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Discussion Paper: Analysis of Data and Methods applied in the SAC MSI and Associated Tools

Prepared on behalf of: Australian Wool Innovation and the International Wool and Textiles Organisation (IWTO)

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Summary

The Sustainable Apparel Coalition (SAC) is a non-government organisation that aims to reduce the environmental and social impacts of apparel, footwear and textile products, by providing a common approach for assessing a product's sustainability performance and to drive behaviour improvement. The SAC has built a strong industry foundation with SAC member companies, which are estimated to represent over one third of global apparel and footwear production. Since its launch in 2010, the SAC has engaged in significant industry research and development to produce tools and datasets to measure sustainability, using an approach based on life cycle assessment (LCA). However, there are still areas of uncertainty, knowledge gaps and inconsistencies in this approach when it is compared to the relevant background LCA standards, and this limits the ability of SAC to reach their laudable goals. The aim of this paper is to provide a constructive summary of methodological issues, and practical recommendations, that the SAC could use to increase the scientific robustness of their tools, to achieve its environmental sustainability goals. This summary document was developed after a comprehensive review of the public SAC Higg Materials Sustainability Index (MSI) methodology, database and SAC communications of relevance, with reference to the International Standards from the 14040 and 14020 series, and the European Commission Product Environmental Footprint (PEF) guidelines.

This discussion paper has highlighted a series of issues, many that relate to inconsistencies with the international guidelines and best practice for LCA. This discussion paper concludes that to achieve its long-term vision of transforming the apparel industry so that it produces no unnecessary environmental harm and has a positive impact on the people and communities associated with its activities, SAC must address the following shortcomings in it's methodologies. These are related to:

(1) the guidance for comparative analysis and public disclosure;
(2) the choice of system boundaries and functional unit;
(3) the exclusion of important impact categories;
(4) the choice of LCA method and handling multi-functionality;
(5) data quality, transparency and handling of uncertainty;
(6) weighting and normalisation; and
(7) the comprehensive coverage of non-LCA assessed issues.

It is noted that the key issues raised here have the potential, if not addressed, to result in burden shifting, unintended consequences, and incorrect guidance from the MSI and associated tools. If not addressed, these issues could lead to less sustainable fibre choices, which may compromise the SAC's goal of promoting a sustainable apparel industry.

Based on the analysis and discussion paper reported here, a list of key inconsistencies and risks to the scientific robustness of the MSI have been identified, and recommendations have been provided to rectify these. Overall, the discussion paper found that the provision of, and adherence to the appropriate Standards for LCA and best practice in LCA, would rectify most, if not all of the issues raised. The authors recognise that addressing these issues may, in some cases, be a substantial undertaking and therefore the following recommended ranking of key issues is provided:

i) Development or adherence to Product Category Rules (PCRs) is a recommendation of this discussion paper, to improve consistency between datasets. In the interim, withholding results from public disclosure and comparison is a priority to ensure erroneous conclusions are not drawn.

ii) Inclusion of the full life cycle in the MSI and use of the correct functional unit for textiles is an urgent priority. To be consistent with the raw material and manufacturing

stages, and to be consistent with good practice in LCA, an evidence-based approach, reflecting actual garment use and end-of-life by consumers is essential. Application of a durability approach, which has a weak correlation with garment lifetime during consumer use, is inconsistent with the MSI and good scientific practice, and may result in directing users towards choices that result in burden shifting.

iii) Inclusion of currently omitted impact categories, such as microplastics, is a high priority to increase the coverage and relevance of the MSI.

iv) Clarification of LCA methods is recommended, and consequential LCA (cLCA) methods with system expansion, are recommended, considering the goals of the MSI and associated tools.

v) Inclusion of a quantitative uncertainty analysis and confidence intervals with all MSI results, and coefficient of variation's with data sources, is strongly recommended to ensure only scientifically valid comparisons are made. In addition to this, a full justification of the use of proxy data is recommended, together with improvement in the description of methods and datasets used in the MSI.

vi) Disclosure of non-weighted and normalised data is recommended in the MSI tool.

vii) Inclusion of a broader range of impact categories, including those not easily assessed by LCA, is recommended, using a similar approach to how chemicals are currently handled in the MSI. This will provide a broader commentary to accompany results. For example, assessing renewability and biodegradability is recommended.

It is essential that this important work to improve sustainability of the textile industry continues, and that robust, accurate and reliable methods are used to generate results that can be trusted by all parts of the textiles supply chain, including consumers. Although further development of methodologies is necessary, SAC and their tool has the potential to significantly improve the sustainability performance within the industry, reducing environmental impacts of the global apparel, footwear and textile industries. In commissioning this discussion paper, the wool industry continues its constructive and science-based approach to promoting the assessment of environmental sustainability in the textiles industry.

Introduction

The textile industry is a vital contributor to global societies, providing clothing that is essential for humanity. The industry is a major contributor to the global economy valued at approximately $830 billion USD in 2015. Textile production systems are many and diverse, ranging from natural fibres produced by small-holder farmers, to manufactured fibres from large-scale factories. As a result of production, manufacturing, use and disposal, all textiles leave an environmental 'footprint'. In a globalised economy, this footprint is rarely limited to the region of the world where the garment is sold and used; but extends to countries that produce raw materials, manufacture and process textiles and garments, and the countries where garments are sold, used and disposed of. Resources such as water and energy, and impacts from greenhouse gases, chemicals, microplastics and wastes are known to be substantial from textile production (Kadolph and Langford, 2007, Claudio, 2007, Chen and Burns, 2006, Kant, 2012, Muthu, 2014, Sandin and Peters, 2018). The environmental impacts are dependent on the type of fibre from which the apparel is made (Muthu, 2015), the manufacturing and processing techniques used, the length of time that garments are used prior to disposal and the way these garments are cared for (washed and dried) by consumers, and how garments are disposal of by the consumer.

To understand and reduce these environmental impacts, a range of industry, government and non-government-organisations (NGOs) have invested in developing systems to quantify impacts. Life cycle assessment (LCA) has been the most commonly applied tool for determining full supply chain impacts and reporting these relative to the final product (i.e. a garment). This method is fundamental to government initiatives such as the Product Environmental Footprint (PEF) and to NGO led initiatives such as the Sustainable Apparel Coalition (SAC) Higg Material Sustainability Index (MSI) (abbreviated to SAC MSI in the following discussion) and Higg Product Module (PM) tools.

LCA is a robust and well-established method with standards available from the ISO 14040 and ISO 14020 series. Detailed guidelines are also available from for PEF (Manfredi et al., 2012) and the ILCD (EU JRC, 2010). These standards and guidelines provide a strong basis for applying the method and reviewing its application. Guidelines specific to different applications of LCA such as the SAC MSI (SAC, 2018) have also been developed, based on the fundamental ISO methods 14040/14044, the EcoInvent database guidelines, and the PEF guidelines.

This discussion paper aimed to:

i) Review the SAC MSI by comparison with the cited, guiding documents, specifically ISO methods 14040 and 14044 (see SAC, 2017).

ii) Review the SAC MSI with reference to ISO 14025. While not cited as a guiding document, ISO 14025 was also a relevant standard, considering the purpose and application of the MSI is to provide public comparative analyses of different products. For this reason, ISO 14025 has also been referred to where this provided further insight.

iii) Review the SAC MSI with reference to the PEF guidelines.

iv) Provide constructive recommendations to improve the robustness of the methods and application in the MSI and tools that rely on MSI data, including the Design and Development Module (DDM) and the Product Module (PM) tool.

The discussion paper has covered all fibres of relevance in the MSI, with specific reference to natural fibres. We present here a summary of the key issues identified and potential solutions to improve the robustness and scientific credibility of the tool. The aim of presenting these issues in a discussion paper is to promote improvement of the methods, data and tools, to advance the goal of improving the sustainability of the global textiles industry. The discussion paper has been broadly structured to follow the pattern of an LCA as outlined in the ISO standards.

Objectives of the SAC MSI (Goal and Scope)

The SAC Higg Index has an array of tools and has aspects that remain 'in development'. These tools are primarily informed by the MSI, which is a cradle-to-gate material scoring tool informed by LCA data and methodology. The stated goals of the MSI (SAC, 2018) are to:

• *"Understand and quantify the sustainability impacts of apparel, footwear, and home textile products."*
• *"Reduce redundancy in measuring sustainability in apparel, footwear, and home textile industries."*
• *"Drive business value through reducing risk and uncovering improvement opportunities."*
• *"Create a common means and language to communicate sustainability to stakeholders."*

The tool is publicly available at: https://apparelcoalition.org/higg-msi/, and clearly encourages users to *"compare materials to make better choices"* (SAC, 2018). In the SAC Higg MSI Terms of Use, it is states that "*Higg MSI Public Users may use MSI Scores to make decisions about material use, make comparisons between materials, and create "Custom Materials"*." (SAC, 2018) (accessed 14/11/2018). The tool has additional modules such as the DDM and the PM tools, which have the following goals respectively:

- *"A tool … [that produces] a design score that can be used for decision-making about different design scenarios."*
- *"A tool to …influence purchasing decisions and scale adoption of leading practices… [for] the full impacts of a finished product."*

The MSI, DDM and PM focus on comparative analysis of different fibres, at different stages of the supply chain, as well as promoting improvements that can be made in manufacturing processes or (to a lesser extent) design. The MSI compares fibres at the 'fabric' stage, the DDM compares fibres at the garment stage, and the PM tool will ultimately compare fibres and garments across the full life cycle.

Issue 1 – Guidance for comparative analysis and public disclosure

According to ISO 14044, additional requirements exist for comparative studies intended for public disclosure. It is also notable that ISO 14025 specifies that "all relevant environmental aspects of the product throughout its life cycle shall be taken into consideration". Where relevant aspects do not cover all stages of the life cycle, then it is a requirement that these are stated and justified. Where results are made available for public comparison and promotion of selection between one product and another, both ISO (via the 14020 series and Product Category Rules – PCRs and Environmental Product Declarations - EPDs), and PEF (via PEFCRs), provide a strong and clear structure for ensuring analyses are made "on like terms". No such process (PCRs or PEFCRs) is applied by the MSI (see Figure 1) and this is a key weakness in the MSI approach. While the "Gatekeeper" assesses whether datasets are consistent with the Higg MSI Data Submission Requirements and Guidelines, it is unclear if this meets the comparative LCA standard. Additionally, data may be submitted to SAC in two forms, Type 1: data inputs/outputs at the process level, and Type 2: LCIA results that have been modelled by independent companies. The latter are difficult to verify, and it is unclear what process exists to ensure comparability in the methods applied.

While it could be argued that the MSI does not aim to provide the level of rigour of an EPD, and that disclaimers are made regarding the use of the data, the website and tool clearly promotes users to compare products to reduce impacts (SAC, 2018), and therefore, arguably, aims to make public disclosures. Moreover, the database has been used, with SAC support, to make clear and contentious public disclosures, such as in the Global Fashion Agenda and The Boston Consulting Group: Pulse of the Fashion Industry report in 2017 (GFA, 2017). Additionally, other textile companies (including Lenzing, Brooks, Kathmandu, VF Corporation, Textile Exchange, Apparel Insider and Carved in Blue) have used the MSI to compare fibres, choose fibre type used in manufacturing and/or make comparative environmental claims about fibres (Kathmandu, 2018, VF Corporation, 2018, Outdoor Industry Association, 2017, Textile Exchange, 2017, Lenzing, 2017, Apparel Insider, 2018, Carved in Blue, 2016). The use of the Higg MSI as evidence to support environmental sustainability claims, considering the limitations, has been cited as a key concern because of the possibility of results being used for so-called "green-washing" (Changing Markets Foundation, 2018).

This discussion paper found the MSI guidelines function at a level that is unsuitable for public disclosures, because there is currently no robust way to ensure MSI scores are developed consistently, from suitable and robust data and with consistent choices around such issues as multifunctionality.

Figure 1 (adapted from Bach et al., 2018) shows the relationship, parallels and inconsistencies between derivative modelling and reporting approaches such as the PEF and MSI, and the ISO Standards.

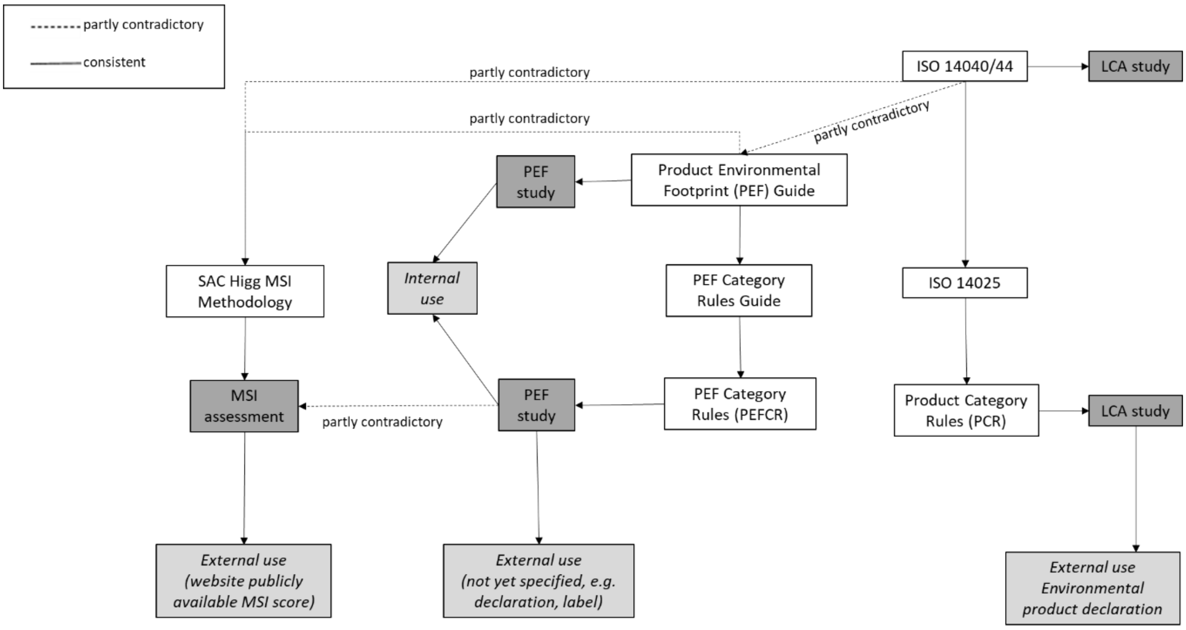

Figure 1. Comparison of SAC Higg MSI, PEF method and the PCR concept based on ISO 14040/44 (modified from Bach et al., 2018)

In brief, ISO 14025 and product category rules (PCRs) are developed to provide detailed rules on how to model the life cycle of a product in a specific category. The results of a LCA that uses these PCR can then be used for an external environmental product declaration (EPD). Effectively, PEFCRs are the PEF version of PCRs. PEF studies that are for external communication and comparison require more rigor than PEF studies for internal communication, so studies need to be consistent with both the PEF guide and PEFCRs. Whereas, internal communication PEF studies can be completed based on only the PEF guide.

The lack of detailed guidance, parallel to PCRs, is a weakness in the MSI system that allows for inconsistency between datasets. Examples of such inconsistencies include variation in methods used to handle multifunctionality (allocation) between fibre types, and extensive use of proxy data with limited reporting of the impact of these proxy data on the final results. We note also that there is an interaction between this recommendation and later issues raised about uncertainty. If these data are insufficient to make comparisons, this would further support the recommendations provided here.

Recommendations

This issue could be addressed in the following two ways:

i) the MSI could be restricted for internal use only (no public disclosure), or
ii) the MSI system requires new, more specific guidance parallel to the PCR system, which could include adopting or adapting PEFCR or PCR guidance where available.

As an interim measure, it is recommended that SAC withhold the use of MSI data for external comparisons, as were made in the GFA (2017) report.

Issue 2: Choice of system boundaries and functional unit

As defined by ISO 14044, the system boundaries for life cycle assessment are "*a set of criteria specifying which unit processes are part of a product system and thus determine which processes shall be included within the LCA*" (ISO, 2006). The choice of system boundary is closely linked to the goal of the study. The functional unit is generally the unit that represents the function of the system and (particularly for cradle-to-gate LCA) represents the reference flow of the system that crosses the system boundary. Thus, the two are interlinked.

The SAC Higg MSI applies a cradle-to-gate (all impacts up to and including fabric manufacture) system boundary. The DDM extends this to include some aspects of the use phase included in a superficial way. The scope of the PM tool includes the use and end-of-life stages.

Exclusion of the use phase in the MSI (and also largely the DDM) in a comparative analysis, requires careful consideration and justification. This must be done to ensure that it's exclusion does not inadvertently contravene the requirement for including "*all relevant environmental aspects*" of the supply chain, and result in the potential for unintended outcomes and burden shifting when fibres are compared. There has been no documented consideration and justification of this exclusion in the MSI system, and this omission has been evaluated here with reference to the LCA literature.

Garment use is well known to be a high source of impact for most garment types (Quantis, 2018, Laitala et al., 2018a) because of the laundering requirements, and because of the duration of wear life. The review of Muthu (2016) considered the use phase of clothing and found that this stage contributed from 31 - 96% of total GHG life cycle impacts, and varied depending on fibre and garment type. Design choice, including choice of fibre, choice of fabric structure and quality, and choice of garment style has a pivotal influence on the wear life time of the garment and the washing requirements (Lundblad and Davies, 2016, Laitala et al., 2015, Goworek et al., 2018, Santos et al., 2016, Roos et al., 2017). Considering these findings, this discussion paper found that there is insufficient justification for excluding the use phase, and this exclusion is a key weakness in the MSI, and its application in the DDM. It was also concluded that the application of the MSI dataset (for example, by GFA, 2017), or the DDM, in the design of the garment, explicitly or implicitly promotes the use of "lower impact" fibre types. But it does so without taking into account variability caused by one of the largest sources of environmental impacts, consumer use and care patterns. This raises the very real risk of burden shifting and 'false positive' recommendations based on MSI scores, challenging the robustness of recommendations that rely on the tool, and undermining the purpose and credibility of the MSI.

The discussion paper found that the choice of functional unit, based on fabric mass, implicitly results in a recommendation that lower impacts from garments will be achieved where lower amounts of fabric are used. However, these two factors; fibre type and garment mass, influence the washing requirements and life time use (total wearings) of the garment. Minimising garment mass, for example, at the expense of durability would result in lower apparent environmental impacts for "throw away" fast fashion garments. However, the unintended consequence of requiring more garments to be manufactured, and the increased impact from disposing of multiple garments, are not considered. This will result in burden shifting and confounded recommendations, again challenging the purpose and credibility of the MSI.

Similarly, an unintended consequence will occur where a 'high score' fibre (such as wool) is replaced with an alternative 'low impact' fibre, if the washing and wearing attributes are not taken into account. It has been demonstrated in the peer reviewed literature that wool garments are worn more times prior to washing, and are washed and dried with lower impact techniques than other fibres (Laitala et al., 2018a). Considering washing and drying are the primary processes that contribute to the environmental impacts from clothing in the use phase (Steinberger et al., 2009, Continental Clothing Co., 2009), the choice of system boundary masks an instance of burden shifting. This may also result in the unintended consequence of promoting actions that have no benefit for or even negative impacts on the environment. This could result in companies trying to reduce their MSI scores, while actual environmental impacts increase during the consumer use phase, because the consumers end up making more environmental impacts. This in turn would give the appearance of companies producing environmentally sustainable fibres/garments, but in reality, products could have higher impacts across the whole life cycle. Considering this possibility, it is concerning that some companies are already using the MSI as evidence to support environmental sustainability claims regarding their products.

Recommendations

It is a recommendation of this discussion paper that the MSI is expanded to include garment finishing, garment make-up, use phase and end-of-life (i.e. cradle to grave). This will resolve the problem of burden shifting and unintended consequences that currently exist with the MSI. It is expected that this functionality would largely make the DDM tool redundant. Because the years of garment wear has a multiplier effect on the impacts on all upstream processes, we recommend including this as a divisor in the tool. Functionally this can operate in the tool similarly to the 'cutting efficiency' function.

It is recommended that the functional unit is revised to 'years of garment wear', with a specified number of wearing events rather than 'mass of fabric' or 'per garment', as is currently used in the MSI and DDM. We recommend that default values for 'years of garment wear' are provided, based on peer-reviewed and published results from properly constructed consumer surveys (i.e. an evidence-based approach, consistent with LCA principles and guidelines, and the approach taken in the raw material and manufacturing stages of the supply chain). In the future, technological solutions that track garment wear may dramatically improve the understanding of, and improvement in consumer behaviour around garment wear life and care habits. This discussion paper found that the preferred method of including the use phase, based on physical durability, was the cause for only 18% of garment disposal, whereas personal reasons (i.e. size, fashion trends and changing needs) were the cause of 75% of garment disposal (WRAP, 2017). Moreover, because this is a predictive method rather than an evidence based method, the approach is inconsistent with other aspects of the MSI which rely on 'actual data' rather than predictive methods. The discussion paper found that this approach will be imperative to ensuring the MSI and the PM tool actively direct practice change to the area with the most significant impacts, viz, consumer wear and care practices. Without correctly constructing the tool and the assumptions used, there is a high likelihood that the tool will direct undue focus on an issue with little bearing on environmental impacts (i.e. durability) and will therefore risk unintended outcomes or 'false positive' mitigation strategies that do not improve the environment.

In addition to the above, the discussion paper also recommends that the PM tool applies a science-based assessment of the functional unit, specifying the quality and functionality of the fabric and garment type to avoid comparison of dissimilar products.

Issue 3: Exclusion of important impact categories

Microfibres are small (< 5 mm) pieces of debris resulting from the weathering of consumer and industrial products, including textiles (Arthur et al., 2009, Cesa et al., 2017). It should be noted that while natural fibres can release microfibres, they are biodegradable (Kozłowski, 2012, Szostak-Kotowa, 2004) and thus do not accumulate in the environment in the same way as microfibre from synthetics (microplastics) (Laitala et al., 2018b, Henry et al., 2019). Recent research has shown microplastic pollution has global distribution, including marine, lakes, rivers, and terrestrial environment (Dris et al., 2017, do Sul and Costa, 2014, Eriksen et al., 2013, Van Cauwenberghe et al., 2013, Cole et al., 2011, Free et al., 2014, Browne et al., 2011). Microplastics have a high surface-area-to-volume ratio which also increases their potential to transport toxic substances. Many studies have showed microplastics are ingested by many marine organisms (molluscs, zooplankton, crustaceans, fish, whales etc), they then bioaccumulate and are transported up food chains (Cole et al., 2013, Wright et al., 2013, Browne et al., 2008, Chua et al., 2014, Rochman et al., 2014, Watts et al., 2014, Lusher et al., 2013, Von Moos et al., 2012, Farrell and Nelson, 2013, Cedervall et al., 2012, Setälä et al., 2014, Barbanera, Besseling et al., 2015). The widespread contamination and persistence of microplastic is projected to lead to its accumulation in the environment, increasing the risk of exposure for fauna and humans over time (Deng et al., 2017).

Microplastics can bioaccumulate and exert localised particle toxicity by inducing or enhancing an immune response when inhaled or ingested (Wright and Kelly, 2017, Zarfl et al., 2011). Chemical toxicity from microplastics can occur due to the leaching of component monomers, endogenous additives or adsorbed environmental pollutants (Bouwmeester et al., 2015, Vethaak and Leslie, 2016, Galloway, 2015). There is also the potential for microplastics to impact human health, however there is limited research on dose-dependent human toxicity, accumulative effects or exposure concentrations (Wright and Kelly, 2017).

Washing textiles made from synthetic materials has been identified as a source of environmental microfibre pollution (De Falco et al., 2018, Hernandez et al., 2017, Jemec et al., 2016, Browne et al., 2011, Cesa et al., 2017, Rochman et al., 2015, Napper and Thompson, 2016, Dris et al., 2017).

Browne et al. (2011) demonstrated that a single synthetic garment can produce over 1900 fibres per wash with domestic washing machines. Similarly, de Falco et al. (2018) showed that the number of microfibres released from a typical 5 kg wash load of polyester fabrics was estimated to be over 6,000,000, depending on the type of detergent used. Napper and Thompson (2016) estimated that washing a 6kg load of polyester-cotton blend could potentially release over 137,900 microfibres, while washing a 6kg load of either polyester fibre or acrylic fibre could potentially release over 496,000 and 728,789 microfibres respectively. These studies suggest that a significant proportion of microfibres in aquatic environment may originate from wastewater treatment plants because of clothes washing (De Falco et al., 2018). Furthermore, Pirc et al (2016) found that release of microfibres fibres during tumble drying was approx. 3.5 times higher than during washing, suggesting that microplastic in the atmosphere may originate from clothes drying as well. Clearly, microfibres must be included in the assessment of environmental impacts of textiles to meet the requirements of ISO 14044*: "The selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied, taking the goal and scope into consideration"* and to avoid the risk of burden shifting when other impact categories are reduced at the expense of higher impacts from microplastics.

Abiotic resource depletion is currently not considered fully in the MSI, despite being a relevant factor known to differ between fibre types. While the MSI assesses abiotic resource depletion for fossil fuel use, it does not assess other minerals or elements associated with abiotic depletion. Depletion of other abiotic resources from the environment could be readily included in the MSI as an impact category, using current indicators.

Abiotic bioaccumulation The MSI does not have an indicator to reflect the impact of textiles on solid waste or "abiotic bioaccumulation". Considering the extensive problems created by solid wastes in land-fill and the clear differences between natural biodegradable fibres and non-biodegradable fibres, the exclusion of this indicator was found to inadvertently favour non-biodegradable fibres and therefore disadvantage biodegradable fibres.

Recommendations

While operational LCA methods are still being developed for microfibres, an interim indicator such as "mass of microfibre released", adjusted with a biodegradation factor (that is a 0 factor for biodegradable to 1 factor for non-biodegradable) and an interim score contribution to the MSI is recommended, enabling the physical impact potential of microfibres to be included. Inventory data are sufficient to enable this to be scored currently, and it's inclusion would promote further inventory development. We note that multiple research groups have started working in this area and further methodological advances are expected in the next 1-2 years. Considering this, a watching brief in this area is also recommended.

Further development of indicators and factors to enable this to be incorporated in toxicity impact categories is underway and should be actively promoted by SAC.

It is a recommendation of this discussion paper that indicators covering abiotic resource depletion and abiotic bioaccumulation are included in the MSI.

Method and Inventory (data)

Issue 4: Choice of LCA method and handling multi-functionality

Depending on the scope of an LCA study, LCAs may be done using either attributional (aLCA) or consequential (cLCA) methods. This issue is not explicitly addressed in the ISO Standards 14040 or 14044, though choices relating to methods for handling multi-functionality (allocation) typically differ substantially depending on which approach is used, which can significantly alter results. The SAC (2017) MSI method, and PEF (Manfredi et al., 2012) have not given prescriptive guidance regarding methods for handling multi-functionality and do not specify use of aLCA or cLCA methods.

The following discussion outlines the key aspects relating to this choice, with a recommendation that cLCA is the most suitable method for application in the MSI. Historically, most LCA research has used the aLCA approach to track environmental impacts through a product's supply chain, during use and disposal (Finnveden et al., 2009). This "accounting" assessment includes all direct inputs and outputs throughout a process chain, regardless of their relevance to a change in system (Tillman, 2000). The aLCA approach characterises the average production of a static system irrespective of market trends and external influences.

In contrast, cLCA estimates the change in environmental impacts in response to a change in output of the functional unit. In effect, the cLCA approach expands the system boundaries to include direct and indirect activities affected by a change in output. Consequential modelling of both direct and indirect environmental impacts provides insight into a complex system that is not captured by aLCA, which ignore the fact that indirect background systems are important in an interlinked global economy. The choice between aLCA and cLCA approach results in differences in the total quantitative outcomes, hotspots, impact contributions, degree of understanding and quality between studies and research interpretation.

According to Weidema (2018) the attributional approach is relevant when the goal of the LCA is to account for the product system, as in:

- environmental management accounting including analysis of significant environmental aspects in the product system,
- management of the value chain or product system, and
- other applications where it is required to trace the value added of a product property backwards in the product system.

While the consequential LCA is relevant when the goal of the LCA is to support decisions that aim for environmental improvements (Weidema, 2018), such as:

- identification of significant environmental aspects of products for improvement (ISO 14001, ISO 14004, ISO 14031, ISO/TR 14032) or for product standards (ISO Guide 64),
- product labelling and declarations that aim at influencing customer purchases (ISO 14020, ISO 14021, ISO 14025),
- design of products (ISO/TR 14062) or policies that aim for environmental improvements
- quantification, monitoring and reporting of environmental additionality of project outcomes (e.g. ISO 14064), and
- analysis of significant environmental aspects in the system that is affected by the decisions.

Currently, the MSI (SAC, 2017) does not specify between aLCA or cLCA methods, which leaves a degree of ambiguity in the methods, that could result in inconsistency between datasets and results.

Recommendations

Considering the goals of the Higg index tools and the recommendations from leading LCA literature and practice, this discussion paper recommends the adoption of cLCA methods and data collection processes in the MSI. Aligned with this is the choice of methods for handling multi-functionality. It is recommended that system expansion methods are applied.

Issue 5: Data quality, transparency and handling of uncertainty

To comply with ISO requirements, the MSI and DDM must apply high standards with respect to data quality assurance because of public disclosure and the comparative nature of the results. This discussion paper found that, in many instances, an external assessment of data quality using the SAC data quality guidance resulted in data being of 'poor' quality. For example, concerns with data quality exist with raw material data for elastane/spandex, lyocell and modal fabric, which were based on data from one factory, which may not be representative. It is also noted that the database relies heavily on generalisation of highly specific papers to estimate world averages, specifically with heavy reliance on van der Velden et al. (2014) for yarn formation, and preparation, Cotton Inc (2012) for colourisation and the Koç and Kaplan (2007) study for textile formation (which reported results from one factory in Turkey). This discussion paper found that in order to bridge data gaps in the textile manufacturing process (i.e. yarn formation, textile formation, preparation, colouration and additional colouring and finishing), SAC have used proxy data sets for many of the fibre types. For example, proxy data was used to assess yarn formation, textile formation, preparation and colouration stage for lyocell fabric, contributing to over 56% of lyocell fabric's total MSI score. Similarity, proxy data was used to assess yarn formation, textile formation, preparation and colouration stage for wool fabric, with these stages contributing 25% of the wool fabric MSI score. The heavy reliance on proxy data from a limited number of studies may not be representative of global textile manufacturing trends and has the effect of neutralising differences between fibres. Research found that electricity use in the wool spinning process between 9 similar plants had a variance of 75% (unpublished AWI data). This is especially relevant where data from the Koç and Kaplan (2007) study was used, as it only investigated only one textile manufacturing plant in Turkey, but is used in the MSI for 16 out of 18 fibres in the textile formation stage, and 5 out of 18 fibres in the yarn formation stage. The impact of such heavy reliance on Koç and Kaplan (2007), van der Velden et al. (2014), Cotton Inc (2012) and Murugesh (2013) in the yarn formation to colouration stages has not been assessed or reported. Despite the high reliance on proxy data from limited sources, the MSI contains no uncertainty analysis, which is considered best practice in published LCA and is needed, in order to make a comparative assertion with scientific confidence (Mendoza Beltran et al., 2018, Ross et al., 2002). It is therefore unclear whether apparent differences between fibre types are statistically valid, or not. That is, it is unclear whether the tool has enough resolution and accuracy to be able to make assertions and comparisons between fibre types. Considering operational methods exist to model uncertainty, this can be readily undertaken. It was also found that there was a lack of regional specificity in the datasets used in the MSI across multiple fibre types, despite the fact that some impacts, such as eutrophication and water scarcity, are highly regionally specific.

The discussion paper also found several transparency issues with the data used in the SAC Higg MSI, including inconsistent referencing, unclear proxy data use, and a lack of description of background datasets. It was not clear in some instances, for example, how the results from a base study that covered only one impact category (for example, GHG or energy) was used to generate data for water use or eutrophication.

Recommendations

It is recommended that specific, robust and geographically representative datasets are used to develop MSI scores. Considering the current, extensive use of proxy data, an analysis and report of the impact of proxy data in the MSI should be developed and publicly released. Where proxy data have a high impact on the total MSI score, this discussion paper recommends providing unambiguous commentary along with the score, noting the potential for high levels of uncertainty in the results. Moreover, considering this, the discussion paper recommends that a formal uncertainty analysis is performed for the datasets to clearly inform users of the confidence intervals in MSI scores. For example, inclusion of 95% CI would be appropriate, and a description of the coefficient of variation (CoV) associated with data sources should be supplied throughout the MSI. In addition, it is recommended that the transparency of data sources and methods used is improved substantially, and that methods and inventory data used to expand impacts assessed from original studies (for example, to expand the coverage of different impact categories) is fully disclosed.

Impact Assessment

Issue 6: Weighting and Normalisation

The SAC Higg MSI method involves a normalisation and weighting process to aggregate greenhouse gas, fossil energy, water stress and eutrophication into a single score. While both normalisation and weighting are optional elements of LCIA, the ISO 14044 requires that normalisation and weighting methods are consistent with the goal and scope of the LCA and are fully transparent. The MSI uses equal weighting, however SAC does not provide justification for this, other than that they plan to improve this into the future. Weighting has significant impacts on the MSI score and the use of immature weighting values could result in unintended environmental outcomes and burden shifting when fibres are compared. Furthermore, both the ISO 14040 and 14044 state that *"there is no scientific basis for reducing LCA results to a single overall score or number"*. This is due to the environmental impact trade-offs and complexities that exist for the systems analysed, which makes it is difficult to present dimensionless single scores in such a way that they are not misleading.

Additionally, as noted by PEF "*Normalised results shall not be aggregated as this implicitly applies weighting. Results from the EF impact assessment prior to normalisation shall be reported alongside the normalised results"*. The MSI does not conform with these requirements.

Recommendations
A clear recommendation from this discussion paper is that reporting of non-aggregated, non-normalised, non-weighted scores must be provided in the tool. Additionally, as global supply chains produce environmental impact in multiple regions, normalisation factors used in environmental assessments must reflect the regions of these impacts. For example, the use of EU 27 normalisation factors on global supply chains, as has commonly been applied in PEF pilot studies, has the potential to distort an analysis and should not be applied in the MSI.

Interpretation

Issue 7: Comprehensive coverage of non-LCA assessed issues

As stated by the ISO 14040, comparative product assessment using LCA should be used as part of a much more comprehensive decision process or used to understand the broad impacts or general trade-offs. Currently, apparel LCA based results only reflect part of the environmental impacts of a garment, as difficulties exist with handling some aspects of a system. For example, renewability, recyclability, biodegradability land management, carbon cycling and biodiversity are three aspects that have proven difficult to integrate into LCA and are much more commonly handled by using an audit system. It is questionable whether these impacts can ever be meaningfully integrated into LCA. Similarly, natural systems that follow a cycle, rather than a pathway, are often difficult to manage in LCA.

Several significant environmental impacts are excluded from the MSI and PM, including recyclability, biodegradability renewability of resource used, microfibres, abiotic resource depletion (minerals) and abiotic bioaccumulation, as current LCIA methods are immature or in need of development. Thus, there are other important environmental impacts that can't yet be assessed in LCA that should be included in the SAC tools to ensure comprehensive coverage of environmental issues.

Recommendations
As there are methodological and scientific limitations to the application of a toxicity LCIA, SAC currently use qualitative questions to assess chemistry. The same qualitative method could be applied to the environmental impacts associated with biodiversity, biodegradation, food-chain bioaccumulation, microfibres, abiotic resource depletion and abiotic bioaccumulation to ensure the MSI and PM results are comprehensive.

Conclusions and Recommendations
The SAC MSI has laudable aims, and the SAC has invested heavily in developing the methods and data required to improve sustainability of the textile industry. It is essential that this important work continues, and that the robust, accurate and reliable methods are used to generate results that can be trusted by all parts of the textiles supply chain including consumers. This discussion paper has highlighted a series of issues, many that relate to inconsistencies with the international guidelines and best practice for LCA. Based on the analysis and discussion paper reported here, a list of key inconsistencies and risks to the scientific robustness of the MSI have been identified and recommendations have been provided to rectify these. It is noted that the key issues raised here have the potential, if not addressed, to result in burden shifting, harmful unintended consequences, and incorrect guidance from the MSI and associated tools. If not addressed, these issues could lead to

unsustainable fibre choices, which may compromise the SAC's goal of promoting a sustainable apparel industry. The discussion paper found that provision of, and adherence to the appropriate Standards for LCA and best practice in LCA, would rectify most, if not all of the issues raised.

The authors recognise that addressing these issues may, in some cases, be a substantial undertaking and therefore the following recommended ranking of key issues is provided:

1. Development or adherence to Product Category Rules (PCRs) is a recommendation of this discussion paper, to improve consistency between datasets. In the interim, withholding results from public disclosure and comparison is a priority to ensure erroneous conclusions are not drawn.
2. Inclusion of the full life cycle in the MSI and use of the correct functional unit for textiles is an urgent priority. To be consistent with the raw material and manufacturing stages, and to be consistent with good practice in LCA, an evidence-based approach reflecting actual garment use and end-of-life by consumers is essential. Application of a durability approach, which has a weak correlation with garment lifetime during consumer use, is inconsistent with the MSI and good scientific practice, and may result in directing users towards choices that result in burden shifting.
3. Inclusion of currently omitted impact categories such as microplastics is a high priority to increase the coverage and relevance of the MSI.
4. Clarification of LCA methods is recommended, and consequential cLCA methods with system expansion are recommended considering the goals of the MSI and associated tools.
5. Inclusion of a quantitative uncertainty analysis and confidence intervals with all MSI results as well as the coefficients of variations with data sources is strongly recommended to ensure only scientifically valid comparisons are made. In addition to this, a full justification of the use of proxy data is recommended, together with improvement in the description of methods and datasets used in the MSI.
6. Disclosure of non-weighted and normalised data is recommended in the MSI tool.
7. Inclusion of a broader range of impact categories, including those not easily assessed by LCA, is recommended, using a similar approach to how chemicals are currently handled in the MSI. This will provide a broader commentary to accompany results. For example, assessing renewability and biodegradability is recommended.

It is the intention of the wool industry to continue to constructively contribute to the development of the SAC MSI and to promote the most robust and scientifically defensible analyses to improve impacts in the textiles sector.

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