



First International Conference Global Framework on Chemicals

16–20 November 2026 | Geneva, Switzerland

Implementation Programme 2

“Industry Engagement and Action along Value Chains”

Workstream on Chemical Footprint approaches

Chemical Footprint - Terminology and Methodological Framework

Convenor: United Nations Environment Programme (UNEP), Llorenç Milà i Canals

About this document:

This document was developed under the Workstream on Chemical Footprint approaches within Implementation Programme 2 of the Global Framework on Chemicals, through an inclusive multi-stakeholder process combining contributions from working-group members, a systematic literature review, iterative drafting and review, coordination with other working groups, and a wide stakeholder consultation. It responds to the absence of broadly agreed terminology and a standardized methodology for chemical footprint assessments, which currently limits the consistency, comparability and practical uptake of chemical footprint approaches, and is intended to inform the first GFC International Conference in November 2026, while laying the foundation for a future international standard.

Key messages:

1. **a chemical footprint should quantify potential toxicity-related impacts** on human health and ecosystem quality from chemical use and emissions across the life cycle of products, processes or organizational activities;
2. assessments **should follow an ISO-aligned, life-cycle-based, and iterative framework** covering goal and scope definition, inventory analysis, impact assessment, and results interpretation;
3. **partial assessments must use clear qualifiers**, such as “chemical usage” or “chemical emission” assessments, rather than being presented as complete chemical footprint assessments;
4. and results should support **transparency, hotspot identification, prioritization, substitution and performance improvement**, while being interpreted with disclosed boundaries, data gaps and uncertainties, and not as measures of chemical safety or risk.

The main applications of chemical footprint approaches are to support management and strategic decision-making across products, processes, organizations, sectors, and value chains. In particular, they can be used to:

- **Identify hotspots and priorities:** Determine which chemicals, chemical groups, processes, emission pathways, or life-cycle stages contribute most to potential human toxicity and ecotoxicity impacts.
- **Guide impact reduction and substitution:** Prioritize chemicals for restriction, phase-out, or substitution, assess alternatives, support safer and more sustainable substitution, and help avoid regrettable substitution or burden-shifting.
- **Track and improve performance:** Monitor reductions in chemical usage, emissions, and potential impacts over time, including comparisons of the same product, process, or organization across different years.
- **Compare alternatives:** Compare functionally equivalent products, processes, services, technologies, or organizational activities, while respecting methodological and ISO-related limitations on public comparative claims.
- **Support supply chain management:** Improve transparency and communication concerning chemical use, emissions, and impacts across suppliers and product value chains.
- **Inform product and process development:** Guide sustainable and green chemistry, innovation, product design, process optimization, and selection of safer and more sustainable alternatives.
- **Support sustainability reporting and finance:** Provide chemical-related, comparable environmental-performance information for corporate reporting, business models, investment decisions, and the integration of sound chemicals and waste management into financial approaches.
- **Inform policy and sector commitments:** Support implementation of relevant targets under the Global Framework on Chemicals, including reducing chemicals of concern and their impacts, promoting sustainable innovation, and demonstrating private-sector action.
- **Support targeted decisions using partial metrics:** Where a complete impact-level 'chemical footprint' assessment is not yet feasible, chemical-usage or chemical-emission results can already inform decisions, such as usage-volume reduction, emission-contribution analysis, and emission-threshold compliance.

Importantly, this document presents 'chemical footprint' as a complement to, not a replacement for, chemical safety and risk assessment. Its primary purpose is to evaluate and improve the overall life-cycle environmental performance of a system regarding potential human toxicity and ecotoxicity impacts. It is not intended to determine whether an individual chemical, product, or activity is "safe."

Suggested citation:

GFC (2026). Chemical Footprint - Terminology and Methodological Framework. Global Framework on Chemicals, UNEP. Available at <https://iomcwebinars.org/chemical-footprint-approaches>

Table of Contents:

1. Context.....	4
2. Scope	6
3. Way of working.....	8
4. Terms and definitions	9
4.1 Terms relating to chemicals	9
4.2 Terms relating to chemical footprint	12
4.3 Terms relating to interpretation and reporting of chemical footprint results.....	18
4.4 Terms relating to product, product system, process and organization	18
4.5 Terms relating to data and uncertainty.....	19
5. Methodological framework	21
5.1 Boundary conditions	21
5.2 General requirements	26
5.3 Goal and scope definition.....	28
5.4 Chemical footprint inventory analysis.....	29
5.5 Chemical footprint impact assessment	30
5.6 Interpretation of chemical footprint results	31
5.7 Limitations of chemical footprint.....	32
Acknowledgements	34

1. Context

1. Chemicals are essential building blocks of our society. Managing the usage, environmental releases and exposure to intentionally manufactured, unintentionally created or otherwise anthropogenically introduced chemicals has become an increasingly important element of the global sustainable development agenda. In this context, it is important to be able to characterize the impact of chemicals associated with their usage along the life cycle of products, processes or organizations, enabling the prevention, assessment and mitigation of chemical-related impacts if they affect human health, ecosystem quality or both. A general term for characterizing such impacts is 'environmental footprint', and a general utility of this is the intuitively clear summary communication of chemical pollution problems, even if they concern an array of chemicals. This asks for guidance on designing a corresponding 'chemical footprint' of human activities that specifically focuses on the quantification of potential environmental impacts in terms of human toxicity damaging human health and ecotoxicity damaging ecosystem quality, both associated with chemical usage and emissions along product and service life cycles.

2. In recent years, markets, investors, the private sector, regulators and the public have placed growing emphasis on transparent and comparable information about the use and impacts of chemicals, creating momentum and the need for wider adoption of chemical footprint approaches. This relevance was highlighted in the [Global Framework on Chemicals](#) (GFC) adopted in 2023 as a voluntary global framework presenting a plan to guide countries and stakeholders in jointly addressing the reduction of impacts along the life cycle of chemicals, including products and waste, with a vision for a safe, healthy and sustainable future. This framework included the chemical footprint approach as part of its strategic objectives and targets. Specifically, chemical footprint approaches are important for Target D6 on reduction in the usage of chemicals of concern or reduction of risks or adverse impacts linked to the usage of chemicals, for Target D3 on integrating strategies and policies for the sound management of chemicals and waste into finance approaches and business models, for Target A3 on minimizing adverse effects across the life cycle, and for Targets D1 to D4 on sustainable innovation and safer alternatives. This requires a globally consistent understanding of different aspects related to a chemical footprint.

3. The [Open-Ended Working Group of the GFC](#) recognized the importance of chemical footprint approaches in achieving the GFC vision of a planet free of harm from chemicals and waste for a safe, healthy and sustainable future. Following the open-ended working group meeting in June 2025, there is a clear interest from stakeholders to strengthen the application of chemical footprint approaches through practical guidance, sector commitments, and harmonized terminology, while advancing toward a robust, science-based international standard clarifying (a) what a chemical footprint refers to, (b) which approaches and data are relevant to assess it, and (c) how the assessment should be performed and its results be interpreted in the different relevant decision contexts. In response to the growing attention and interest in advancing these approaches, this thematic workstream on chemical footprint approaches is proposed to support implementation of the GFC and hopefully be adopted/established by the IC1 at the end of 2026.

4. The chemical footprint approaches workstream will contribute to advancing the targets and objectives of the GFC by strengthening the transparency, comparability, and global effectiveness of chemical footprint approaches. The initial proposal is to organize the work through three working groups, focusing on:

1. Harmonizing chemical footprint terminology, defining scope and principles of a chemical footprint, and initiating work towards developing an international standard, grounded in a robust, science-based systems approach.
2. Developing guidance for applying chemical footprint approaches within sector programmes.
3. Promoting industry sector commitments to implementing chemical footprint approaches aligned with specific GFC targets.
4. The end goal of the working groups is to provide inputs to the first session of the International Conference (IC1) in November 2026, as part of the broader Implementation Programmes to be adopted by IC1. The next sections provide some initial ideas on what the deliverables and work plans of the three working groups between September 2025 and the IC1 could be; this initial draft is open for comments and input by all interested stakeholders.

5. With that, a dedicated working group was established under the chemical footprint approaches workstream to specifically address the problem that there is currently no broadly agreed terminology or standardized methodology for chemical footprint. As a result, assessments and interpretations remain fragmented, have different scopes, and are difficult to compare, ultimately limiting their uptake into practice.

6. There are existing 'footprint' standards, such as carbon footprint ([ISO 14067:2018](#)) and water footprint ([ISO 14046:2014](#)). Moreover, there is a need for a clear and consistent chemical footprint interpretation. Based on that, the present guidance contributes to ongoing global efforts to improve transparency and accountability regarding the human toxicity and ecotoxicity related environmental impacts of chemicals used and emitted along product and service life cycles, by providing a structured terminology and methodological framework for assessing chemical footprint. The ambition is to lay the foundation for a global standard on chemical footprint. Such a standard would support greater consistency, comparability and practical application of 'chemical footprint' and underlying approaches across stakeholders. Additional guidance on, for example, specific data and tools relevant for application in the context of chemical footprint, details on methodological aspects beyond main principles, and practical considerations around calculation and interpretation of chemical footprint results in specific decision contexts and in relation to results from other chemicals management frameworks, such as chemical safety and risk assessment, should be provided beyond the present document in dedicated industry guidance initiatives and working groups.

7. Based on these considerations, the **aim of the present document** is to provide the foundation for a broadly agreed terminology and guidance on the methodological framework for assessing chemical footprint and guide related approaches. Specific

objectives are to (a) propose an aligned set of definitions relating to ‘chemical footprint’ as the foundation for developing an international standard for chemical footprint assessments, (b) provide a list of methodological aspects to support the assessment of chemical footprint and the development and application of chemical footprint approaches, and (c) consolidate background material to the definitions based on discussions and input from the contributing multi-stakeholder working group members. The target audience is all parties that require methodological guidance on assessing ‘chemical footprint’ and applying related approaches.

2. Scope

8. Considering the boundary conditions described in Section 5.1, the present document provides definitions for a set of terms, as well as guidance on aspects related to the methodological framework for carrying out a stand-alone chemical footprint assessment or as part of a more comprehensive environmental impact assessment, such as a life cycle assessment (LCA) or a product environmental footprint (PEF) assessment. The framework will particularly focus on the evaluation and/or comparison of the potential impacts on human health and ecosystem quality associated with chemical usage and related emissions along the life cycle of products, processes or organizations’ activities. Definitions and methodological guidance will be provided for assessing the different elements of a chemical footprint as shown in Figure 1.

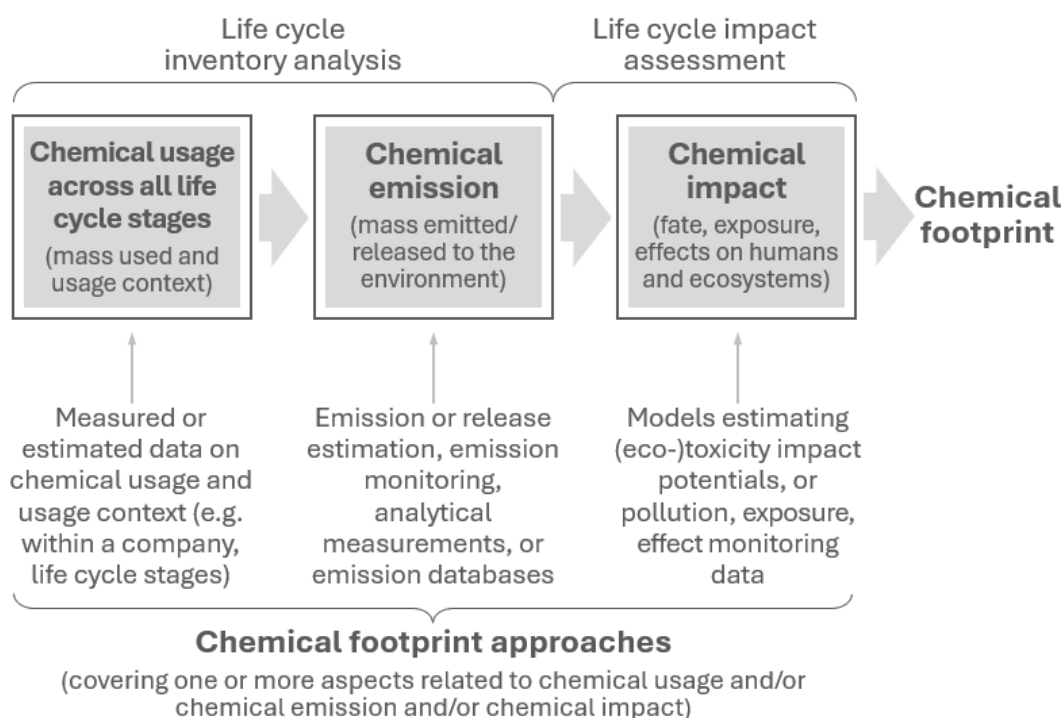


Figure 1. Main elements of a chemical footprint and relevant chemical footprint approaches. A chemical footprint assessment is an iterative process in which individual phases build on the results of one another, and in which different approaches (i.e. measured and estimated data, methods and tools) can be used in the assessment of chemical footprint elements.

9. The present document intentionally proposes a progressive chemical footprint assessment framework, as illustrated in Figure 1, that can be adopted by different

stakeholders depending on data availability, analytical maturity and the intended purpose of the assessment. The framework is intended to follow the life cycle assessment methodology to assess chemical impact, progressing along the elements of chemical usage-based accounting, chemical emission quantification and evaluating human toxicity and ecotoxicity impact potentials, in line with how these elements and related metrics are used in the field of quantitative, comparative frameworks, such as LCA. The progressive perspective is in recognition of the data limitations that may currently be encountered when employing the framework for particular cases (e.g. practitioners might lack emission data or impact potential estimates). With that, the framework is based on the logical set of phenomena along the source-to-receptor pathway, which is often summarized for practical purposes as the DPSIR-model (Driver, Pressure, State, Impact, Response), and which can be recognized in practical (policy) approaches, such as chemical safety and risk assessment, as well as in LCA. Each main element of a chemical footprint -- usage, emissions and impact potentials -- may already inform specific decisions and hence are important results beyond being integral parts of an overall chemical footprint.

10. With each element, the methodological comprehensiveness (e.g., data requirements, coverage of the source-to-impact pathway) increases while moving closer to the fundamental objective of footprint approaches: to derive **aggregate results from the quantification of (eco-)toxicity-related potential environmental impacts** on human health and ecosystem quality across contributing chemicals, processes, and life cycle stages. Furthermore, given the potential future application of the chemical footprint within sustainability reporting frameworks, the methodological framework is intended to remain flexible and adaptable as scientific methods and data availability evolve. It is to be noted that the bridging of data gaps may evolve considerably, for example, based on machine learning methods applied to the available data on chemical and human toxicological and ecotoxicological impacts.

11. The assessment includes the usage, environmental emissions and potential impacts on humans and/or ecosystems associated with intentionally manufactured, unintentionally created or otherwise anthropogenically introduced chemicals over product and service life cycles, along with the connected degradation, speciation or other relevant transformation, distribution and removal processes. On the other hand, impacts on human health and/or ecosystem quality associated with aspects other than those defined in human toxicity and ecotoxicity impact categories within LCA are not part of a chemical footprint. For example, impacts associated with emissions of greenhouse gases, nutrients, or ozone-depleting substances are assessed in separate impact categories, footprints, or comprehensive LCA.

12. Chemical footprint approaches may in principle be conducted at different levels of application, including products, services or organizations' activities. Consistently with the LCA methodology, the system boundaries of an assessment may cover the full life cycle of the assessed system or be limited to specific life cycle stages, depending on the intended purpose and scope of the assessment. Transparent documentation and communication of system boundaries is essential for the interpretation of results, and certain system boundary choices may limit the suitability of results for specific purposes (e.g. comparative assertions), consistent with ISO-

based LCA principles ([ISO 14040:2006](#), [ISO 14044:2006](#)). Together, the progressive chemical footprint framework and the flexibility in defining system boundaries are intended to facilitate uptake and practical application of chemical footprint approaches across stakeholders, and for a diversity of situations where the assessment of chemical footprints is considered relevant.

13. With this scope, the present document seeks to establish a glossary proposal as well as a foundation for developing an international standard for guiding chemical footprint assessments.

3. Way of working

14. During the [Open-Ended Working Group \(OEWG\)](#) of the GFC, organized in Uruguay in June 2025, stakeholders proposed to strengthen the application of 'chemical footprint' approaches through three working groups (WG), focusing on:

- WG1: Harmonizing chemical footprint terminology, defining scope and principles of chemical footprint approaches, and initiating work towards an international standard, grounded in a robust, science-based systems approach.
- WG2: Developing industry guidance for applying chemical footprint approaches within sector programmes.
- WG3: Promoting sectoral commitments to implementing chemical footprint approaches aligned with specific targets of the GFC.

15. The end goal of the working groups is to provide inputs to the GFC – [First International Conference \(IC1\)](#) in November 2026, as part of the broader Implementation Programmes to be adopted by IC1. The current document provides the outcomes of WG1 in terms of terminology and methodological framework guidance for chemical footprint assessments and has been aligned with the work of WG2 and WG3. Within WG1, the process of developing the present document followed the following steps to ensure inclusion of all contributing stakeholders and aiming for broad acceptance of definitions and methodological guidance for the chemical footprint:

1. WG1 members were asked to submit at any point in time during the development of the present document any material to WG1 co-leads that they find relevant, including documents or other items referring to existing definitions and/or terminology of chemical footprint, and/or application of chemical footprint approaches.
2. WG1 co-leads were then tasked to collect and store any material sent by WG1 members, to check all material sent by WG1 members and to consider the material to inform the drafting of definitions and methodological guidance related to chemical footprint and underlying approaches.
3. The draft terminology and methodological guidance on chemical footprint assessments (e.g. methodological choices, criteria, boundary conditions) were complemented by a systematic literature review coordinated by the WG1 co-leads.

16. WG1 members reviewed and contributed to the drafted document during multiple iterations and provided feedback and further input to the document in the form of edits and comments.

4. Based on continuous input from WG1 members to the document as well as based on continuous exchanges with WG2 and WG3 chairs including reviewing and commenting on related draft documents to ensure cross-WG consistency and alignment, WG1 co-leads refined the draft terminology and methodological guidance and implemented online meetings with the WG1 members to inform members on progress and updates in the document as well as to discuss remaining aspects that require further input or refinement.
5. Following review by WG1 members, the revised terminology and methodological guidance document was shared for wider stakeholder consultation.
6. The document was sent out for a wider stakeholder consultation, where all interested parties including and beyond WG1 members were invited to provide input and comments on the document.

17. WG1 co-leads revised and finalized the document based on input from the broader stakeholder consultation and discussed open questions, where relevant with WG1 members before final submission as input to the GFC – [First International Conference \(IC1\)](#).

4. Terms and definitions

4.1 Terms relating to chemicals

4.1.1 Chemical

18. *Proposed definition:* Substance of constant molecular composition with characteristic properties.

Note 1: This definition includes chemical elements and their compounds in the natural state or obtained by any manufacturing process. The definition covers any additive necessary to preserve the stability of the chemical and any impurity deriving from the process used but excludes any solvent which may be separated without affecting the stability of the substance or changing its composition ([GHS Rev. 11, 2025](#)). Chemicals are assessed at constituent level where data permit; where constituent identity/proportions are unavailable, this should be reported transparently as a data/completeness gap in *chemical footprint assessments* (4.2.5).

Note 2: Specific guidance should be provided to clarify that all chemicals are relevant for inclusion in a *chemical footprint assessment* (4.2.5), that practical inclusion is governed by cut-off criteria (see Section 5.3), and how to consider chemicals with missing information (e.g. missing *characterization factors* (4.2.15) as data gaps rather than assuming zero impact. Some initial guidance on how to consider chemicals with missing characterization factors is provided in Section 5.1.5.

Note 3: Certain decision contexts might require a special focus on so-called chemicals of concern, which should be clearly identified in the goal and scope definition phase (Section 5.3) of a chemical footprint assessment. Where details on identifying chemicals of concern are relevant in the context of a chemical footprint assessment, we refer to the dedicated GFC Cross-Thematic Group on Chemicals of Concern, which will develop a mapping of existing regulatory and voluntary approaches that identify/list chemicals of concern, also documenting the purpose, scope, criteria used under these different approaches, as well as commonalities and gaps. The group furthermore discussed the development of elements of guidance to support industry to identify and prioritize chemicals of concern for action.

[Source: Adapted from [IUPAC 2025](#)]

4.1.2 Chemical usage

19. *Proposed definition:* Quantity of *chemical* (4.1.1) mass used along the *life cycle* (4.2.7) of products, processes or organizations' activities.

Note 1: Useful to complement information on *chemical emissions* (4.1.3) and related *potential environmental impacts* (4.1.4) associated with chemical usage, especially where information on chemical emissions and/or related potential environmental impacts is not available or not feasible to determine. Chemical usage needs to be assessed within the same system boundaries that apply to other elements of a *chemical footprint assessment* (4.2.5) as defined in the assessment's goal and scope definition phase (Section 5.3).

Note 2: At organizational level, chemical usage could capture the following dimensions, depending on the specific business activities: chemicals manufactured and procured for use in own operations (e.g. manufacturing of chemicals).

[Source: Own definition]

4.1.3 Chemical emissions

20. *Proposed definition:* Quantity of *chemical* (4.1.1) mass released into the environment along the *life cycle* (4.2.7) of products, processes or organizations' activities.

Note 1: The term 'emission' is used to describe any form of release of a *chemical* (4.1.1) entering the environment. The term 'environment' is used to describe any part that is not included in the assessed system, and includes for example indoor and outdoor air, freshwater and marine water, agricultural and natural soil, consumer and worker environments, and direct contact.

Note 2: Useful to complement information on *potential environmental impacts* (4.1.4) associated with chemical emissions or information on chemical hazard information, especially where information on potential environmental impacts is not available or not feasible to determine. Chemical emissions need to be assessed within the same system boundaries that apply to other elements of a *chemical footprint assessment* (4.2.5) as defined in the assessment's goal and scope definition phase (Section 5.3).

Note 3: At organizational level, chemical emissions may include information related to chemicals procured, chemicals manufactured, and chemicals placed on the market as they leave the facilities of an organization. For value chain emissions, different data sources might need to be distinguished, such as actual measurement data, supplier-provided data, industry averages, and model estimates, which should be defined in the goal and scope definition phase (Section 5.3) of a chemical footprint assessment.

Note 4: Depending on the specific business activity, emissions can occur across environmental media (i.e. air, water and soil, consumer and worker environments, direct contact) and can include unintentional releases (e.g. from spills).

[Source: Own definition]

4.1.4 Potential environmental impacts

21. *Proposed definition:* Potential biological harm on human health via *human toxicity* (4.1.5) and/or on ecosystem quality via *ecotoxicity* (4.1.6) associated with exposure following *chemical usage* (4.1.2) and *chemical emissions* (4.1.3) along the *life cycle* (4.2.7) of products, processes or organizations' activities.

Note 1: Potential environmental impacts are interpreted as “relative expressions, as they are related to the functional unit of a product system” (ISO 14040:2006). In the context of *chemical footprint assessments* (4.2.5), potential environmental impacts refer to *impact categories* (4.2.11) representing specific environmental issues of concern associated with exposure following chemical usage and chemical emissions in *life cycle assessment* (4.2.8), namely *human toxicity* (4.1.5) and *ecotoxicity* (4.1.6). Specific guidance should be provided on which aspects are included in these impact categories, and how to derive related *characterization factors* (4.2.15) for each relevant *chemical* (4.1.1) to translate *chemical usage* (4.1.2) and/or related *chemical emissions* (4.1.3) into the associated potential environmental impacts related to human toxicity (including impacts associated with exposures to chemicals emitted to the environment, occupational exposures to chemicals and direct exposures to chemicals in products) and ecotoxicity.

Note 2: Potential environmental impacts include aspects related to *chemical usage* (4.1.2) and/or related *chemical emissions* (4.1.3), along with information linking chemical usage and/or chemical emissions to potential environmental impacts via *characterization factors* (4.2.15). Relevant characterization models follow the life cycle impact assessment approach based on providing quantitative, comparative, physically interpretable estimates of *human toxicity* (4.1.5) and *ecotoxicity* (4.1.6) impact scores, respecting the boundary conditions in Section 5.1. Other approaches may be relevant for specific decision contexts, to evaluate for example relevant hazard aspects associated with chemicals used or emitted within the life cycle of products, processes or organizations' activities. Initial guidance on how to consider chemicals with missing characterization factors is provided in Section 5.1.5.

[Source: ISO 10993-1:2025, #3.24, modified to apply a broader perspective beyond medical devices; Panko & Hitchcock 2011, modified to avoid using terms like ‘risk’ in the definition]

4.1.5 Human toxicity

22. *Proposed definition: Impact category (4.2.11)* concerning the extent to which contact with a chemical resulting from *chemical usage (4.1.2)* and/or *chemical emissions (4.1.3)* can lead to adverse effects on humans from cell to population level.

Note 1: Human toxicity is an *impact category (4.2.11)* considered in *life cycle assessment (4.2.8)*. Human toxicity *characterization factors (4.2.15)* consistently combine as the underlying *environmental mechanism (4.2.17)* aspects related to environmental fate and distribution of chemicals, subsequent human exposure (i.e. contact) with humans, and human toxicological effect potency.

[Source: based on [UNEP Life Cycle Initiative](#); [Bijster et al. 2017](#)]

4.1.6 Ecotoxicity

23. *Proposed definition: Impact category (4.2.11)* concerning the extent to which contact with a chemical resulting from *chemical usage (4.1.2)* and/or *chemical emissions (4.1.3)* can lead to adverse effects on ecosystem organisms from cell to biodiversity level.

Note 1: Ecotoxicity is an *impact category (4.2.11)* considered in *life cycle assessment (4.2.8)*. Ecotoxicity *characterization factors (4.2.15)* consistently combine as the underlying *environmental mechanism (4.2.17)* aspects related to environmental fate and distribution of chemicals, subsequent ecological exposure (i.e. contact) with ecosystem organisms, and ecotoxicological effect potency.

[Source: based on [UNEP Life Cycle Initiative](#); [Bijster et al. 2017](#)]

4.2 Terms relating to chemical footprint

4.2.1 Footprint

24. *Proposed definition:* Metric to report *life cycle assessment (4.2.8)* results for products, processes or organizations' activities, addressing an area of concern defined as an aspect of the natural environment, human health or resources of interest to society.

Note 1: A footprint does not replace any regulatory or other risk or safety assessment but focuses on any element of an organization's activities covering its products and processes that interact or can interact with the environment.

[Source: [ISO 14050:2020](#), #3.2.11 and #3.7.17, modified to combine definitions of 'footprint' and 'area of concern' in a single definition]

4.2.2 Chemical footprint

25. *Proposed definition:* Metric that quantifies the *potential environmental impacts (4.1.4)* associated with *human toxicity (4.1.5)* and *ecotoxicity (4.1.6)* related to *chemical usage (4.1.2)* and *chemical emissions (4.1.3)*.

Note 1: Potential environmental impacts are interpreted as "relative expressions, as they are related to the functional unit of a product system" ([ISO 14040:2006](#)). In the context of *chemical footprint assessments (4.2.5)*, potential environmental impacts refer to the *impact categories (4.2.11)* of *human toxicity (4.1.5)* and *ecotoxicity*

(4.1.6) representing specific environmental issues of concern associated with chemical emissions in *life cycle assessment* (4.2.8).

Note 2: If *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and/or *ecotoxicity* (4.1.6) have not been comprehensively quantified, the term ‘chemical footprint’ can only be applied with an additional qualifier to differentiate the interpretation of a chemical footprint from any other metric. A qualifier is one or several additional words that are used in conjunction with the term ‘chemical footprint’ to describe the aspects studied in the *chemical footprint assessment* (4.2.5), e.g. *chemical usage* (4.2.3) or *chemical emission* (4.2.4). Assessments involving a qualifier in the footprint name may serve as an input to assess one or more specific elements of a chemical footprint. The term ‘chemical footprint’ without any qualifier is to represent a metric at the level of potential environmental impacts, building on information on *chemical usage* (4.1.2), related *chemical emissions* (4.1.3) and linking chemical usage and/or chemical emissions to potential environmental impacts via *characterization factors* (4.2.15). Which results are communicated externally/publicly will depend on the intended application of the results and the decision context of the study.

Note 3: Specific guidance should be provided on what the result of a *chemical footprint assessment* (4.2.5) should include, which will depend on the specific decision context, e.g. whether aggregated numerical values per impact category are sufficient to inform on overall performance of an organization over its activities or whether additional information needs to be reported, such as *chemical usage* (4.1.2) context and *life cycle* (4.2.7) stage, *chemical emissions* (4.1.3) pathways and/or impact potentials expressed as *characterization factors* (4.2.15) for each contributing *chemical* (4.1.1) to inform specific management decisions at the relevant level(s) within an organization. Where appropriate characterization factors are not available, specific guidance should be provided to support the development of approaches to link chemical usage and/or related chemical emissions to potential environmental impacts.

Note 4: Specific guidance should be provided on the physical unit in which a chemical footprint result should be reported, at what level of disaggregation to calculate results for each considered *chemical* (4.1.1) or chemical group, and how to aggregate results across chemicals or chemical groups, to ensure aggregation approaches preserve chemical-specific properties (e.g., speciation, bioavailability, compound form), and clarify appropriate levels of disaggregation prior to aggregation.

[Source: [ISO 14046:2014](#), #3.3.1, modified to adapt the focus to chemicals]

4.2.3 Chemical usage

26. *Proposed definition:* Metric that quantifies the *chemical* (4.1.1) mass used along the *life cycle* (4.2.7) of products, processes or organizations’ activities.

Note 1: This metric provides results for a specific element of a *chemical footprint* (4.2.2), namely results associated with *chemical usage* (4.1.2). Combining all relevant elements, namely chemical usage, *chemical emissions* (4.1.3) and *characterization factors* (4.2.15), will then be considered the ‘chemical footprint’.

With that, chemical usage information is a component of a chemical footprint (i.e. chemical usage is based on mass used but also provides a narrative statement on the relationship between the metric and the final chemical footprint), while it can already provide useful evaluation results as a standalone metric.

Note 2: Specific guidance should be provided on the physical unit in which a chemical usage result should be reported, at what level of disaggregation to calculate results for each considered *chemical* (4.1.1) or chemical group, what additional information might be relevant to be reported along with usage results (e.g. specific hazard classification information), and how to aggregate results across chemicals or chemical groups in a way that ideally facilitates that chemical usage can be translated into related *chemical emissions* (4.1.3) and/or directly into *potential environmental impacts* (4.1.4).

[Source: Own definition, aligned with 4.2.2]

4.2.4 Chemical emission

27. *Proposed definition:* Metric that quantifies the *chemical* (4.1.1) mass emitted to the environment along the *life cycle* (4.2.7) of products, processes or organizations' activities.

Note 1: This metric provides results for a specific element of a *chemical footprint* (4.2.2), namely results associated with *chemical emissions* (4.1.3). Combining all relevant elements, namely *chemical usage* (4.1.2), chemical emissions and *characterization factors* (4.2.15), will then be considered the 'chemical footprint'. With that, chemical emission information is a component of a chemical footprint (i.e. chemical usage is based on mass emitted but also provides a narrative statement on the relationship between the metric and the final chemical footprint), while it can already provide useful evaluation results as a standalone metric.

Note 2: Specific guidance should be provided on the physical unit in which a chemical emission result should be reported, into which environmental compartment emissions take place (such as indoor and outdoor air, water, soil, and occupational and consumer environments), at what level of disaggregation to calculate results for each considered *chemical* (4.1.1) or chemical group, what additional information might be relevant to be reported along with usage results (e.g. specific hazard classification information), and how to aggregate results across chemicals or chemical groups in a way that ideally facilitates that chemical emissions can be translated into related *potential environmental impacts* (4.1.4).

Note 3: Since *chemical footprint* (4.2.2) is defined as a metric representing *potential environmental impacts* (4.1.4) in terms of *human toxicity* (4.1.5) and *ecotoxicity* (4.1.6), there is no separate definition for a potential environmental impact footprint. Metrics that comprehensively combine *chemical usage* (4.1.2), *chemical emissions* (4.1.3) and human toxicity and/or ecotoxicity *characterization factors* (4.2.15) to express potential environmental impact related to human health and/or ecosystem quality can directly be referred to as chemical footprints, for the specified system boundaries.

[Source: Own definition, aligned with 4.2.2]

4.2.5 Chemical footprint assessment

28. *Proposed definition:* Compilation and evaluation of the inputs, outputs and *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and *ecotoxicity* (4.1.6) related to *chemical usage* (4.1.2) and *chemical emissions* (4.1.3) affected by products, processes or organizations' activities.

Note 1: If a chemical footprint assessment reflects the comprehensive evaluation of *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and/or *ecotoxicity* (4.1.6), it can be called 'chemical footprint assessment' without any qualifier. If a chemical footprint assessment does not comprehensively evaluate potential environmental impacts, it needs to be associated with a qualifier that describes objectively what has been assessed, in line with *chemical footprint* (4.2.2), Note 1.

Note 2: Since every *chemical* (4.1.1) can potentially contribute to a *chemical footprint* (4.2.2) as a cumulative metric, all chemicals are within the scope of a chemical footprint assessment unless the chemical scope of such an assessment is explicitly defined differently. However, the evaluation targets and levels of detail (e.g. related to underlying substance data) across considered chemicals may be determined through transparent screening and prioritization that should be transparently documented in the goal and scope definition phase (Section 5.3) of a chemical footprint assessment, also considering that some chemicals may occur naturally in the environment (see Section 5.6).

Note 3: Chemical footprint assessments must follow the general methodological framework based on an iterative process of goal and scope definition (Section 5.3), chemical footprint inventory analysis (Section 5.4), chemical footprint impact assessment (Section 5.5), and interpretation of chemical footprint results (Section 5.6). Specific guidance should be provided on the methodological approach to be followed for conducting these phases of a chemical footprint assessment.

[Source: [ISO 14046:2014](#), #3.3.2, modified to adapt the focus to chemicals]

4.2.6 Chemical footprint approach

29. *Proposed definition:* Data and methods that provide relevant contributions to a *chemical footprint assessment* (4.2.5) for deriving a *chemical footprint* (4.2.2) or one or more of its elements, that is *chemical usage* (4.1.2), and/or related *chemical emissions* (4.1.3), and/or *impact characterization factors* (4.2.15).

Note 1: While *chemical footprint* (4.2.2) comprehensively quantifies *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and/or *ecotoxicity* (4.1.6), any approach might be called a 'chemical footprint approach' that quantifies any one or more specific aspects that are relevant for deriving a chemical footprint.

Note 2: Specific guidance should be provided on the criteria that need to be fulfilled for any data and methods to be considered relevant chemical footprint approaches.

[Source: Own definition]

4.2.7 Life cycle

30. *Definition:* Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal.

[Source: [ISO 14044:2006](#), #3.1]

4.2.8 Life cycle assessment (LCA)

31. *Definition:* Compilation and evaluation of the inputs, outputs and the *potential environmental impacts* (4.1.4) of a product system throughout its *life cycle* (4.2.7).

[Source: [ISO 14044:2006](#), #3.2]

4.2.9 Life cycle inventory (LCI) analysis

32. *Definition:* Phase of *life cycle assessment* (4.2.8) involving the compilation and quantification of inputs and outputs for a product throughout its *life cycle* (4.2.7).

Note 1: Inventory analysis involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system referring to the life cycle of products, processes or organizations' activities.

[Source: [ISO 14044:2006](#), #3.3]

4.2.10 Life cycle impact assessment (LCIA)

33. *Definition:* Phase of *life cycle assessment* (4.2.8) aimed at understanding and evaluating the magnitude and significance of the *potential environmental impacts* (4.1.4) for a product system throughout the *life cycle* (4.2.7) of the product.

[Source: [ISO 14044:2006](#), #3.4]

4.2.11 Impact category

34. *Definition:* Class representing environmental issues of concern to which *life cycle inventory analysis* (4.2.9) results may be assigned.

[Source: [ISO 14044:2006](#), #3.39]

4.2.12 Category endpoint

35. *Definition:* Attribute or aspect of the natural environment, human health, or resources, identifying an environmental issue giving cause for concern.

Note 1: For the *human toxicity* (4.1.5) *impact category* (4.2.11), this refers to *characterization factors* (4.2.15) expressed as human toxicity potential with units expressing population-level incidence risk (midpoint level) or population-level lifetime loss (damage level). For the *ecotoxicity* (4.1.6) *impact category*, this refers to *characterization factors* expressed as ecotoxicity potential with units expressing potentially affected fractions (PAF) of species integrated over exposure volume and time (midpoint level) and potentially disappeared fractions (PDF) of species integrated over exposure volume and time.

[Source: [ISO 14044:2006](#), #3.36]

4.2.13 Impact category indicator

36. *Definition:* Quantifiable representation of an *impact category* (4.2.11).

Note 1: The shorter expression ‘category indicator’ can be used for improved readability.

[Source: [ISO 14044:2006](#), #3.40]

4.2.14 Chemical footprint profile

37. *Proposed definition:* Compilation of *impact category indicator* (4.2.12) results addressing *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and *ecotoxicity* (4.1.6) related to *chemical usage* (4.1.2) and *chemical emissions* (4.1.3).

Note 1: If a chemical footprint profile reflects comprehensively *potential environmental impacts* (4.1.4) associated with *human toxicity* (4.1.5) and/or *ecotoxicity* (4.1.6), it can be called a ‘chemical footprint profile’ without any qualifier. If a chemical footprint profile does not reflect comprehensively potential environmental impacts, it needs to be associated with a qualifier that describes objectively what has been assessed, in line with *chemical footprint* (4.2.2), *Note 1*.

[Source: [ISO 14046:2014](#), #3.3.13, modified to adapt the focus to chemicals]

4.2.15 Characterization factor

38. *Definition:* Factor derived from a *characterization model* (4.2.16) which is applied to convert an assigned *life cycle inventory analysis* (4.2.9) result to the common unit of the *category indicator* (4.2.12).

Note 1: This metric provides results for a specific element of a *chemical footprint* (4.2.2), namely results associated with linking *chemical usage* (4.1.2) and/or *chemical emissions* (4.1.3) to *potential environmental impacts* (4.1.4). Combining all relevant elements, namely chemical usage, chemical emissions and characterization factors, will then be considered the ‘chemical footprint’.

Note 2: The common unit allows calculation of the *category indicator* (4.2.12) result.

Note 3: Specific guidance should be provided on which *environmental mechanism* (4.2.17) should be addressed by the characterization factors, which *characterization model* (4.2.16) is applicable to derive characterization factors, and how to address methodological limitations and data gaps to derive a comprehensive set of characterization factors for each relevant *chemical* (4.1.1). Some initial guidance on how to consider chemicals with missing characterization factors is provided in Section 5.1.5.

[Source: [ISO 14044:2006](#), #3.37]

4.2.16 Characterization model

39. *Definition:* Characterization models reflect the *environmental mechanism* (4.2.17) by describing the relationship between the *LCI* (4.2.9) results, *category indicators* (4.2.12) and, in some cases, *category endpoint(s)* (4.2.13). The characterization model is used to derive the *characterization factors* (4.2.15).

Note 1: *Environmental mechanism* (4.2.17) refers to mechanisms affecting human health via *human toxicity* (4.1.5) aspects or to mechanisms affecting ecosystem quality via *ecotoxicity* (4.1.6) aspects.

[Source: [ISO 14044:2006](#), #4.4.2.2.1]

4.2.17 Environmental mechanism

40. *Definition*: System of physical, chemical and biological processes for a given *impact category* (4.2.11), linking the *life cycle inventory analysis* (4.2.9) results to *category indicators* (4.2.12) and to *category endpoints* (4.2.13).

[Source: [ISO 14044:2006](#), #3.38]

4.3 Terms relating to interpretation and reporting of chemical footprint results

4.3.1 Comparative assertion

41. *Definition*: Environmental claim regarding the superiority or equivalence of one *product* (4.4.1) versus a competing product that performs the same function.

Note 1: Product in this context refers to the life cycles of products, processes, or organizations' activities.

[Source: [ISO 14044:2006](#), #3.6]

4.3.2 Regrettable substitution

42. *Proposed definition*: Replacing a *chemical* (4.1.1) where the alternative turns out either to result in similar or worse *potential environmental impacts* (4.1.4) than the replaced chemical, or to involve shifting the burden of the impact to another entity.

Note 1: Chemical footprint results constitute specific input with respect to human toxicity and/or ecotoxicity and should be complemented with other considerations (e.g. results from other assessing potential environmental impacts associated with other impact categories, technical feasibility, and social aspects) that are relevant to support regrettable substitution decisions and to avoid burden shifting across life cycles, impact categories or other assessment-relevant aspects.

[Source: [UNEP GCO II](#) (mandated by [UNEA resolution 2/7](#)), Section 5.3, p. 443, modified to align with other defined terminology used in the present document]

4.3.3 Interested party

43. *Definition*: Person or organization that can affect, be affected by, or perceive themselves to be affected by the results of a *chemical footprint assessment* (4.2.5).

[Source: [ISO 14046:2014](#), #3.4.2, modified to adapt the focus to chemicals]

4.4 Terms relating to product, product system, process and organization

4.4.1 Product

44. *Definition*: Any item, whether or not it is interconnected to other items, supplied or made available, whether for consideration or not, including in the context of providing a service, which is intended for consumers or is likely, under reasonably foreseeable conditions, to be used by consumers even if not intended for them.

Note 1: The term 'Product' includes any good or service in use industrially, professionally and/or by consumers. The term "whether for consideration or not" refers to the intention of bringing a product to the market.

[Source: [Regulation \(EU\) 2023/988](#), Article 3, #1]

4.4.2 Product system

45. *Definition*: Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the *life cycle* (4.2.7) of a *product* (4.4.1).

Note 1: The considered product system may address any type of system from products, processes and organizations' activities as should be transparently defined in the goal and scope definition phase (Section 5.3) of a *chemical footprint assessment* (4.2.5).

[Source: [ISO 14044:2006](#), #3.28]

4.4.3 Process

46. *Definition*: Set of interrelated or interacting activities that transform inputs into outputs.

[Source: [ISO 14044:2006](#), #3.11]

4.4.4 Organization

47. *Definition*: Person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives.

Note 1: An organization's activities include all its marketed items, its own operations and operations of its upstream suppliers, depending on the stated scope in the goal and scope definition phase (Section 5.3).

[Source: [ISO 14046:2014](#), #3.5.11]

4.4.5 Waste

48. *Definition*: Substances or objects which the holder intends or is required to dispose of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

Note 1: The definition is taken from the [Basel Convention](#) on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (22 March 1989) but is not confined in this International Standard to hazardous waste.

Note 2: Waste in the context of *chemical footprint* (4.2.2) refers to the *life cycle* (4.2.7) of *chemicals* (4.1.1), including *products* (4.4.1) and waste. The term "Substances" includes chemicals and materials. The term "objects" includes products.

[Source: [ISO 14044:2006](#), #3.35]

4.5 Terms relating to data and uncertainty

4.5.1 Primary data

49. *Definition*: Quantified value of a unit process or an activity obtained from a direct measurement or a calculation based on direct measurements at its original source.

Note 1: Primary data do not necessarily originate from the *product system* (4.4.2) under assessment because primary data may relate to a different but comparable product system to that being assessed.

Note 2: The term “unit process” refers to the smallest element considered in the *life cycle inventory analysis* (4.2.9) for which input and output data are quantified.

Note 3: In the context of *chemical footprint* (4.2.2), it should be clearly indicated whether each data point is actual measurement data, supplier-provided data, industry average, model estimate, or refers to any other source.

[Source: [ISO 14046:2014](#), #3.6.1]

4.5.2 Secondary data

50. *Definition:* Data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source.

Note 1: Secondary data sources can include but may not be restricted to databases and published literature validated by competent authorities.

Note 2: In the context of *chemical footprint* (4.2.2), it should be clearly indicated whether each data point is actual measurement data, supplier-provided data, industry average, model estimate, or refers to any other source.

[Source: [ISO 14046:2014](#), #3.6.2]

4.5.3 Uncertainty analysis

51. *Definition:* Systematic procedure to quantify the uncertainty introduced in the results of a *life cycle inventory analysis* (4.2.9) and in the results of the *life cycle impact assessment* (4.2.10), due to the cumulative effects of model imprecision, input uncertainty and data variability.

Note 1: Either ranges or probability distributions are used to determine uncertainty in the results, and referring to aspects related to parameter and model errors or variability.

Note 2: Specific guidance should be provided on how to conduct an uncertainty analysis, and in which form to present its results as part of a *chemical footprint assessment* (4.2.5).

Note 3: Uncertainty should explicitly address the temporal and geographical representativeness of chemical use, emission, and associated impact results, as well as information on the treatment of geographical and temporal differentiation in *characterization factors* (4.2.15), including assumptions, applicability, and potential implications for result interpretation. These aspects, along with the selection and justification of relevant impact indicators, should be defined in the goal and scope definition phase (Section 5.3). Uncertainty should moreover transparently report on which and for how many chemicals there are no inventory and/or characterization factor results available.

[Source: [ISO 14044:2006](#), #3.33, modified to also include uncertainty in impact assessment]

5. Methodological framework

52. In the following chapter, methodological guidance associated with the concept of 'chemical footprint' and related 'chemical footprint approaches' is provided, starting with relevant boundary conditions (Section 5.1) and general guidance related to the underlying principles. As part of this general guidance, no specific data, methods or tools will be proposed or mentioned, as this should be part of more detailed guidance in relation to assessing and interpreting chemical footprint results in different sectors, regions, and decision contexts. However, data, methods and tools used in chemical footprint assessments should be transparent and scientifically justified and be as much as possible aligned with widely accepted regulatory or other data classification frameworks, product stewardship, and modelling standards that are compatible with the boundary conditions outlined in the following section.

5.1 Boundary conditions

53. The following section describes the boundary conditions that define the elements and the scope of the chemical footprint concept. Such elements define the purpose of having a unitary definition (Section 5.1.1), the practical relevance of the concept (Section 5.1.2), the importance of leveraging existing frameworks (Section 5.1.3), the complementary nature of the concept with existing chemicals management tools with each tool having its own decision contexts and assessment conditions (Section 5.1.4), and finally the feasibility in applying it for decision-making (Section 5.1.5).

5.1.1 Clear interpretation

54. To enable a consistent application of chemical footprint approaches across stakeholders, companies, sectors, regions, capacities and application contexts, and to enable a consistent interpretation of chemical footprint results, including facilitating comparison across assessments where appropriate, terms related to chemical footprint must be clearly defined. More specifically, providing a single, unitary definition and interpretation for each term and metric is key to a common understanding of the proposed terms, with an appropriate level of granularity to accommodate for sectoral specificities, company-specific circumstances, and different decision contexts. In this context, different approaches, data and tools might be relevant that consider the specific usage, emission, fate, exposure and effect characteristics of different chemicals, while ensuring that the underlying metrics facilitate aggregation and comparison across chemicals.

55. Where current practice, specific conditions (e.g. the feasibility of an assessment), or limited capacity (e.g. companies with very few employees, such as Small and Medium-sized Enterprises) led to terms being interpreted differently depending on various aspects (e.g. assessment scopes), qualifiers should be proposed to the relevant terms to support a clear and unambiguous interpretation and facilitate differentiation of assessment scope and focus (see Section 5.1.5). Such qualifiers are consistent with other ISO-standardized footprint assessment frameworks, such as the Water Footprint ([ISO 14046:2014](#), see #3.3.1), where a qualifier is described as one or several additional words used in conjunction with a specific term to avoid multiple interpretations of the same term and provide additional

specificity to relevant terms to clarify, for instance, differences in assessment scope. Moreover, a periodic review mechanism might be needed to consider how methodological advancements over time might potentially influence the interpretation of chemical footprint results.

5.1.2 Supporting management decisions

56. The proposed definitions of terms and methodological guidance related to chemical footprint and its underlying approaches should be designed to meaningfully inform its intended applications. Intended applications of chemical footprint results include informing management decisions towards integrating strategies and policies for the sound management of chemicals and waste across stakeholders, companies, sectors, regions, capacities and application contexts, as well as product comparisons, supply chain management, sustainability reporting and improvement assessment, while respecting ISO limitations on comparative assertions.

57. Different intended applications of chemical footprint results may require different levels of detail, depending on the actual decision context. This can in the simplest way be an aggregated numerical value per impact category in support of, for example, comparing the chemical footprint performance of two products, processes or organizations' activities, or comparing the performance of the same product, process or organization's activities across years. In other contexts, details beyond an overall chemical footprint result might be required to facilitate making actual management decisions. This may include, for example, information on the specific chemical usage context, emissions, emission media, emission routes, exposure conditions, involved human and/or ecological receptors that are affected, an overview of the specific contribution of individual chemicals or chemical groups, processes and/or life cycle stages to overall chemical footprint performance, management measures, reduction performance, substitution status, or governance aspects. In addition, depending on the goal and scope of a chemical footprint assessment, further information may be needed to support interpretation and decision-making, (e.g. hazard characteristics, regulatory considerations, or data availability and quality aspects). Finally, certain decision contexts might not require results at the level of chemical footprint but may already use results for certain chemical footprint elements. Examples are decisions related to the exceedance of emission levels as such, which might not require impact-level information. Such aspects need to be clearly defined in the Goal and Scope definition phase of a chemical footprint assessment (see Section 5.3).

58. Where different decision contexts require different levels of details in chemical footprint results, methodological guidance should be provided to facilitate the broad application of chemical footprint and its underlying approaches across decision and management contexts.

5.1.3 Alignment with other footprint tools and standards

59. The term 'footprint' is used in policy frameworks, voluntary market practices and standardization documents. ISO standards exist that follow a specific structure for describing terms and methodological framework in relation to a 'footprint' assessment, such as the [ISO 14067:2018](#) for 'carbon footprint' and [ISO 14046:2014](#) for 'water footprint'. In these standards, 'footprints' summarize complex information related to

human activities, environmental emissions or resource consumption and related potential impact on the climate and water system, respectively, in a single metric with meaningful interpretation of potential environmental impacts (on human health, ecosystem quality and natural resources), which can be summarized per product, process, or an organization's activities. While the underlying mechanisms of these existing footprint frameworks differ in various aspects, such as spatiotemporal dimensions, both consistently follow and build upon the principles, requirements and guidelines identified in international standards on **life cycle assessment (LCA)**, [ISO 14040:2006](#) and [ISO 14044:2006](#). Footprint standards addressing a single issue of concern are using these standards as normative references covering all relevant environmental impacts.

60. Specifically, both footprint standards use the LCA methodology with focus on a specific impact category, to help avoiding burden-shifting across life cycle stages, products, processes or organizations' activities, facilitate transparent quantification of 'footprint' results and express them in terms of potential environmental impact, and enable aggregation, for example across life cycle stages and emitted substances.

61. For facilitating a straightforward process to use the present document as a foundation for developing an ISO standard for chemical footprint that is as much as possible aligned with existing footprint standards while adequately addressing aspects that are unique to chemicals in the context of chemical footprint, we build on the same methodological foundation as other footprint standards, namely LCA, aiming at facilitating the consideration of different life cycle stages, allow for aggregation across relevant aspects, such as chemicals and/or life cycle stages, and considering both inventory analysis and impact assessment to inform decisions, with focus on one or more specific impact categories relevant for chemical footprint, namely **human toxicity and/or ecotoxicity**.

62. The knowledge base for the characterization of a chemical footprint consists of information on chemicals (physicochemical characteristics), usage and emissions, fate and exposure processes as well as hazard (for human health and ecosystem quality), which should be combined according to well-established and scientifically sound methodological approaches. Where hazard information is relevant, it should be compliant with well accepted and established classification and evaluation approaches, such as the Globally Harmonized System of Classification and Labelling of Chemicals ([GHS](#)) as adopted by multiple countries. Current impact characterization models might not equally apply to all chemicals and need to consider data and processes that are applicable to different types of chemicals, for example considering phase partitioning for organic chemicals, speciation for metal compounds and chemical reactions for certain inorganic substances. Based on that, chemical footprint approaches, including relevant data and models, need to consider important differences in behavior, exposure pathways, and environmental effects across different types of chemicals to ensure overall comparability of chemical footprint results.

5.1.4 Complementing existing management tools

63. Specifically for chemicals, national and international regulatory frameworks, such as chemical safety assessment and environmental impact assessment, are in place to address specific hazards or risks. For these frameworks, various tools, data and classification systems allow the deployment of assessments according to the specific decision contexts, boundary conditions, and requirements of these frameworks. This includes, for example, the introduction of conservative assumptions aimed at achieving certain protection levels or the binning (i.e. transforming numerical data into discrete categories) of certain criteria results where aggregation is not needed. Such frameworks, however, have their specific decision space, which differs considerably from the decision space that ‘footprint’ assessments can inform. Chemical footprint assessments explicitly aim to support sustainable chemicals and waste management strategies by characterizing human toxicity and ecotoxicity impacts over the life cycle of products, processes or organizations’ activities on a common functional basis, facilitating supply chain communication and aggregation of results at the level of overall impact performance. In practice, specific priority aspects might be defined as part of the Goal and Scope phase of a chemical footprint assessment (see Section 5.3).

64. While differing in scope and purpose, chemical footprint approaches draw on many of the same underlying data and concepts used in regulatory assessments, including, for example, information on usage, emissions, exposure, and intrinsic hazard properties (e.g. chemical partitioning or speciation informing fate and distribution, bioaccumulation and bioavailability informing exposure and toxicity potency informing toxicological effects). The purpose of a chemical footprint, however, is to enable supply chain transparency, chemical prioritization/substitution and environmental performance tracking at a system level, enabling aggregation and comparison across chemicals, processes, life cycle stages and systems. With that, a chemical footprint complements other frameworks. That is, the footprint approach aims to eventually provide quantitative insights into the aggregated potential environmental impacts of an assemblage of chemicals involved in and emitted along product, service or technology life cycles due to human activities. More specifically, chemical footprint approaches complement existing chemical management tools and support prioritization, substitution, and continuous improvement efforts, based on a clear interpretation that might require complementary information, including information related to chemical hazards, data availability, and other decision-relevant aspects.

65. Chemical hazard data are being used in risk assessment as well as in LCA-based assessment approaches. Hence, existing global chemical classification systems accepted for use in risk assessment can also serve to provide a common baseline for classifying chemicals that are assessed in chemical footprint assessments. However, differences in the respective underlying requirements (e.g. protective context using conservative estimates to inform safety or risk decisions versus comparative context using central estimates to support sustainable chemical and waste management strategies) and boundary conditions (e.g. quantitative results that need to be quantitatively aggregated versus using discrete data categories and scores) influence how such hazard data are processed in the different frameworks.

Differences in such requirements and boundary conditions necessarily lead to methodological differences between LCA-based 'footprint' assessments and other chemicals management frameworks, even if the same data are used as inputs. Based on these considerations, a chemical footprint result is not to be interpreted in terms of safety or risk but in relation to an overall environmental performance of a considered system over its entire life cycle with respect to potential human toxicity and ecotoxicity impacts. The aim of the present document is to comply with the specific methodological framework underlying 'footprint' assessments, respecting related decision spaces and application contexts.

5.1.5 Considering feasibility

66. To inform management decisions, chemical footprint approaches need to be feasibly applied, and chemical footprint results be feasibly derived by the various relevant stakeholders, including small companies with limited assessment capacity.

67. On the inventory analysis side, which includes information on chemical usage and related information on chemical emissions, existing efforts focus on deriving company-specific and/or sector-specific data for a broad set of chemicals (for usage), as well as on national or other inventory datasets (for emissions). Such data and information already provide a feasible starting point for various stakeholders to generate inventory results, which are an important element of an overall chemical footprint.

68. On the impact assessment side, there are tools that aim at translating chemical usage and/or related chemical emissions into potential impacts on humans and/or ecosystems via so-called 'characterization factors' for 'human toxicity' and 'ecotoxicity' impacts, respectively. However, even though some widely used methodologies that generate relevant characterization factors already provide results for thousands of chemicals, characterization factors are not available for the larger share of currently marketed chemicals that are relevant for the purpose of chemical footprint assessments.

69. It is currently not feasible to task the stakeholders that apply chemical footprint approaches with the generation of characterization factors where these are currently missing. This is due to the complexity of the underlying characterization methods and the lack of current agreement on the application of input data sources, data processing and reporting from existing characterization methods across stakeholder groups, regions and sectors, which can compromise interpretation and comparison of related results.

70. Given these feasibility constraints, various stakeholders might in practice not currently be able to implement all phases of a chemical footprint assessment based on different assessment capacity and being at different levels of operationalizing chemical footprint approaches. In such cases, stakeholders can start with focusing on different phases as all phases will provide important input for a chemical footprint assessment, and they might already use the results of the phases that they can implement to support certain decisions. Moreover, it should be highlighted for how many chemicals characterization factors are missing. Further guidance will be required to clarify how to generate new characterization factors, for example based on data gap

filling methods using machine learning or other techniques, who should provide such factors, and how to ensure consistency with existing factors. As a starting point, characterization factors are generally compiled by experts using life cycle toxicity characterization models and made available to all stakeholders in an open and transparent way. Furthermore, a mechanism should be implemented to task relevant experts and providers of toxicity characterization models with the generation of missing characterization factors. Whenever new characterization factors are generated, additional validation efforts will be needed to ensure consistency with existing factors.

71. Several aspects related to assessing a chemical footprint might vary over space and time. This includes, for example, regionally varying emission patterns, chemical background concentrations in the environment, and species richness, and seasonal variations in chemical usage, human exposure patterns, and species abundance. Relevant data for some of these aspects are in many cases not available to enable spatiotemporal assessments, and further guidance should be provided on how to consider spatiotemporal aspects in chemical footprint inventory analysis and impact assessment phases, in line with the Goal and Scope definition.

72. To accommodate the progress in developing and applying chemical footprint approaches, as well as interpreting and using chemical footprint results for informing relevant management decisions, certain qualifiers might be used, if relevant chemical footprint approaches provide results that do not yet reflect an LCA-based, impact-level chemical footprint. With such qualifiers, it will be possible to generate results for certain elements (e.g. inventory results at the level of chemical usage) of an overall chemical footprint, while making explicit what these results represent. Results based on assessments using such qualifiers may serve (a) as standalone results for specific decision contexts that do not require a full chemical footprint assessment, or (b) as input to a chemical footprint assessment by providing results of a relevant chemical footprint element, which may be combined with results of other elements to yield chemical footprint results as soon as this is becoming feasible. Specific decisions that can be supported by results from individual chemical footprint elements include, for example, decision related to emission threshold compliance, overall usage volume reduction ambitions, or emission contribution analysis. Whenever specific choices in terms of aspects covered are relevant for a chemical footprint assessment (e.g. characterizing only a sub-set of exposure pathways, focusing on specific protection areas, including emissions only for a certain scope, or specific model choices), such information needs to be transparently communicated and justified where relevant according to the Goal and Scope definition phase (see Section 5.3).

5.2 General requirements

73. This section provides methodological guidance for the quantification, evaluation, and reporting related to chemical footprint assessments, adopting a life cycle perspective. The framework is based on the principles laid out in relevant ISO standards, namely [ISO 14040:2006](#) and [ISO 14044:2006](#) for Life Cycle Assessment (LCA), and incorporating concepts from [ISO 14046:2014](#) (water footprint) and [ISO 14067:2018](#) (carbon footprint), to ensure scientific consistency and environmental relevance. A chemical footprint assessment is defined as an iterative process that

includes the analysis of chemical usage and emissions along entire life cycles of products, processes and organizations' activities, as well as an evaluation of environmental fate, human and ecological exposure, and toxicity/ecotoxicity potency, for both the chemicals used and the formation of chemical transformation products. With that, a chemical footprint assessment considers approaches to derive results related to the different elements of a chemical footprint, namely chemical usage, chemical emissions and characterization factors linking chemical usage and/or chemical emissions to potential environmental impacts related to human toxicity and ecotoxicity as considered impact categories within LCA. In this context, it is essential to ensure consistency across data, models, and tools applied to assess the different chemical footprint elements, which might require international guidelines to support the coordination of such alignment efforts. A chemical footprint assessment includes the following four phases:

- Definition of the goal and scope (see Section 5.3),
- Chemical footprint inventory analysis (see Section 5.4),
- Chemical footprint impact assessment (see Section 5.5),
- Interpretation of chemical footprint results (see Section 5.6).

74. Key principles for a chemical footprint assessment include the application of a full life cycle perspective, having an environmental focus while also including impacts from direct exposure of humans to chemicals in different product applications, being a relative approach using a functional unit as the basis for a consistent comparison, following an iterative approach, and adhering to transparency, comprehensiveness, and accuracy in assessment and results. These key principles are consistent with principles applied in LCA, carbon footprint, and water footprint assessments. As part of any chemical footprint assessment, the limitations, uncertainties, and methodological constraints associated with the chemical footprint approaches applied should be transparently documented and their implications for the given decision context be discussed. Where relevant, sector-specific rules or guidance documents may need to be developed to support consistency, comparability, and reproducibility of chemical footprint studies.

75. **Life cycle perspective:** A chemical footprint assessment of a product, process or an organization's activities considers the entire life cycle, from raw material extraction and acquisition, through material production and manufacturing, to use and end of life treatment and final disposal. With that, a chemical footprint assessment does not only focus on the potential environmental impact associated with a certain chemical, but on the potential environmental impact associated with all emissions along the life cycle of a chemical (i.e. where a chemical itself is considered a product), a product, a process or an organization's activities. Through such a systematic overview and perspective, the shifting of a potential environmental burden between life cycle stages or individual processes can be identified and possibly avoided.

76. **Environmental focus:** A chemical footprint assessment addresses the environmental aspects and impacts of the considered system over its life cycle. In

accordance with relevant impact categories within the LCA framework, this includes potential environmental impacts associated with human toxicity and ecotoxicity, where pathways associated with exposure to chemical emissions and direct exposure to chemicals in products are included. Economic and social aspects and impacts (other than toxicity-related impacts on humans and/or ecosystems) are, typically, outside the scope of the assessment. Other tools may be combined with a chemical footprint assessment for more extensive assessments.

77. **Relative approach and functional unit:** A chemical footprint assessment is related to a functional unit as the basis for comparison (of life cycle stages, products, processes or organizations' activities) and the result(s) of a chemical footprint assessment are calculated relative to this functional unit. The functional unit thereby ensures that different compared systems must be functionally equivalent. The definition of all terms relevant for enabling a functional comparison of different systems should be fully aligned with related ISO standards, such as the 'functional unit' ([ISO 14044](#), #3.20) and 'reference flow' ([ISO 14044](#), #3.29).

78. **Iterative approach:** A chemical footprint assessment is an iterative technique. The individual phases of a chemical footprint assessment build on the results of the other phases. The iterative approach within and between the phases of a chemical footprint assessment contributes to the comprehensiveness and consistency of the study and the reported results.

79. **Transparency:** Sufficient and appropriate information is disclosed in order to allow users of the chemical footprint assessment to make decisions with reasonable confidence, where the level of detail needed for a proper interpretation of results from a chemical footprint assessment can differ as a function of the decision context of the study.

80. **Comprehensiveness:** All relevant chemical data and information that may affect the results of a chemical footprint assessment should be considered and transparently documented.

81. **Accuracy:** Bias and uncertainties associated with a chemical footprint assessment are reduced as far as is practicable.

5.3 Goal and scope definition

82. Goal and scope of a chemical footprint assessment are defined in alignment with [ISO 14040:2006](#) and [ISO 14044:2006](#). The goal definition of a chemical footprint assessment must clearly establish the intended application, the reasons for the study, and the target audience. The scope definition, in turn, must determine the following aspects:

83. **System boundary:** Life cycle stages included (e.g., from raw material extraction to final disposal). The assessment by default should cover the full life cycle of a considered system and all related chemical usages and emissions. Where specific decision contexts might require focusing on specific life cycle stages only, this should be transparently justified. Where relevant, requirements for communicating assumptions, value choices, data gaps, proxy data, uncertainty management, and

limitations should be established to ensure transparency and reproducibility of a chemical footprint assessment. For example, where specific choices in terms of aspects covered have been made (e.g. assessing a subset of chemicals of specific concern, characterizing only a sub-set of exposure pathways, focusing on specific protection areas, including emissions only for a certain assessment scope, or specific model choices), such information needs to be clearly communicated and the choices justified. Furthermore, where the decision context requires focusing on specific chemicals, priority aspects based on regulatory and stakeholder importance, or data availability, this should be transparently justified and documented. It should also be transparently stated where certain chemical footprint qualifiers are used (see Section 5.1.5), where relevant chemical footprint approaches provide results that do not yet reflect an LCA-based, impact-level chemical footprint.

84. **Functional unit:** The basis for comparison of the results. Quantified performance of a studied system, such as the life cycle of a product, process, or organization's activity, for use as a reference unit. All subsequent analyses are then conducted relative to that functional unit, as all inputs and outputs in the chemical footprint inventory analysis and consequently the chemical footprint impact assessment profile are related to the functional unit.

85. **Cut-off criteria and allocation procedures:** Rules for the inclusion of minor chemical flows and the distribution of potential environmental impacts among products and byproducts.

86. **Cut-off criteria:** Specification of the usage, emissions or toxicity/ecotoxicity characterization factors of chemicals or the level of environmental significance associated with unit processes or product systems to be excluded from a study. Even if a chemical has low emissions, care should be taken in applying cut-off criteria so that chemicals with high hazard, persistence, mobility, bioaccumulation, and/or exposure potential are not excluded from the chemical footprint assessment.

87. **Allocation:** Partitioning the input or output flows of a process or a considered system (i.e. life cycles of products, processes or organizations' activities) between the system under study and one or more other systems.

5.4 Chemical footprint inventory analysis

88. This phase of a chemical footprint assessment consists of the compilation and quantification of inputs and outputs for a considered system (i.e. products, processes or organizations' activities) throughout its life cycle. The inventory should cover the measured or estimated data on the chemical usage and usage context, and associated life cycle emissions of chemicals to the environment, including air, water, and soil.

89. For the analysis of emission inventories of chemicals, a series of guidelines on emission analysis is available and might be consulted for reference. Moreover, typical sources of information that should be considered to perform a chemical footprint inventory analysis include a considered system's bills of materials or recipes for specific products or processes, procurement inventories, purchase and replacement of process chemicals such as solvents or catalysts, average or recommended use of

chemicals in the cleaning, operation, and maintenance of products during their use stage, and similar information. We note that the availability and accessibility of such information may vary across considered systems, stakeholders, and regions.

5.5 Chemical footprint impact assessment

90. This phase of a chemical footprint assessment evaluates the magnitude of the potential environmental impacts identified in the chemical footprint inventory analysis phase. It includes one or more specific impact categories relevant for chemical footprint, namely human toxicity and/or ecotoxicity, depending on the defined goal and scope of the study. The steps of a chemical footprint impact assessment phase as well as its relation to the chemical footprint inventory analysis and chemical footprint interpretation phases are illustrated in Figure 2.

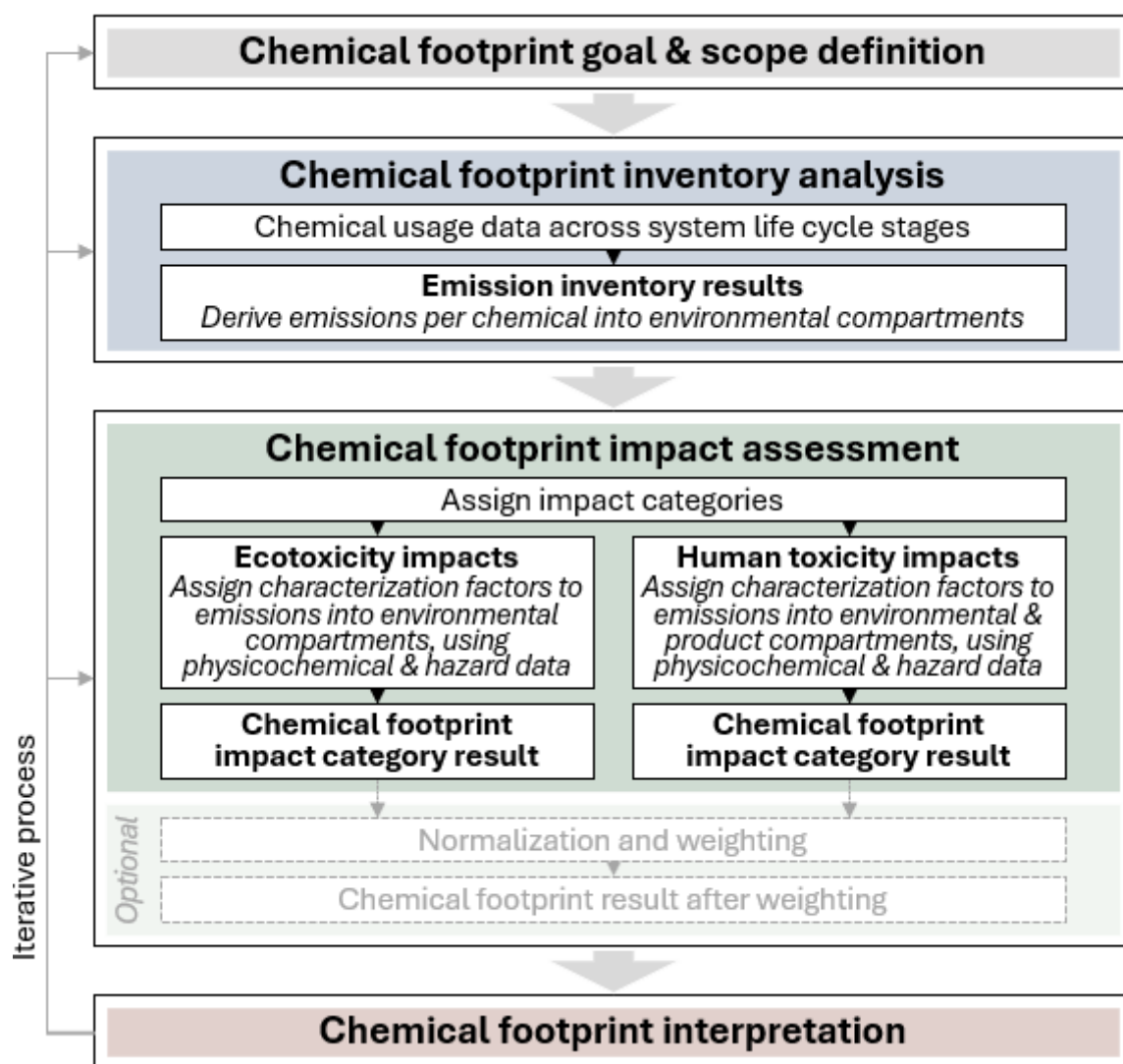


Figure 2. Chemical footprint phases, with details on impact assessment steps and relation of impact assessment to goal & scope definition, inventory analysis and interpretation phases of a chemical footprint assessment.

91. **Classification and characterization:** Assignment of inventory data to impact categories and calculation of results using characterization factors that consider environmental fate, human/ecological exposure and human toxicity/ecotoxicity effects

of chemicals. After classification and characterization steps, the main chemical footprint result is obtained, denoted 'chemical footprint impact category result' in Figure 2.

92. Beyond these steps, optionally a normalization and weighting step may be performed that allows aggregation of chemical footprint results into a single score indicator. However, choices for example associated with a specific weighting scheme need to be transparently documented and reported. In addition, results after normalization and weighting should never be reported without also reporting the underlying impact category-specific results, i.e. the chemical footprint impact category results.

5.6 Interpretation of chemical footprint results

93. In the present document, the results of a chemical footprint assessment are interpreted in the broadest possible sense and are not linked to any specific decision context, application area, or policy framework. Therefore, this document will not include any interpretation of chemical footprint results in relation to specific decision contexts, such as the objectives or targets of the GFC as a specific international policy framework. However, given the context of this document (see Section 1), we provide below some example interpretations of chemical footprint results in relation to the objectives and targets of the GFC. In this context, the different elements of a chemical footprint assessment focus on providing results that inform different aspects along the value chain and the pathway from source to impact. This includes:

94. **Chemical usage results:** Provides information on inputs in relation to chemical usage along a considered system's life cycle. This can inform for instance GFC Target D6 in its intention "to reduce the[ir]... input [of chemicals of concern] along the value chain".

95. **Chemical emission results:** Provides information on chemical emissions as a pressure on human health and ecosystem quality as related areas of protection in LCA.

96. **Chemical footprint results:** Provide information on potential environmental impacts associated with human toxicity and/or ecotoxicity impacts on, respectively, human health and ecosystem quality. This information can inform, for instance, GFC Target D1 in its intention to provide "innovations towards advancing sustainable chemistry and resource efficiency throughout the life cycle of chemicals" or to identify the safer and sustainable alternatives and solutions required by GFC Targets D2 and D4. Once an ISO standard establishment effort for chemical footprint is launched, chemical footprint results will also be very useful to inform GFC Target D3, for example to demonstrate that the private sector is using such a standard to guide decisions for enhanced management of chemicals and waste.

97. Additionally, the chemical footprint impact assessment phase serves to identify hotspots or critical points of potential environmental impacts, evaluate the integrity of the study, and conduct sensitivity and uncertainty analyses. Hotspot identification should support interpretation and prioritization by identifying significant contributors, dominant chemical groups, life cycle stages, and areas where uncertainty or limited

characterization may substantially influence chemical footprint results. In this context, aggregate results may need to be supplemented by disaggregated information on significant contributors, including chemicals, chemical groups, processes, or life cycle stages, to support interpretation and decision-making.

98. Where relevant, it should be clarified how chemical footprint results differentiate impacts from intentionally manufactured, unintentionally created or otherwise anthropogenically introduced chemicals as compared to, for example, background concentrations of certain naturally occurring chemicals.

99. Overall, interpretation of chemical footprint results should maintain traceability to underlying inventory information, including chemical usage and emissions, to facilitate identification of significant contributors, hotspot analysis, and support interpretation and management actions. Additional guidance, likely differing by considered sectors, should be provided to define all relevant aspects of reporting on chemical footprint results, including results of individual chemical footprint elements, such as chemical usage, chemical emissions or characterization factors, including considerations of uncertainty and relevance for the different defined decision contexts. Beyond the present document, further guidance should be provided on the following aspects: (a) defining specific requirements for data collection, data quality assessment, process-level and value-chain data, (b) identifying and justifying the selection of characterization models and factors, (c) defining criteria for representativeness, completeness, consistency, reliability, model selection and applicability, (d) how to address chemical releases during transportation, including accidental leakages, spills, and routine losses, (e) how to identify, quantify and document accidental, irregular, and emergency chemical emissions as part of a chemical footprint assessment, and (f) how service life, product lifetime, and use-phase duration are considered in the calculation and interpretation of chemical footprint results.

100. Finally, additional aspects beyond chemical footprint results might be relevant for certain decision contexts, such as chemical substitution, where aspects beyond human toxicity and ecotoxicity need to be considered. In such decision contexts, chemical footprint results must be used together with other considerations to facilitate appropriate decision support.

5.7 Limitations of chemical footprint

101. The results of a chemical footprint assessment represent potential environmental impacts in terms of human toxicity and ecotoxicity associated with chemical usage and emissions over the life cycle of a considered system based on scientific data and models. With that, chemical footprint results represent one dimension of potential chemical-related impacts and should be interpreted in the context of the assumptions, system boundaries, data availability, and methodological limitations of the assessment. Additional information may be necessary to support interpretation and decision-making, depending on the goal and scope of the assessment and the intended application.

102. Generally, chemical footprint results must always be interpreted considering the limitations of the available data, spatial variability, and toxicological knowledge, which,

in some cases, may be incomplete. These limitations must be communicated transparently to avoid misinterpretations of the results. Specifically, where characterization factors or supporting data are unavailable, this should be transparently documented, acknowledging that lack of characterization should not be interpreted as evidence of negligible impact. Moreover, chemical footprint results are not to be interpreted in terms of safety or risk but in relation to an overall environmental performance of a considered system over its entire life cycle with respect to potential human toxicity and ecotoxicity impacts to support sustainable chemicals and waste management strategies, such as the GFC.

Acknowledgements

Lead authors (working group co-leads): Peter Fantke (Goethe University Frankfurt am Main, Germany; University of South Africa, South Africa; substitute ApS, Denmark), Jianguo Liu (Peking University, China), Ricardo Barra (University de Concepción, Chile), Yi Yang (Chongqing University, China), Lamin Jaiteh (National Environment Agency, The Gambia).

Contributors (working group members, alphabetical order): Cecilia Aburto (Ministry of Environment, Chile), Mohamed Shahine Alhilali (UNEP, Morocco), Marvin Bachmann (Carbon Minds GmbH, Germany), Thomas Backhaus (RWTH University Aachen, Germany), Georgii Balianov (CIS Center Russia, Russia), Marie-Ange Baucher (OECD, France), Monica Becker (Cradle to Cradle Products Innovation Institute, United States), Werner Brack (Helmholtz Centre for Environmental Research UFZ, Germany), Anne Laure Brison (WBCSD, Switzerland), Lydie Camus (SOLVAY, France), Alberto Santos Capra (Basel Convention Regional Centre for South American Region, Argentina), Alexandra Caterbow (Health and Environment Justice Support, Germany), Nina Challand (BASF, Germany), Pooi Yin Chang (Independent Environmental and Sustainability Expert, France), Mamadou Lamine Diame (Ministère de l'Environnement et de la Transition écologique, Sénégal), Jing Dong (Dow, China), Elitsa Dzhongova (Kozloduy NPP - New Builds EAD, Bulgaria), Ilia Efros (Russian Chemical Society, Russia), Yasmine Emara (Sanofi, France), Rico Euripidou (groundWork, Friends of the Earth South Africa, South Africa), Saskia Finckh (Helmholtz Centre for Environmental Research GmbH - UFZ, Germany), Bernhard Frey (EFRAG, Belgium), Taketoshi Fujimori (Kao Corporation, Japan), Justina Garro (National Institute of Industrial Technology, Argentina), Stacy Glass (ChemFORWARD, United States), Ouedraogo Hamadou (Agent chargé de la réglementation de la gestion des produits chimiques, Burkina Faso), Emiko Hase (Kao Corporation, Japan), Kohjiro Hashizume (Japan Chemical Industry Association, Japan), Inez Hua (Purdue University, United States), Marina Lebedeva (SIBUR, Russia), Eleonore Lebre (International Council on Mining and Metals, Australia), Shaobin Li (Xiamen University, China), Olena Liakh (EFRAG, Belgium), Lu Liu (CAS, China), Anna Mainka (Silesian University of Technology, Poland), Phatchari Mankong (DTU, Denmark), Ben Marks (Responsible Business Alliance, United States), Ann-Lise Mikolajczak (Global remit, Switzerland), Llorenç Milà i Canals (UNEP, France), Shigeru Moriyama (Japan Chemical Database Ltd., Japan), Danielle Morrison (International Council on Mining and Metals, Canada), Hirohisa Nagahori (Japan Chemical Industry Association, Japan), Iman Fadhil Nassar (Ministry of Environment, Iraq), Veronica Ngole-Jeme (University of South Africa, South Africa), Susan Oginah (Technical University of Denmark, Denmark), Zhehan Pan (Dow Chemical, China), Julie Panko (ToxStrategies LLC, United States), Angela Pinilla (CSO representative - Independent assessor, United States), Leo Posthuma (Dutch National Institute for Public Health and the Environment; Radboud University Nijmegen, Netherlands), Andreas Prevodnik (Senior Policy Advisor, Chemicals and Chemical Pollutants, Sweden), Mark Rossi (Lowell Center for Sustainable Production at the University of Massachusetts Lowell, United States), Cécile Rousseau (Ramboll, France), Tomas Rydberg (IVL Swedish Environmental Research Institute, Sweden), Kavita Sachwani (UNEP FI, India), Serenella Sala (European Commission Joint Research Centre, Italy), Peter Saling

(BASF SE, Germany), Susan Sanchez (UL LLC, United States), Erwan Saouter (Net-Zero Impact SAS, France), Franz-Manfred Schüngel (Merck Healthcare KGaA, Germany), James Sherwood (Green Rose Chemistry, United Kingdom), Mathijs Smit (Shell Global Solutions International BV, Netherlands), Chrysanthi Sofokleous (International Council of Chemical Associations, Belgium), Olga Speranskaya (Health and Environment Justice Support, Canada), Koki Takaki (Ministry of the Environment, Japan), Raj Tanna (OWNER, India), Natalia Tarasova (D. Mendeleev University of Chemical Technology of Russia, Russia), Mauro Tomasi (The European Chemical Industry Council, Belgium), Myriam Tryjefaczka (Tarkett, France), Dmitrii Vadivasov (LCA-specialist, Russia), Larissa van der Feen (UNEP, Netherlands), Martijn van Velthoven (Rules4Regulatory B.V., Netherlands), Katharina Wache (World Resources Institute - Corporate Water Engagement Team, Science-based Target Network Freshwater Hub, Netherlands), Arisa Wada (Ministry of the Environment, Japan), Nicole Wenzel (BASF, Germany), Weijia Xia (CAS, China), Maryam Zare Jeddi (Shell Global Solutions International BV, Netherlands), Jing Zhao (Solid Waste and Chemicals Management Center, MEE, China), Youssef Zidi (ENVIRONMENT, Tunisia).

Reviewers (alphabetical order):

Abhinav Arora (UNEP, France), Barba Berin (AstraZeneca), CIS Center (Russia), Yasmine Emara (Sanofi, France), Jiliang Guo (CATARC, China), Hindustan Zinc Limited (India), Hanna Holmquist (IVL Swedish Environmental Research Institute, Sweden), ICCA, Eeva Leinala (OECD), Llorenç Milà i Canals (UNEP, France), Ministry of the Environment Japan, Shigeru Moriyama (Japan Chemical Database Ltd., Japan), Danielle Morrison (ICMM), PharmaLCA Consortium, Leo Posthuma (RIVM, Netherlands), Tomas Rydberg (IVL Swedish Environmental Research Institute, Sweden), F-M Schuengel (Merck Healthcare KGaA), Benjamin Warr (UNEP FI), Jenna Shields (Health Canada, Canada), Rachel Simon (ChemFORWARD, USA), Katharina Wache (WRI), Yue Wu (UNEP, France)