020). These guidelines provide the first generic datasets and approaches for assessing the release of both macro- and microplastics from various sources throughout a product's life cycle while accounting for their distribution across different environmental compartments. The methodology is applied to waste mismanagement of macroplastics (such as packaging and other plastic products) and microplastics generated through processes like textile washing, tire abrasion and pellet production (Peano et al., 2020).

The PLP highlights several limitations to consider when analysing the results, pointing out areas for further research:

- There is a lack of robust data for assessing sedimentation rates in coastal areas (which represent shorter distances from the point of release to the sea) or the retention rates in runoff water infrastructures.
- The fragmentation mechanism is not considered in the PLP methodology due to insufficient data on fragmentation rates.
- Current metrics treat the inclusion of degradation as optional, as data on degradation rates of different plastic materials in various environments is limited.
- For the biodegradation rates considered, the effects of additives on biodegradation or their environmental impact are not accounted for. In addition, testing is conducted in laboratories, so results may not accurately reflect what happens in natural environments and should be interpreted cautiously.

Nevertheless, statistical estimation remains one of the most practical ways to obtain case-specific data on microplastic emissions in the absence of primary data.

Once the quantity of microplastics is estimated, evaluating their environmental impact presents another challenge. LCA is commonly used to quantify the environmental impacts of products across their full life cycle. Despite the widespread use of this methodology in the plastics industry, and considering that scientific literature frequently emphasizes the ecotoxicity of microplastics on marine biodiversity, human health, and animal ingestion, these impacts are rarely integrated into LCA analyses, besides, the inclusion of the effects of microplastics is still largely discussed. This exclusion stems from the complexity and variability of measuring such effects and the difficulty of directly linking them to the persistence of plastics (Sabate & Kendall, 2024).

At present, comprehensive and reliable impact assessment models to evaluate the effects of both non-biodegradable and biodegradable plastics on biodiversity and ecosystems are lacking. To address this gap, additional impact categories must be incorporated into assessments, as recommended by the JRC (Joint Research Centre) Plastics LCA guidelines (Nessi et al., 2021).

In response to these challenges, several researchers have focused on the development of Characterization Factors (CFs) to assess the environmental impact of microplastics. CFs convert Life Cycle Inventory (LCI) flows into impact indicators, with their corresponding units of measurement. The development of CFs involves integrating fate, exposure, and effect factors. The Fate Factor (FF) accounts for the movement and transformation of microplastic particles within and between environmental compartments and sub-compartments. The eXposure Factor (XF) considers the potential pathways through which organisms may come into contact with microplastics. Finally, the Effect Factor (EF) describes the harm microplastics cause to various receptors (Fantke et al., 2018). **Figure 1** illustrates these CFs in the Life Cycle Impact Assessment (LCIA) step.

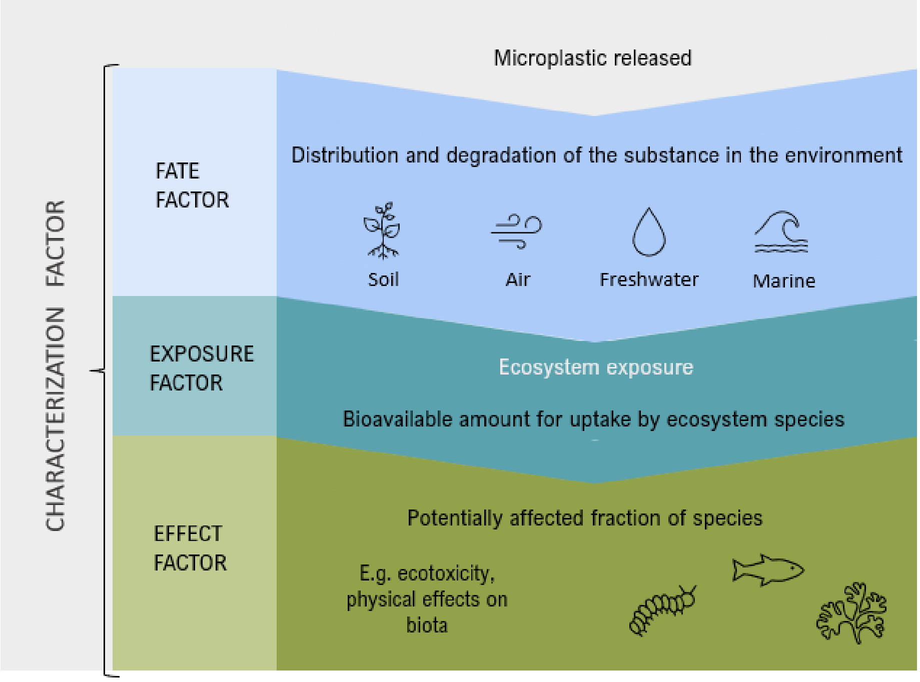


Figure 1. Conceptual representation of ecotoxicity impact pathway in LCIA (Life Cycle Impact Assessment).

In the development of CFs, it is essential to account for the origin of the materials that constitute microplastics, as their residence time directly influences fate, exposure, and effect factors. Consequently, CFs are polymer-dependent and exhibit marked variations according to residence time, distinguishing between non-biodegradable polymers and those with slow, medium, or fast biodegradability.

Moreover, the specific environment in which microplastics are ultimately deposited —whether soil, freshwater, or marine ecosystems— must also be considered. This is critical, as the degradation processes of polymers and their associated toxicity to organisms in these ecosystems differ significantly. To date, marine ecosystems have been the predominant focus of research, leaving a remarkable gap in the understanding of terrestrial and freshwater environments.

In this context, Maga et al. (2022) introduced a CF that focuses on the residence time of plastics in the environment, without accounting for the exposure and effects associated with plastic emissions. Consequently, this CF is determined solely by the FF, which considers the final compartment where the plastic is disposed of after potential redistribution, as well as the expected degradation rate in that compartment relative to a reference degradation rate, typically set at one year. Thus, the results are dependent on factors such as polymer type (dependent on the density), size, shape, and the environmental compartment where the plastics ultimately accumulate. The resulting FF is expressed in a dimensionless way in mass terms of kg of Plastic Pollution equivalent (PPe) per kg of plastic emitted. The authors highlight several limitations of the methodology:

- For some polymers, data on degradability is scarce, particularly for conventional fossil-based polymers such as polyethylene (PET) and polypropylene (PP). One reason for this limited data availability is the lengthy experimental durations required for slowly degrading polymers, along with the high costs associated with conducting realistic degradability tests.
- Estimated residence times may be relatively low, as it is scientifically challenging to differentiate between (bio)degradation and fragmentation processes as the primary drivers for observed mass losses of plastics in the environment.
- Laboratory results are not always transferable to field conditions, which limits the availability of usable data, as microplastics found in the environment often differ from those used in laboratory experiments. In cases where no degradation data exists for a polymer in a specific environmental compartment, researchers may use degradation data from other compartments as approximations, resulting in increased data uncertainty.
- The analysis did not consider specific additives used in plastics.
- Although environmental compartments such as freshwater, marine water, soil, river sediment, and marine sediment were included in the study, additional environmental compartments as distinctions within marine compartments (e.g., eulittoral, pelagic, benthic) and variations across climate zones were not included because of lack of information.

On the other hand, Saling et al. (2020) formulated a CF for different types of polymers based on the number of particles per product entering the environment, the ecotoxicological effects on different organisms, and the time horizon these particles will persist. These findings led to the development of the midpoint-related Marine Microplastic Potential (MMP), measured in pellet equivalents. Due to limited data availability, certain assumptions were made by the authors. These are outlined below:

- There were significant limitations in the availability of data regarding the fragmentation process and even less data on the actual biodegradation of polymers in aquatic environments. As a result, it was assumed that 100% of the weight loss of the plastic litter was attributed solely to fragmentation, with the resulting fragments being uniform in size and shape. Furthermore, it was considered that microplastics degrade gradually by reducing in size rather than splitting into additional particles.
- The size of the particle was not considered a variable in the study. It was assumed that all microplastics have a spherical form, with no further changes in form occurring until the particles eventually degraded.
- The effects of additives were excluded due to the lack of migration models for each additive. Additionally, the impacts of chemical sorption, such as persistent organic pollutants, as well as the transport of invasive species and pathogens by plastics, were not included in the model.
- Only the marine environment was considered in this study; other environmental compartments were not contemplated.
- Polymer density was not incorporated into the model, meaning that the rates at which polymers float on the surface or sink to deeper layers (which are influenced by density) were also not accounted for.

In addition, Salieri et al. (2021) calculated a simplified CF for microplastics in the impact category of freshwater ecotoxicity following the USEtox approach. The goal of the study was to assess whether microplastic emissions into freshwaters could influence the LCA results when considering the impact category of freshwater ecotoxicity using worst-case assumptions. In this regard, the EF was calculated using 26 ecotoxicity data points of various freshwater aquatic species obtained from the literature. For the FF, the authors utilized degradation rates of microplastics in water, also sourced from the literature, and modelled a hypothetical worst-case scenario in the USEtox model, assuming the high persistence of microplastics in freshwater. To achieve this, they considered a high molecular weight to confer high impact resistance, an extremely low partitioning coefficient between octanol and water to represent the non-solubility of plastics, an extremely low Henry law coefficient to represent that microplastics have no potential of partitioning between air and water, an extremely low vapor pressure, as well as assuming no solubility.

It is noteworthy to mention that the study is based on worst-case scenario assumptions and simplifications, so the results must be interpreted with caution, as they may be overestimated. The following limitations are highlighted:

- The ecotoxicity data do not distinguish between polymer type and size for calculating the effect factor due to the limited knowledge in the field.
- The removal of microplastics from the water phase by agglomeration and settling was not considered. Consequently, the removal of microplastics from the system was represented by the residence time of the substance in freshwater as accounted by the USEtox model at the continental scale.
- The same limitations as those identified by Saling et al. (2020) were mentioned, including the strong reliance on assumptions regarding degradation, exposure, and the role that the size, polymer type, and other physicochemical properties of the microplastics will play in determining its fate and toxicological effect on species.
- Only the freshwater environment was considered in this study.

Lastly, the MarILCA project is noteworthy in this field for its focus on assessing the impacts of microplastics in the ocean (Boulay et al., 2021), making it the most promising reference for evaluating microplastic impacts so far. The MarILCA project focuses on developing a framework to integrate the potential environmental impacts of marine litter (specifically plastics) into LCA. To this end, it works on harmonizing the development of environmental impact pathways and CFs for marine impact assessment through the impact category of *physical effects on biota*. This impact category aims at capturing the physical impacts of plastic litter on organisms, both through internal (ingestion) and external (entanglement, smothering) pathways (Corella-Puertas et al., 2022). In this method, the effect factor was developed by updating the existing model by Lavoie et al. (2022), where the USEtox approach was used to calculate the ecotoxic effects for each polymer analysed. On the other hand, the FF was developed for different polymers, sizes and shapes. For this purpose, degradation and sedimentation rates were considered in the calculation of the factor (Corella-Puertas et al., 2023). Based on this methodology, the following limitations were identified:

- A steady-state approach was adopted, assuming a constant mass of microplastics without accumulation over time. This assumption does not reflect the actual dynamic behaviour of microplastic emissions in oceans. Instead, it provides a framework to quantify potential impacts on the marine ecosystem, as is typical of all LCIA models.
- Only the marine environment (and a simplified representation of the freshwater compartment) was assessed, leaving other environments, such as terrestrial systems, to be addressed in future research.
- Due to the scope of this study, the CFs quantify potential impacts in the water surface and water column but do not account for impacts in sediments. Currently, data on the effects of nano- and microplastics in sediments are lacking.

- A simplified sedimentation model was proposed, which considers only polymer density and does not account for size or shape.
- Data from polymers containing additives were excluded, as the CF developed focuses specifically on quantifying the effects of the physical attributes of polymers, rather than their chemical toxicity. However, the effects of additives are analysed in other works by the MarILCA group, such as in Casagrande et al. (2024).
- Research on the fate of plastic litter in oceans is still evolving, so critical data needed to generate rate constants remain unavailable, including degradation and fragmentation rates for different polymer types in various oceanic sub-compartments.

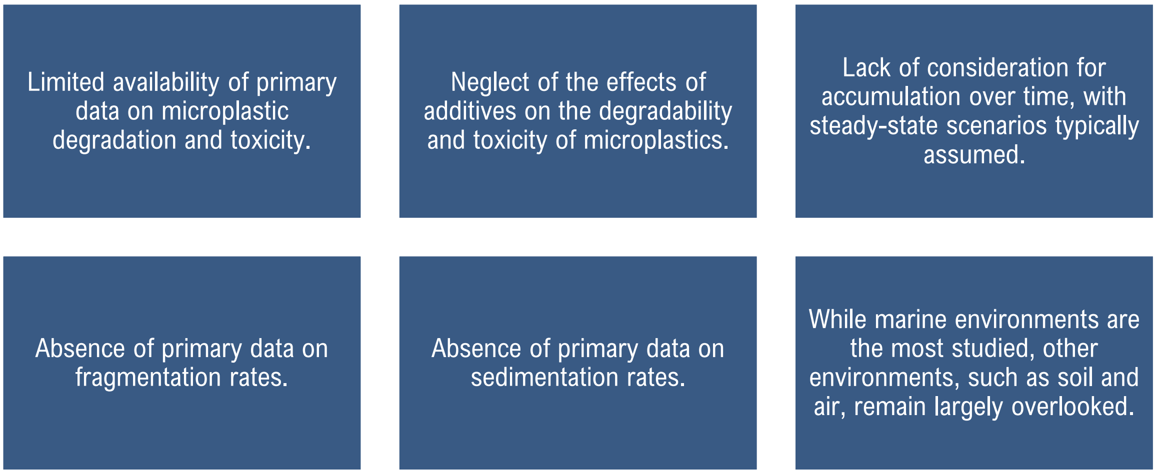
Conversely, regarding the assessment of the impacts of microplastics on soil, there is currently a lack of established methods or scientific literature covering it. Vázquez-Vázquez et al. (2024) addressed this gap by calculating CFs for microplastic ingestion and additive release within terrestrial environments. They developed FFs based on mass loss from photooxidation, identified as the primary degradation pathway for microplastics in terrestrial ecosystems. Furthermore, the EF was determined using the USEtox model.

They compared their results with those obtained by Corella-Puertas et al. (2023) and found that the latter are three orders of magnitude higher for biopolymers (PHA – polyhydroxyalkanoates, and PLA – polylactic acid), and five and six orders of magnitude higher for PP and LDPE, respectively. They concluded that the high mobility and accessibility of microplastics in the aquatic environment make this difference consistent between the factors of the two compartments. This also emphasizes the need to include both compartments in the environmental assessment of mismanaged plastics to avoid overestimating the impacts. Additionally, they encountered some challenges, such as the fact that photo-oxidation, identified as the primary degradation pathway for plastics, does not follow first-order kinetics but instead has at least three stages (initiation, propagation, and termination). These stages occur over different time scales and have distinct impacts, but the current methodology does not adequately incorporate these phases or their specific effects.

2.2 Main findings

Based on the literature review conducted, it has been observed that the evaluation of the formation and impacts of microplastics throughout the life cycle of plastics has been addressed to a very limited extent in LCA studies. The primary reason for this is the lack of primary data, either due to limited understanding of the underlying mechanisms or because obtaining such data is time-consuming and expensive.

In conclusion, two distinct key areas can be identified when addressing gaps: (i) the **leakage rates of microplastics**, and (ii) the assessment of their impacts through the development or adaptation of **CFs**. As discussed, these limitations stem from a lack of data, leading to reliance on estimates (e.g., Corella et al. (2023) assume three fragmentation scenarios —10%, 50%, and 100%) or, in some cases, the exclusion of these effects altogether (e.g., none of the reviewed studies considers the impact of microplastic additives). The most relevant gaps, identified as recurring issues, are summarized below (see **Figure 2**):



Limited availability of primary data on microplastic degradation and toxicity.

Neglect of the effects of additives on the degradability and toxicity of microplastics.

Lack of consideration for accumulation over time, with steady-state scenarios typically assumed.

Absence of primary data on fragmentation rates.

Absence of primary data on sedimentation rates.

While marine environments are the most studied, other environments, such as soil and air, remain largely overlooked.

Figure 2. Summary of the main gaps found in the literature review conducted.

As part of the LABPLAS project, various experiments have been conducted to assess the abundance, distribution and toxicity of SMNP in the environment. These efforts address current knowledge gaps by generating primary data on the biodegradability and toxicity of SMNP in both terrestrial and aquatic environments, including toxicity data related to additives in the latter. Additionally, time trends in plastic accumulation have been determined using relevant data series from two marine areas: the Baltic Sea and the North Sea.

Primary data have been integrated into the LCA study of T5.5, incorporating toxicity data from marine and terrestrial environments for the case studies on plastic bags and mulch films. However, despite the availability of data, integrating them into LCAs is often challenging due to the need for developing specific impact assessment methodologies. For example, toxicity impacts from SMNP and their additives require dedicated CFs, which are still under development. Without such adaptations, the potential for accurately quantifying the impacts of SMNP remains limited.

Moreover, conventional (or attributional) LCA has inherent limitations, particularly its inability to account for temporal dynamics or the cumulative effects of long-term accumulation. So, future efforts should focus on harmonizing primary data with advanced methodologies (e.g., dynamic indicators) to provide a more comprehensive assessment.

3 DISCUSSION WITH EXPERTS

A questionnaire was developed to gather the opinions of experts in the field regarding the identified gaps and how they would address them. This questionnaire, available in **Annex I. Questionnaire**, was sent to 11 professionals with expertise in LCA methodologies, the plastic industry, or both. Notwithstanding, four experts responded to it. All of them specialize in LCA and actively incorporate microplastic emissions into their current analyses. Two of the respondents are from academia or higher education institutions, focusing on sustainability and LCA research, while the other two represent sustainability research companies—one dedicated to making scientific knowledge accessible to the general public and the other specializing in corporate carbon footprints and plastic footprint assessments for specific clients. In terms of company size, three organizations have approximately 15–20 employees, while the fourth has more than 5,000 employees.

Each response will now be carefully analysed. Regarding the approaches used to assess the environmental impacts of microplastics, two experts apply the methodology developed by MarILCA (Corella-Puertas et al., 2023). Another expert combines the Plastic Footprint Network (PFN) methodology to quantify plastic leakage with the MarILCA methodology for impact assessment. The final respondent utilizes the methodology developed by Schwarz et al. (2024), which integrates plastics effects into LCA using the ReCiPe2016 methodology, applying CFs to assess marine and freshwater ecotoxicity. This study quantifies plastic pollution, using Material Flow Analysis (MFA) to estimate macro- and microplastic losses throughout the life cycle. In addition, Simplebox4Plastics, an adapted fate model, determines microplastic fate factors, incorporating degradation, fragmentation and intermedia transport.

In terms of the main barriers, the most significant one highlighted is the neglect of additive effects on the degradability and toxicity of microplastics. This is followed by the limited availability of primary data on the degradation and toxicity of microplastics and the fact that environments such as soil and air continue to be overlooked, while marine environments have been extensively studied. Another critical barrier mentioned is the absence of primary data on fragmentation rates.

Besides, respondents identified additional gaps that they considered relevant. These include the lack of secondary data preparation in LCI databases to account for plastic emissions, as well as insufficient information on loss rates in inventory analysis before impact assessment —for example, the number of pellets lost during production and recycling processes. Another key issue is the incomplete composition data of plastic items, including the quantity of polymers and the identification of additives.

It was emphasized that further research is needed, as multiple knowledge gaps remain. These include the fate of plastics, their degradation and fragmentation in different environments and with various polymer types, as well as the effects of size and shape on the plastic EF, which determines the CF. Moreover, LCA methodologies tend to overlook critical environmental compartments, such as aquatic sediments and shorelines.

Regarding the question of whether new impact categories specific to microplastics and nanoplastics should be incorporated into LCA, one expert suggests that, as a first step, these impacts should be considered separately, focusing on their physical effects on biota. This is because ecotoxicity CFs already account for additives, which vary between different types of plastics. Eventually, once the methodologies are sufficiently developed, these categories could be integrated. The main reason for having a distinct category, in addition to ecotoxicity, is to capture effects such as entanglement and smothering caused by larger plastic items.

Two other experts emphasize the need to assess impacts beyond the marine environment, incorporating effects on other ecosystems. They also highlight the importance of considering the toxic effects of additives, entanglement rates caused by macroplastics, and aspects related to resource depletion. Finally, the last expert raises the point that when introducing new impact categories, endpoint levels and normalization should also be considered. According to this expert, if these impacts are incorporated into existing categories, such as environmental toxicity, this additional step might not be necessary. However, physical impacts may be best assessed separately. If this approach is taken, it is important to ensure that the evaluation is not limited to plastics alone but also includes other materials that may be lost to the environment.

When addressing the challenges encountered in data collection during the assessment, all experts agree that inventory data (specifically regarding plastics released into the environment) is limited. To overcome this limitation, they rely on scientific methods such as MFA and the PFN. Additionally, one of the respondents points out that the exact composition of plastics, including polymer and additive content, is often unknown.

Concerning their opinions on the extent to which current models reflect the impacts of microplastics, the responses varied, as can be seen in **Table 1**. It is important to note that the answers are based on the current level of knowledge and may include studies that are not yet publicly available, as they are still under review.

Table 1. Expert opinions on the extent to which current models reflect the impacts of microplastics. The responses range from more to less comprehensive assessments, categorized as follows: properly, moderately well, with limitations and unproperly.

	Expert 1	Expert 2	Expert 3	Expert 4
Marine ecosystems	Moderately well	Properly	With limitations	With limitations
Terrestrial ecosystems	Moderately well	Unproperly	Unproperly	Unproperly
Freshwater ecosystems	Moderately well	Moderately well	Unproperly	With limitations

Regarding the priorities for advancing the modelling of microplastics in LCA, two respondents emphasize the need for further research on degradation and fragmentation mechanisms in natural environments. Another expert highlights the importance of developing impact assessments for terrestrial environments. Lastly, the remaining respondent points out that the slow integration of microplastic modelling into commercial software and databases is currently the main bottleneck.

The final question is related to novel tools or approaches that experts consider useful for assessing the real-world environmental impacts of microplastics. One expert mentions the importance of transparent information on product composition. Another suggests regionalized LCAs, while a third recommends a broader use of Brightway, a tool that enables more direct LCA programming compared to traditional commercial software, potentially allowing for faster integration of plastic emissions. Finally, one respondent highlights dynamic LCA, which is useful for modelling the long-term effects of plastic accumulation in the environment or the human body, as well as social LCA, which can help map the social consequences of EoL management, particularly in less developed countries.

4 CONCLUSIONS AND RECOMMENDATIONS

Different gaps have been identified through the literature review conducted in studies related to the impact assessment of microplastics. These gaps can be grouped into two areas that are: (i) the leakage rates of microplastics, and (ii) the assessment of their impacts through the development or adaptation of CFs.

It can be observed that the number of studies focusing on this topic has increased in recent years, along with growing concern about including this impact in LCA studies. Given that this field is still under development, it is reasonable to expect certain limitations. In this regard, most of these gaps stem from insufficient knowledge or a lack of data. Notably, there is a lack of secondary data preparation in LCI databases to account for plastic emissions, as well as an omission of additive effects on the degradability and toxicity of microplastics. Additionally, there is limited data on degradation and fragmentation across different environments and polymer types, as well as the effects of size and shape. Likewise, critical environmental compartments, such as aquatic sediments and shorelines, are often overlooked.

The marine environment is the most studied, followed —though to a much lesser extent— by the freshwater environment, which has been the focus of some research. Finally, the terrestrial environment has received the least attention.

Lastly, two recommendations can be made for two different groups. On the one hand, for researchers and LCA experts, more experimental studies are needed to fill data gaps, particularly regarding degradation and fragmentation processes, as well as the effects of additives. In addition, efforts should be made to accelerate the inclusion of new or adapted CFs into LCA software, facilitating more comprehensive impact assessments and comparisons. On the other hand, for end users, while more accurate methodologies are still under development, a preliminary inclusion of microplastic impacts in LCA can already be performed using existing scientific approaches, such as the MarILCA method. In this regard, a general approach to overcoming data limitations is to rely on assumptions based on literature, official statistics, expert judgment and validated proxy data, ensuring the best possible approximation in the absence of complete datasets.

5 ACKNOWLEDGEMENTS

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LABPLAS

Questionnaire for identifying key levers for improvement of plastic leakage assessment methodology

Horizon 2020
European Union Funding
for Research & Innovation

PROJECT INFORMATION

Nowadays, it is estimated that about 5,250 billion plastic particles are floating on the surface of the seas and oceans around the world. Once in the ocean, these particles fragment into smaller ones and move with the currents and ocean gyres before washing up on the coastline. They are hardly removed from the ocean, so proactive action regarding research on plastic alternatives and strategies to prevent plastic from entering the environment should be taken promptly. Despite the research increasing, there is still a lack of suitable and validated analytical methods for the detection and quantification of small micro- and nano-plastics (SMNP) evidencing a huge obstacle for large-scale monitoring.

In this sense, the LABPLAS Project is a 48-month project whose vision is to create capacities to evaluate rapidly and precisely the interactions of plastics with the environmental compartments and natural cycles leading to the development of effective mitigation and elimination measures, as well as making management decisions. It will assess reliable identification methods for more accurate assessment of the abundance, distribution and toxicity determination of SMNP in the environment. It will also develop practical computational tools that should facilitate the mapping of plastic-impacted hotspots and promote scientifically sound plastic governance.

AIM OF THE QUESTIONNAIRE

This questionnaire is part of a task in the LABPLAS Project, which aims to support plastics leaks methodology development. To this end, several gaps in existing methods for evaluating the environmental impacts of plastic leakage have been identified. Subsequently, based on the findings and expert opinions, recommendations can be made to enhance the methodology for assessing the potential impacts of plastic leakage in Life Cycle Assessment (LCA).

We kindly ask for your assistance in answering a few questions. Completing the questionnaire should take no more than 10 minutes. Participation is entirely voluntary, and you are free to skip any questions you prefer not to answer or withdraw your participation at any time. Non-sensitive or personal data will be collected. Your responses will remain anonymous unless you choose to grant permission for identification. If desired, your name or company may also be included in the acknowledgements of the final report.

QUESTIONS ON GENERAL INFORMATION

Question number	Question	Answer
#1	Company name	
#2	Company sector	
#3	Main focus of the company	
#4	Size of company (number of employees)	
#5	Description of your role in the company	
Observations *Please describe any observations you consider necessary*		

QUESTIONS ON LIFE CYCLE METHODOLOGIES

Question number	Question	Answer
#6	In your current role, are you using Life Cycle Assessment (LCA) for products containing plastics? *- If yes, go to question #8* *- If no, go to question #7*	☐ Yes ☐ No
#7	Have you ever used LCA in another context?	
#8	Do you currently include microplastic emissions in your analysis? *- If yes, go to question #9* *- If no, go to question #10*	☐ Yes ☐ No
#9	What approaches do you use to assess the environmental impact of microplastics?	
#10	What do you consider are the main barriers to integrate microplastic impacts into LCA? Select one or a maximum of two of the six gaps proposed	☐ Limited availability of primary data on microplastic degradation and toxicity ☐ Neglect of the effects of additives on the degradability and toxicity of microplastics ☐ Lack of consideration for accumulation over time, with steady-state scenarios typically assumed ☐ Absence of primary data on fragmentation rates ☐ Absence of primary data on sedimentation rates ☐ While marine environments are the most studied, other environments, such as soil and air, remain largely overlooked

#11	In relation to question #10, can you propose any additional gap you consider relevant?	
#12	Should new impact categories specific to microplastics (and nanoplastics) be incorporated into LCAs? If so, which categories would you suggest? (e.g., “physical effects on biota”, “plastic toxicity on marine environments”, etc.)	
#13	• Have you faced data (foreground or background) collection problems during the assessment? • What was the problem? • Please, suggest any method you follow to overcome those problems	
#14	To what extent do you think current models reflect the impacts of microplastics in: a. Marine ecosystems? ☐ Properly ☐ Moderately well ☐ With limitations ☐ Unproperly b. Terrestrial ecosystems? ☐ Properly ☐ Moderately well ☐ With limitations ☐ Unproperly c. Freshwater ecosystems? ☐ Properly ☐ Moderately well ☐ With limitations ☐ Unproperly	
#15	What should be the priorities for advancing the modelling of microplastics in LCA?	
#16	What novel tools or approaches would you consider useful for assessing the real-world environmental impacts of microplastics? (e.g., "dynamic LCA methods," "prospective LCA”, “consequential LCA”, “social-LCA”, etc.)	
Observations *Please describe any observations you consider necessary*		