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Fibre Loss Risk Assessment (FLoRA) toolkit: Supporting document

A document designed to be used alongside the FLoRA Risk Assessment (Excel File) to support and guide users through the process and to provide additional information and reference materials for subsequent action.

Executive summary

It might be surprising to learn that microplastic fibre pollution is prolific around the world. Microplastic fibres (synthetic fibres <5mm), shed from a variety of textiles, including clothing, carpets and ropes, throughout a products lifecycle, including in the production phase, use phase and end-of-life phase. It is estimated that on a global scale, the laundering of synthetic textiles contributes the greatest amount (35%) of primary microplastic pollution in the ocean¹. The problem has long existed, but awareness of the issue and the impact of microplastic fibre pollution on animals and human health is increasing rapidly.

Microplastics pose a significant threat to biodiversity. Their small size makes them easily digested which can impact physiological functions, and the toxic chemicals contained in and on plastics can impact reproductive and cause disease and cancer. Furthermore, these toxins bioaccumulate, meaning the toxins can be passed and magnified up the food chain. Microplastic fibre pollution is a global, transboundary issue, and to date, lack of knowledge and action on this issue means that it is now impossible to avoid microplastic fibres. They are in the air, freshwater, the ocean, arctic ice, and are commonly ingested by humans and numerous species.

Fauna & Flora's work is focused on synthetic microfibres: fibres generally derived from common polyesters, including nylon and acrylic, which now represent about 70% of all materials used in textiles, and this number is expected to grow. To date, many of the conversations around reducing fibre loss have focused on microfibre shedding at the consumer level and domestic laundering. However, estimates suggest that nearly 50% of microfibre shedding happens upstream, at the production phase. Therefore, significant, positive impact can be made if we make changes at this stage to prevent microplastic fibre loss.

Increasingly, consumer awareness and demand for sustainable products has resulted in questions being asked of textile and clothing manufacturers and regulations to tackle microplastic pollution, including microplastics lost from textiles are on the horizon from both the European Union and under the auspices of the Global Plastics Treaty. While there are early-stage initiatives emerging, such as that led by The Microfibre Consortium, to standardise monitoring and approaches to tackle microfibre shedding; many textile manufacturers are unaware of the risk of microplastic fibre loss from their facilities and are thus unsure how to avert risk and improve their practices.

To address this gap, Fauna & Flora has developed a Fibre Loss Risk Assessment (FLoRA) Toolkit. to provide a crucial first step in assessing the risk of fibre loss from any given facility. The FLoRA toolkit aims to provide companies, at all stages in the textile supply chain, with an entry point to assess and understand how their operations might contribute to the problem of fibre pollution, identify where intervention might be necessary to reduce the risk of fibre loss, and what can be done to prevent shedding and loss of fibres to the environment.

¹ Boucher, J. and Friot, D., 2017. *Primary microplastics in the oceans: a global evaluation of sources* (Vol. 10). Gland, Switzerland: IUCN.

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The FLoRA Toolkit: Instructions for use

The FLoRA Toolkit consists of two interrelated files that should be used in tandem to help yarn, textile and garment manufacturers identify risk points of microplastic fibre loss. The documents are:

1. **The Fibre Loss Risk Assessment (FLoRA)** – This is an open source, Excel-formatted Risk Assessment intended to be an accessible entry point for all stakeholders in textile and garment manufacturing supply chains.
2. **The FLoRA Supporting document** – This provides supplementary material to be used alongside the risk assessment. It provides an overview of points and procedures identified as being at risk of fibre loss throughout the supply chain. Where possible, the supporting document provides signposting to recommended interventions, loss prevention and/or mitigation measures and links to further resources.

Together, the FLoRA toolkit takes a holistic view of possible sources of microplastic fibre loss and pathways to the environment. It provides an indication of the risk of fibre loss from different processes, for different businesses and facilities, and does not aim to quantify fibre loss.

Full user instructions are included in the 'DIRECTIONS' tab of the Risk Assessment file. Your overall indicative Risk Rating will be generated automatically as you work through Sections 1, 2, and 3 (completing only those sections relevant to your business).

This supporting document can be used while you conduct your risk assessment, or afterwards, once you have identified areas of concern at the facility where microplastic fibre loss needs to be addressed.

Fibre loss risk points at a facility can be identified at multiple stages of a business. This toolkit covers a broad range of processes, rather than a Pareto Principle approach. However, having completed the toolkit, facility managers might find it useful to initially focus mitigation measures on the most impactful, high-risk processes, before addressing the facility as a whole.

This toolkit was developed to target synthetic fibre loss, but it can equally be used to identify both natural and synthetic fibre loss at a facility.

Wherever possible we have signposted users to more information, emerging solutions and useful resources.

As research in this space and global and national level legislation increases, mitigation techniques and developments in best practice guidance should become more widely available. Fauna & Flora invites users of the toolkit to share their interventions and solutions with us so that we can update information accordingly.

Section 1. Facility-level questions

1.1 Facility plan and walk-through:

1.1.1 Access to a facility plan/schematic/map

Explanation: *Full access to a facility plan, schematic, or map that shows all ventilation units, windows, drains and other forms of wastewater outflow helps companies to identify all potential leakage points of fibres shed by facility activities and machinery.*

1.1.2 Level of filtration at potential microplastic fibre leakage points. This includes filters on wet (drains) and dry (air vents) ducting that can be localised on or near machines and processes (i.e., drain directly from dye tank), and site level drains (i.e., main drain from site) and vents.

Explanation: *Installation of filtration systems are some of the most essential and effective ways to reduce or eliminate microplastic fibres from polluting the environment. These systems can also treat polluted water from textile manufacturing processes. This is already a mandatory requirement in many jurisdictions for manufacturers to operate. While standards vary between countries, it is likely that stricter legislation will come.*

Signposting:

- Adhere to or go beyond government and/or regional regulations that require suppliers to install filters on drains and air vents.
- It is recommended that air filters have a high (9 – 13) Minimum Efficiency Reporting Value (MERV) rating and/or High Efficiency Particulate Air filter (HEPA)².
- The Microfibre Consortium have released Preliminary Manufacturing Guidelines³ to control the release of microfibres within textile manufacturing wastewater. Guidance includes filtration at machine outlets, screens and strainers, and using Membrane Bioreactors (MBR) and/or ultrafiltration and/or reverse osmosis for effluent treatment.
- Forum for the Future's report (see appendix D, p. 86 – 89)⁴ details best practices and recommended upgrades for filtration and wastewater management for all wet processing facilities. These include ultrafiltration with fine membranes, Membrane Bioreactors (MBRs) and reverse osmosis, to capture the smallest microfibres.
 - MBRs have been found to filter out up to 99% of microfibres and are significantly more effective than traditional sludge treatments.
 - Ultrafiltration systems use a fine membrane to remove particles as small as 0.1–0.01 µm. Ultrafiltration systems are also associated with wastewater recycling systems which can enable a facility to have a more closed-loop system.

² United States Environmental Protection Agency. Available [here](#).

³ The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

⁴ Forum for the Future, Tackling microfibres at source, (Appendix D, p. 86 –89). Available [here](#).

- Reverse osmosis uses even finer membranes than ultrafiltration (0.001 µm) and can yield fresh water that can then be reused at a facility. The report recommends that other filtration systems such as ultrafiltration or MBRs are used alongside reverse osmosis to improve overall efficiency.
- Acousweep⁵, is another emergent technology created by the Hong Kong Research Institute of Textiles and Apparels (HKRITA). It is heralded as an innovative eco-alternative to wastewater separation systems, that filters and captures microplastic fibres using sweeping acoustic waves. Fibres are easily removed, and the technology does not require any chemicals, solvents or additives, nor membrane filters.
- The Roadmap to Zero Programme, by ZDHC⁶, provides the fashion industry with tools to eliminate harmful chemicals from its global supply chain. While the focus is not microplastic fibres, ZDHC does provide various guidelines, parameters, limit values and test methods, including ZDHC Wastewater Guidelines on wastewater discharge, sludge quality and disposal pathways.

1.1.3 Maintenance or inspection of identified leakage points and filtration systems

Explanation: *Frequent, scheduled inspection and maintenance of identified leakage points and filtration systems will lower the risk of microplastic fibre loss. Processes known to generate significantly larger amounts of fibre loss should be checked and maintained even more frequently.*

⁵ Acousweep, Hong Kong Research Institute of Textiles and Apparels (HKRITA). Available [here](#).

⁶ Roadmap to Zero Programme, ZDHC. Available [here](#).

1.2 Fabric and/or material inventory:

1.2.1 Types of synthetic fibres and textiles used at facility

Explanation: Research is on-going by various organisations to identify which material type has the highest shed rate. This toolkit currently addresses synthetic fibres, including Acetate, Acrylic, Nylon, Polyamide, Polyester, Polycotton blend, Polypropylene, Polyvinyl Chloride (PVC), Rayon, Viscose, Lyocell, Recycled polyester, Elastane, Lycra, Spandex, and other synthetic blends.

Current research shows that in addition to material type, many compounding factors affect the shed rate, biodegradability and ecotoxicity of fibres/fabrics. For example, natural and bioplastic yarns and fabrics coated with synthetic polymers (e.g., dyes, chemicals, flame retardants, UV stabilisers, antimicrobial agents) can persist and act like microplastics when they enter the environment. As such, at present it is difficult to confidently assign a risk rating to specific synthetic fibres.

More robust research is needed that compares like-for-like fabric shed rates for the industry to have more conclusive results. For example, some like-for-like shed rate comparison studies for PET and rPET found that rPET had a higher shed rate than PET, while others found that rPET did not shed more (see Forum for the Future's report, Tackling microfibres at source, Appendix B⁷, and The Microfibre Consortium's rPET Technical Research Report⁸ on this topic). Already, many brands and organisations are taking the microfibre loss issue seriously by promoting research and development in fabric design and finishing options or considering internal audits of clothing shed risk. These include, the European Outdoor Group, Ocean Wise, The Microfibre Consortium, Forum for the Future, and brands such as Patagonia, REI, MEC, H&M, Arc'teryx, Polartec, Vaude, and Adidas.

It is also critical that the textile industry considers comparisons of microfibre shed rates, alongside environmental impacts when selecting preferred materials.

Signposting:

The Microfibre Consortium (TMC)⁹, a UK-based non-profit organisation facilitates cross-industry collaboration on the problem of microfibre shedding from textiles. TMC have created a 'Microfibre Data Portal' to record data on shed rates and technical specifications of different materials. TMC intend to use this to develop a baseline for fibre fragmentation of finished fabrics and provide a database of materials with lower shed rates. TMC have some resources⁸ available online and aim to publicly launch a Microfibre Knowledge Hub¹⁰ as an online tool. TMC's 2021/2022 report noted that fabrics of all compositions shed fibres. They state that composition is not the only driver for fibre fragmentation and all fabric specifications influence fragmentation - fibres and yarn type, fabric structure, colouration, and both chemical and mechanical finishing.

⁷ Forum for the Future, Tackling microfibres at source (2023). Available [here](#).

⁸ The Microfibre Consortium, Resources. Available [here](#).

⁹ The Microfibre Consortium. Available [here](#).

¹⁰ The Microfibre Consortium, Knowledge Hub. Available [here](#).

Ocean Wise¹¹, a Canadian based non-profit organisation, formed the Microfiber Partnership¹², working with retailers to inform science-based solutions to microfibre release from textiles. They published a study on microfibre shedding from different consumer apparel textiles in domestic laundry and continue to work on innovative solutions to address microfibre loss.

Section 2. Facility-level protocol

2.1 Personal Protective Equipment (PPE) - Mandatory questions

2.1.1 Use of personal protective equipment (PPE)

Explanation: *Personal Protective Equipment (PPE) is specialised clothing or equipment worn by employees for protection against injury and infection, such as physical hazards, chemicals and airborne particulate matter.*

Recommendations:

- FFP3 face masks are considered to provide the highest filtration efficiency and breathing resistance¹³.
- High quality, regular staff training and guidance on how to best use PPE helps educate employees how to reduce their exposure to microplastic fibres.

2.1.2 Laundering of uniform and/or PPE

Explanation: *Loose microplastic fibres can easily attach to staff uniform and PPE when working in the facility. Therefore, how uniform and PPE are laundered can have an impact on microplastic fibre loss to the environment.*

Recommendations:

- To reduce microplastic fibre loss to the environment we recommend that staff change into/out of uniform and/or PPE on-site. Best practice includes washing all uniform and reusable PPE on-site in a controlled setting, using industrial washing machines with ultrafiltration on wastewater systems to capture microplastic fibres. This is best practice guidance and might not be possible for all facilities.
- PPE that creates an intermediary barrier layer to trap fibres (e.g., aprons) will likely reduce the risk of fibres attaching to the staffs' clothing and will likely reduce loss to the environment.

¹¹ Ocean Wise. Available [here](#).

¹² Ocean Wise, Microfiber Partnership. Available [here](#).

¹³ Sharma, A., Omidvarborna, H. and Kumar, P., 2022. Efficacy of facemasks in mitigating respiratory exposure to submicron aerosols. *Journal of hazardous materials*, 422, p.126783.

2.1.3 Disposal of single-use PPE items

Explanation: *Loose microplastic fibres can easily attach to employees PPE when working in the facility. Correct disposal of single-use PPE can help reduce microplastic fibre loss to the environment. For example, collection of single-use PPE on-site and safe disposal helps contain fibre loss and ensure that it is managed in a controlled environment.*

Recommendations:

- High quality, regular staff training and guidance on how to best use and then dispose of PPE helps educate employees how to reduce their exposure to microplastic fibres and reduce environmental impacts.

Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16}, or disposing of single-use PPE in general waste. The key is to establish safe, re-useable PPE options that reduces waste generation whilst protecting users and to select an appropriate disposal method for single-use PPE that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

- We recommend collecting and recycling any recyclable components of PPE.

2.1.4 Use of air hoses (pneumatic lines) to remove microplastic fibres from clothing

Explanation: *The use of air hoses/pneumatic lines to blow off microplastic dust and fibre fragments from clothing during and after shifts results in microfibrils being blown about the facility in an uncontrolled manner. Use of air hoses can also disturb microfibrils that may have settled on the operating floor. This practice increases the movement of microfibrils in the air and facility, making it more difficult to control and manage the collection and disposal of microfibrils.*

Recommendations:

- Consider how often air hoses are used by staff to remove microfibrils from their clothing. Enforcement of Standard Operating Procedures that prohibit the use of air hoses for this practise is a simple step to reduce the spread and disruption of microfibrils. Best practice could require staff to change in/out of uniform in an assigned, sealed changing room. Whereby the facility washes all uniform on-site in machines with filters that capture fibres and these fibres are safely disposed of or reused.

¹⁴ Kallenbach, E.M., Eriksen, T.E., Hurley, R.R., Jacobsen, D., Singdahl-Larsen, C. and Friberg, N., 2022. Plastic recycling plant as a point source of microplastics to sediment and macroinvertebrates in a remote stream. *Microplastics and Nanoplastics*, 2(1), pp.1-15.

¹⁵ Yang, Z., Lü, F., Zhang, H., Wang, W., Shao, L., Ye, J. and He, P., 2021. Is incineration the terminator of plastics and microplastics? *Journal of Hazardous Materials*, 401, p.123429.

¹⁶ Shen, M., Hu, T., Huang, W., Song, B., Qin, M., Yi, H., Zeng, G. and Zhang, Y., 2021. Can incineration completely eliminate plastic wastes? An investigation of microplastics and heavy metals in the bottom ash and fly ash from an incineration plant. *Science of the Total Environment*, 779, p.146528.

2.2 Cleaning of facilities

2.2.1 General cleaning of different process areas. E.g., Dry and wet cleaning processes

Explanation: *Implementation of robust, regular, facility-wide cleaning protocols reduce the chance of microplastic fibres being discharged and lost to the environment. Wet cleaning processes are improved when protocols exist to process wastewater and trap fibres collected during cleaning. Both wet and dry-cleaning processes are improved when protocols exist to also capture any fibres collected on cleaning equipment.*

2.2.2 Collection and processing of microplastic dust and fibres

Explanation: *Robust standard operating procedures for collecting, handling, processing and safe disposal of microplastic dust and fibres at a facility can significantly help to reduce fibre loss. For example, fibres collected via a central vacuum system are safely contained and can potentially be upcycled for use within the facility or elsewhere.*

Recommendations:

- Staff training and guidance on how to best collect and dispose of microplastic dust and fibres helps educate employees how to reduce environmental impacts.
- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15,16} or disposal of dust and fibres in general waste. The key is to reduce waste generation wherever possible and to select an appropriate disposal method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

2.2.3 Equipment & techniques used for cleaning the facility

Explanation: *Highly efficient and specialised machinery, including vacuum systems, can help a facility to reduce risks of microplastic fibre loss. Whereas, more traditional methods, including hand-held brushes, wet cleaning practices (e.g., mop and bucket) and using fabric off-cuts as disposable cleaning cloths have limited effect in terms of reducing microplastic fibre loss risk. These latter methods have the potential of redistributing fibres into the air and/or wastewater systems.*

2.2.4 Staff training programmes on microplastic fibre loss

Explanation: *Regular training programmes educate staff on best practices to reduce microplastic fibre loss throughout a facility and best practices to avoid and prevent fibre loss. This benefits the environment, staff health and corporate sustainability.*

2.3 Management of air and water quality control

2.3.1 Filters on windows and air vents

Explanation: *Installation and regular maintenance of filters on windows and air vents is a recommended early step to containing microplastic fibre loss within a facility and reducing risk of loss to the environment.*

2.3.2 Compliance with national or international standards or industry requirements on ventilation and/or air quality

Explanation: *Many national or international standards or industry requirements for ventilation and air quality already exist. Best practice includes the adoption and adherence to these standards. Airborne microplastics can have severe consequences to human health. Staff that regularly work with synthetic textile manufacturing processes, without appropriate protection measures, are particularly vulnerable to negative health impacts¹⁷.*

Recommendations:

- The United Kingdom's Health and Safety Executive (HSE) provides guidance for ventilation in the workplace¹⁸ and includes guidance for matters such as the Control of Substances Hazardous to Health Regulations (COSHH)¹⁹. For further guidance on United Kingdom ventilation requirements in workplace buildings see Approved Document F: Volume 2²⁰ (p. 13 and 14) which provide links to regulations and guidance on Industrial Ventilation²¹ and Controlling Airborne Contaminants at Work²².
- See also the United States Environment Protection Agency information on air quality²³ and report on Building Air Quality²⁴.

2.3.3 Disposal of fly/dust/fibres from filters on windows and vents

Explanation: *Robust standard operating procedures for collecting, handling, processing and the safe disposal of microplastic dust and fibres collected from filters can significantly help to reduce fibre loss. Best practice may include regular collection of fibres via a central vacuum system and upcycling those fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

¹⁷ Prata, J.C., 2018. Airborne microplastics: consequences to human health? *Environmental pollution*, 234, pp.115-126.

¹⁸ United Kingdom's Health and Safety Executive (HSE). Guidance on ventilation in the workplace. Available [here](#).

¹⁹ The United Kingdom's Health and Safety Executive (HSE). Guidance on the Control of Substances Hazardous to Health Regulations (COSHH). Available [here](https://www.hse.gov.uk/coshh/index.htm). <https://www.hse.gov.uk/coshh/index.htm>

²⁰ United Kingdom Government Statutory Guidance. Ventilation: Approved document F. Available [here](#).

²¹ Industrial Ventilation: A Manual of Recommended Practice for Operation and Maintenance (American Conference of Government Industrial Hygienists, 2020)

²² HSG 258 Controlling Airborne Contaminants at Work (HSE, 2017)

²³ United States Environment Protection Agency. Do you suspect your office has an air problem? Available [here](#).

²⁴ United States Environmental Protection Agency. Build Air Quality – A guide for building owners and facility managers. Available [here](#).

2.3.4 Compliance with national or international standards or industry requirements on treatment of effluent and wastewater

Explanation: *Textile effluent can be heavily contaminated with pollutants such as microplastic fibres, toxic, non-biodegradable synthetic dyes and polymers, additives, PVA sizes, surfactants, PFAS, chemicals, dissolved solids, suspended solids and toxic metals. These pollutants can pose serious threats to soil health, crop production, human and animal health. In countries where municipal wastewater treatment facilities exist, they are not 100% effective at removing microfibres, therefore it is necessary that facilities have highly effective wastewater systems to capture and prevent loss of microfibres to the environment.*

There are already regulatory discharge standards that most facilities must comply with, and it is likely that more vigorous standards to capture microfibre discharge will be implemented soon. Facilities may be required to increase the efficiency of current filtration processes and invest in more advanced technologies, e.g., zero-discharge filtration technologies.

Signposting:

- Adhere to or go beyond government and/or regional regulations that require suppliers to regularly measure and report microfibre concentrations in effluent.
- The Microfibre Consortium have released Preliminary Manufacturing Guidelines²⁵ to control the release of microfibres within textile manufacturing wastewater.
- Forum for the Future's report (see appendix D, p. 86 – 89)²⁶ details best practices and recommended upgrades for filtration and wastewater management for all wet processing facilities. These include ultrafiltration with fine membranes, membrane bioreactors (MBRs) and reverse osmosis, to capture the smallest microfibres.
 - MBRs have been found to filter out up to 99% of microfibres and are significantly more effective than traditional sludge treatments.
 - Ultrafiltration systems use a fine membrane to remove particles as small as 0.1–0.01 µm. Ultrafiltration systems are also associated with wastewater recycling systems which can enable a facility to have a more closed-loop system.
 - Reverse osmosis uses even finer membranes than ultrafiltration (0.001 µm) and can yield fresh water that can then be reused at a facility. The report recommends that other filtration systems such as ultrafiltration or MBRs are used alongside reverse osmosis to improve overall efficiency.
- Acousweep²⁷, is another emergent technology created by the Hong Kong Research Institute of Textiles and Apparels (HKRITA). It is heralded as an innovative eco-alternative to wastewater separation systems, that filters and captures microplastic fibres using sweeping acoustic waves. Fibres are easily removed and the technology does not require any chemicals, solvents or additives, nor membrane filters.

²⁵ The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

²⁶ Forum for the Future, Tackling microfibres at source, (Appendix D, p. 86 –89). Available [here](#).

²⁷ Acousweep, Hong Kong Research Institute of Textiles and Apparels (HKRITA). Available [here](#).

- The Roadmap to Zero Programme, by ZDHC²⁸, provides the fashion industry with tools to eliminate harmful chemicals from its global supply chain. While the focus is not microplastic fibres, ZDHC does provide various guidelines, parameters, limit values and test methods, including ZDHC Wastewater Guidelines on wastewater discharge, sludge quality²⁹ and disposal pathways.

2.3.5 Disposal of waste/breakage/fly from filters on wastewater treatment

Explanation: *Robust standard operating procedures for safe disposal of microplastic fibres collected from wastewater filters will significantly help to prevent fibre loss to the environment. Best practice may include regular maintenance of filters and collection of fibres and responsibly upcycling those fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incinerating^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

2.3.6 Disposal of sludge from filters on wastewater treatment

Explanation: *Robust standard operating procedures for handling and disposing of sludge from wastewater treatment to minimise loss to the environment will significantly help to prevent fibre loss to the environment.*

Signposting:

- See ZDHC's Sludge Reference Document (2022), Version 1 for disposal pathways, sludge testing and wastewater guidelines²⁹, which is part of a set of guidelines and solutions provided by ZDHC.

²⁸ Roadmap to Zero Programme, ZDHC. Available [here](#).

²⁹ ZDHC Sludge Reference Document (2022), Version 1. Available [here](#).

Section 3. Process-based assessment: A systematic review of risk points for microfibre loss. Questions regarding processes are broken down into sub-sections by manufacturing stage.

3.1 Yarn Construction:

3.1.1 Vacuums on the spinnerets

Explanation: *Polymer strands/fibres/fragments can be lost to the surrounding area during extrusion, and when fibres are cut. There is further risk of fibres shedding as they are twisted into yarns, when fibres are glued to the central core, and when fibres are bound by the filament. It is important to consider the type of yarn construction and method used at the facility because this can affect the amount of shedding. For example, the shed risk of yarns can be affected by whether it is a continuous filament yarn (which are longer) or non-continuous staple yarn (which are shorter), as well as the number of filaments in a yarn, the tightness of knit, and the temperature used when producing a fibre. For example, studies on polyester fabric showed a great variety in the number of fibres shed depending on construction³⁰.*

Signposting:

- When melting and spinning pre-production pellets³¹ into fibres, lower and graduated temperatures can maximise tensile strength, reducing likelihood of microfibre formation^{30, 32}.
- Continuous filament yarns shed less than discontinuous or staple yarns³². Similarly, The Microfibre Consortium report³³ noted that fabrics made of staple fibre release on average 50% more fibre fragments than those made of filament yarns.
- A high number of filaments in yarn results in more shedding than a low number of filaments in yarn³⁴.
- Plied yarns detach fewer microfibres than single yarns³².
- Higher gauge (i.e., tighter knit) results in more shedding than lower gauge (i.e., looser knit)³⁴, although MERMAIDS³⁵ findings contradict this.

³⁰ Fauna & Flora, Literature review. Possible solutions to microplastic fibre pollution from textiles. Available [here](#).

³¹ Fauna & Flora, Stemming the tide: putting an end to plastic pellet pollution (2022). Available [here](#).

³² MERMAIDS (2018), cited in Belzagui, F. and Gutiérrez-Bouzán, C., 2022. Review on alternatives for the reduction of textile microfibers emission to water. *Journal of environmental management*, 317, p.115347.

³³ The Microfibre Consortium, 2021/2022 Report. Available [here](#).

³⁴ Carney Almroth, B.M., Åström, L., Roslund, S., Petersson, H., Johansson, M. and Persson, N.K., 2018. Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. *Environmental Science and pollution research*, 25, pp.1191-1199.

³⁵ MERMAIDS, Ocean, Clean, Wash. Available [here](#).

- The lower the yarn count (linear density of the yarn), the lower the number of fibres per cross-section, and the lower the release of microplastic fibres³².
- Forum for the Future³⁶ conducted preliminary research comparing different yarn spinning systems and found that open-end (rotor-spun) yarn construction shed the least and vortex yarn construction shed the most (p.82 of their report).

3.1.2 Collection & disposal of fly/dust

Explanation: *Robust standard operating procedures for collecting, handling and the safe disposal of microplastic dust and fibres during yarn construction can help to reduce fibre loss. For example, operating yarn construction machinery within a sealed environment, and utilising specialised vacuums on machinery aid collection of microplastic fibres/fly/dust. Fibres collected via a central vacuum system can be upcycled for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.1.3 Dyeing of yarns

Explanation: *Wet processing of textiles, including scouring, bleaching, dyeing and finishing treatments, whereby mechanical agitation in heat baths and drums causes shedding and breakage, are processes in the textile industry that can have one of the greatest impacts on microplastic fibre loss³⁶. However, alternative dry dyeing processes can reduce the risk of microfibrils being shed into water systems, as can dyeing yarns at the extrusion phase (e.g., dope dyeing).*

Signposting:

- Dope dyeing is a dyeing process that significantly reduces water, dye, chemical and energy consumption³⁷. The process adds a coloured pigment to liquid polymers before extrusion, the process where liquid polymer is forced through a spinneret to make continuous semi-solid filaments (fibres) to be twisted/spun into synthetic yarns. Dope dyeing technology can be expensive, but facilities can purchase dope dyed yarns from external producers³⁸.
- Forum for the Future's report³⁶ (see Appendix C, p. 83) advises the textile industry to rapidly move away from conventional processing in heated baths and tanks filled with water, to operations-based innovations that already exist, and machinery that requires very little to no water, and significantly less energy and chemistry.

³⁶ Forum for the Future, Tackling microfibrils at source. Available [here](#).

³⁷ IKEA. (2015). "IKEA Facts: Textile Dyeing". Available [here](#).

³⁸ We aRe SpinDye. Available [here](#).

- See the European Union (EU) Textiles Strategy for sustainable and circular textiles³⁹ for guidance on addressing unintentional release of microplastics from synthetic textiles.
- Further, to address chemical pollution from dyes, see the European Union (EU) Industrial Emissions Directive⁴⁰ to reduce air, water and soil pollution to levels harmless to health and the environment. Again, part of the EU Textiles Strategy for sustainable and circular textiles³⁹, provides Best Available Techniques (BATs) to reduce water and air emissions, and transition to practices with lower environmental impact. New environmental legislation⁴¹ provides Best Available Techniques (BATs) to reduce water and air emissions, and transition to practices with lower environmental impact.

3.1.4 Wastewater and filters from dyeing yarns

Explanation: *Globally, water pollution associated with textile manufacturing is a significant issue, mostly due to wet dyeing processes. As such wastewater treatment systems are already a requirement for companies to operate in many countries, but installation of highly efficient wastewater treatment systems is a key solution to consider because these systems can greatly reduce or eliminate microplastic fibre loss from polluting the environment. Wastewater systems can also treat polluted water (i.e., dyes and chemicals) before effluent is discharged into the water body. Furthermore, innovations in wastewater technology can facilitate closed-loop water cycling at a facility.*

Signposting:

- Adhere to or go beyond government and/or regional regulations that require suppliers to regularly measure and report microfibre concentrations in effluent.
- The Microfibre Consortium have released Preliminary Manufacturing Guidelines⁴² to control the release of microfibres within textile manufacturing wastewater.
- Forum for the Future's report (see appendix D, p. 86 – 89)⁴³ details best practices and recommended upgrades for filtration and wastewater management for all wet processing facilities. These include ultrafiltration with fine membranes, membrane bioreactors (MBRs) and reverse osmosis, to capture the smallest microfibres.
 - MBRs have been found to filter out up to 99% of microfibres and are significantly more effective than traditional sludge treatments.
 - Ultrafiltration systems use a fine membrane to remove particles as small as 0.1–0.01 µm. Ultrafiltration systems are also associated with wastewater recycling systems which can enable a facility to have a more closed-loop system.
 - Reverse osmosis uses even finer membranes than ultrafiltration (0.001 µm) and can yield fresh water that can then be reused at a facility. The report recommends that other filtration systems such as ultrafiltration or MBRs are used alongside reverse osmosis to improve overall efficiency.

³⁹ European Union Textiles Strategy for sustainable and circular textiles. Available [here](#).

⁴⁰ European Union, Industrial Emissions Directive. Available [here](#).

⁴¹ European Union (EU), Access to EU Law. Available [here](#).

⁴² The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

⁴³ Forum for the Future, Tackling microfibres at source, (Appendix D, p. 86 –89). Available [here](#).

- Acousweep⁴⁴, is another emergent technology created by the Hong Kong Research Institute of Textiles and Apparels (HKRITA). It is heralded as an innovative eco-alternative to wastewater separation systems, that filters and captures microplastic fibres using sweeping acoustic waves. Fibres are easily removed and the technology does not require any chemicals, solvents or additives, nor membrane filters.
- The Roadmap to Zero Programme, by ZDHC⁴⁵, provides the fashion industry with tools to eliminate harmful chemicals from its global supply chain. While the focus is not microplastic fibres, ZDHC does provide various guidelines, parameters, limit values and test methods, including ZDHC Wastewater Guidelines on wastewater discharge, sludge quality and disposal pathways.

3.1.5 Frequency of cleaning the wastewater filters

Explanation: *Robust standard operating procedures for cleaning and maintaining wastewater equipment and filters will significantly help to prevent fibre loss to the environment. Best practice may include regular, scheduled maintenance of filters and equipment, and regular, scheduled collection of microplastic fibres.*

3.1.6 Disposal of waste material captured by filters

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from wastewater filters and sludge will significantly help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres and/or waste for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.2 Textile and/or fabric construction:

3.2.1 Location of sizing machines

Explanation: *The process of sizing coats yarn with size paste to help it withstand weaving tension. The sizing paste also helps to improve yarn's abrasion resistance, covering protruding fibres in the yarn to reduce entanglement and breakage. After fabric production a chemical process is used to remove sizing chemicals, which can cause fibres to shed.*

The location of sizing machinery is an important consideration to reduce microplastic fibre loss. For example, locating machinery within well-managed, enclosed or sealed spaces helps contain shed fibres within the facility and reduces the risk of airborne fibre loss to the environment.

⁴⁴ Acousweep, Hong Kong Research Institute of Textiles and Apparels (HKRITA). Available [here](#).

⁴⁵ Roadmap to Zero Programme, ZDHC. Available [here](#).

3.2.2 Protocols to reduce loss of fibres and fly from sizing machines

Explanation: *Microplastic fibre loss can occur during use of sizing machines.*

Recommendations:

- To reduce microfibre loss, a facility can experiment with different machine settings to understand how this might affect fibre loss.
- Furthermore, specialised vacuums on the machinery could help capture fibre breakage and contain fibres within a centralised vacuum system, which can potentially be upcycled for use within the facility or elsewhere.
- The quantity or the nature of sizing agents used in the weaving process could be optimised, and the velocity of the weft transporter could be reduced to minimise fibre loss⁴⁶.

3.2.3 Frequency of cleaning the sizing machines

Explanation: *Robust standard operating procedures for cleaning and maintaining sizing machines will help to prevent fibre loss to the environment. Best practice may include regular, scheduled cleaning (e.g., using vacuums) of equipment and collection of microplastic fibres.*

3.2.4 Capture and disposal of fibres and fly from the sizing machines

Explanation: *Robust standard operating procedures for capturing and safely disposing of microplastic fibres collected from sizing machines will help to prevent fibre loss to the environment. Best practice may include capturing fibres in a centralised vacuum system and responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.2.5 Types of mechanisms used to weave or knit textiles

Explanation (loom): *During weaving and knitting processes, threads are interlaced lengthwise (warp) and width-wise (weft) on a loom. Industrial loom types can include air jet and water jet. Fibres can fragment and shed from the yarn as it is interlaced and tightened on the loom. Tension, friction, and movement are likely to result in a lot of shedding.*

Explanation (knitting): *Multiple loops of yarn are placed in a creel, then interwoven by a knitting machine according to a set pattern. Fibre's fragment and shed from the yarn as it is looped and interwoven by the knitting machine's needles. Tension, friction, and movement are likely to result in a lot of shedding.*

⁴⁶ Belzagui, F. and Gutiérrez-Bouzán, C., 2022. Review on alternatives for the reduction of textile microfibers emission to water. *Journal of environmental management*, 317, p.115347.

Signposting:

- The yarn carrier velocity of knitting and weaving could be reduced to decrease damaging fibres. This will likely increase production time but might cause less fibre loss⁴⁷.
- One study noted that high-density fabrics have a tighter structure than lower ones, which can reduce the loss of microplastic fibres⁴⁷. However, another study stated that there is no clear correlation between fabric weight and fibre loss⁴⁸.
- Plain weave fabrics detach fewer microfibrils than twill weave ones⁴⁷. Weft knit fabrics shed on average twice as many fibre fragments as woven fabrics⁴⁸.

3.2.6 Location of weaving / knitting processes

Explanation: *The location of weaving and knitting machinery is an important consideration to reduce microplastic fibre loss. For example, locating machinery within well-managed, enclosed or sealed spaces helps contain shed fibres within the facility and reduces the risk of airborne fibre loss to the environment.*

3.2.7 Mechanisms in place to capture fibres/fly/dust from looms, knitting machines and creels. (E.g., vacuums to remove fibres)

Explanation: *Weaving and knitting processes can cause microplastic fibres to be lost to the surrounding area, due to abrasion and friction of yarns.*

Recommendations:

- Robust standard operating procedures for collecting and processing microplastic dust and fibres during weaving and knitting can help to reduce fibre loss. For example, operating weaving and knitting processes within a sealed environment, and utilising specialised vacuums on machinery to aid collection and capture of microplastic fibres/fly/dust. Fibres collected via a central vacuum system can be upcycled for use within the facility or elsewhere.
- To reduce the possibility of yarn breakage and friction, lubricated yarns (i.e., using natural wax) can drastically reduce the amount of fly produced.
- Some facilities use fabric offcuts as cloths to clean machinery and/or remove fibres/fly/dust. This practice can disperse shed fibres into the air or surrounding environment and often the cloth is discarded as waste. Best practice could be the use of vacuums that remove fibres to a centralised vacuum system and upcycle offcuts for reuse in the facility or externally.

⁴⁷ Belzagui, F. and Gutiérrez-Bouzán, C., 2022. Review on alternatives for the reduction of textile microfibers emission to water. *Journal of environmental management*, 317, p.115347.

⁴⁸ The Microfibre Consortium, 2021/22 Report. Available [here](#).

3.2.8 Disposal of captured fibres and fly from weaving and knitting processes

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from weaving and knitting processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.3 Scouring, dyeing and finishing

3.3.1 Processes used to dye fabric and finished garments.

Explanation (processes): *Conventional processes to dye yarns and fabrics are water intensive, wet processes that immerse material in dye chemicals, often in the same drum/machine/water bath where pre-treatment (scouring and bleaching), and finishing chemicals applied to textiles, and initial washing take place. Mechanical agitation during these processes can cause fibre shedding and breakage, and wastewater from scouring, dyeing and finishing processes can carry a significant number of microfibrils.*

Explanation (dyes): *Dyes are applied to textiles to provide a certain level of permanent colour. Dyes can be derived from natural sources, such as plants, but are more often synthetically produced from substances such as petrochemicals. Dyes are often mixed with other additives and different dyes tend to be used for different fibres and stages of textile production. Conventional wet dyeing processes in the textile industry can cause the greatest risk of microplastic fibre loss⁴⁹, and mechanical agitation in heat baths and drums cause shedding and breakage. However, alternative dyeing processes, such as cold pad-batch dyeing, use much lower water consumption, and dry dyeing processes avoids microfibrils being shed into water systems.*

Recommendations:

- Dry dyeing processes can have a very significant impact on reducing the number of microfibrils lost to waterways. Best practice would require facilities to move away from wet dyeing techniques that use heated baths and water tanks, and transition towards processes that require little or no water, such as dry dyeing (see 3.3.2). These changes will also reduce energy consumption, water use and pollution.
- If a facility uses a lot of water for dyeing, they can reduce their impact with the installation of a closed-loop water system that reuses wastewater within the facility.

⁴⁹ Forum for the Future, Tackling microfibrils at source. Available [here](#).

Signposting:

- Dope dyeing is a dyeing process that significantly reduces water, dye, chemical and energy consumption⁵⁰. The process adds a coloured pigment to liquid polymers before extrusion, the process where liquid polymer is forced through a spinneret to make continuous semi-solid filaments (fibres) to be twisted/spun into synthetic yarns. Dope dyeing technology can be expensive, but facilities can purchase dope dyed yarns from external producers⁵¹.
- Forum for the Future's report⁵² (p. 34 – 40) evaluates different dyeing solutions to reduce microfibre loss during dyeing processes. The report includes a table (p. 40) that compares alternative dyeing techniques, including dope dyeing, cold pad-batch dyeing, supercritical CO₂ dyeing, ultrasonic assisted dyeing and dry digital printing that could have the most impact on reducing fibre loss in the industry.
- Facilities are advised to assess and monitor fibre shedding from their current dyeing processes. Forum for the Future have developed a research methodology that facilities can replicate to test for fibre loss in dyeing processes⁵².
- To reduce environmental impact and the use of abrasive synthetic chemicals and dyes, facilities could consider using natural dye alternatives, or dyes known to be more sustainable, less toxic and less harmful.

3.3.2 Processes used to finish fabrics and garments

Explanation: *Finishing processes add specific aesthetic and technical qualities to fabrics and garments via chemical, physical and mechanical (see 3.6) treatments. The process is performed after dyeing yarn or fabric to improve the look, performance or feel of the finished textile or garment. Given that many of these are wet processes, there is a higher risk of fibre loss. The chemical impact of finishes should also be considered to avoid polluting wastewater.*

3.3.3 Types of finishes used at the facility

Explanation: *Types of chemical finishing include membrane lamination, water-repellent coatings, enzyme washing, anti-static, anti-stain and anti-fungal finishes. Given that many of these are wet processes, there is a higher risk of fibre loss.*

Textile effluent can be heavily contaminated with pollutants, especially from wet dyeing and finishing processes and the chemical impact of finishes should also be considered to avoid polluting wastewater. Pollutants such as microplastic fibres, toxic, non-biodegradable synthetic dyes and polymers, additives, PVA sizes, surfactants, finishing chemicals (including per- and polyfluoroalkyl substances (PFAS)) and toxic metals can pose serious threats to soil health, crop production, human and animal health.

⁵⁰ IKEA. (2015). "IKEA Facts: Textile Dyeing". Available [here](#).

⁵¹ We aRe SpinDye. Available [here](#).

⁵² Forum for the Future, Tackling microfibres at source. Available [here](#).

Recommendations:

- An example of innovative research being undertaken to reduce microplastic fibre loss includes techniques such as natural finishing treatments, for example *pectin coating*⁵³ derived from agro-by products, applied to fabrics that might dramatically reduce the loss of fibres.
- Even in countries where municipal wastewater treatment facilities exist, they are not 100% effective at removing microfibrils. Therefore, it is necessary that facilities have highly effective wastewater systems to capture and prevent loss of microfibrils to the environment and adhere to the highest level of regulations for treating wastewater.

Signposting:

- Adhere to or go beyond national and/or regional regulations and industry standards that require suppliers to regularly measure and report microfibre concentrations in effluent.
- We recommend that wherever possible a facility substitutes any substances of very high concern and/or substances restricted by the Stockholm Convention and EU regulations, such as the European Chemicals Agency (ECHA)⁵⁴. This is especially important because if textiles are coated with harmful chemicals and those fibres are lost to the environment, these chemicals can persist and negatively impact environmental, animal and human health.
- Facilities can commit to textile industry standards and certifications, such as OEKO-TEX, STANDARD 100⁵⁵ that tests textiles for harmful substances. This standard has banned the use of perfluorinated and polyfluorinated alkyl substances (PFAS/PFC) in textiles, leather and footwear, in co-ordination with the ZDHC Manufacturing Restricted Substances List (ZDHC MRSL) version 3.0⁵⁶.
- Under the European Union (EU) Industrial Emissions Directive⁵⁷ to reduce air, water and soil pollution to levels harmless to health and the environment, the textile industry will have to comply with new legal norms.
- The new environmental legislation⁵⁸ under the EU Strategy for Sustainable and Circular Textiles⁵⁹ addresses the production and consumption of textiles, as well as environmental issues relevant to circular economy principles. The new directive advocates for the textile industry to transition to more sustainable practices, such as substituting harmful and hazardous chemicals to more environmentally friendly

⁵³ De Falco, F., Gentile, G., Avolio, R., Errico, M.E., Di Pace, E., Ambrogi, V., Avella, M. and Cocca, M., 2018. Pectin based finishing to mitigate the impact of microplastics released by polyamide fabrics. *Carbohydrate polymers*, 198, pp.175-180. Available [here](#).

⁵⁴ The European Chemicals Agency (ECHA). Available [here](#).

⁵⁵ OEKO-TEX. Available [here](#).

⁵⁶ ZDHC MRSL Version 3.0. Available [here](#).

⁵⁷ European Union, Industrial Emissions Directive. Available [here](#).

⁵⁸ European Union (EU), Access to EU Law. Available [here](#).

⁵⁹ European Union Strategy for Sustainable and Circular Textiles. Available [here](#).

alternatives, as well as address energy and resource efficiency and waste generation.

- The new EU directive also provides Best Available Techniques (BATs) to reduce water and air emissions, and transition to practices with lower environmental impact.

3.3.4 Filtering effluent from scouring, dyeing and rinsing processes

Explanation: *The textile industry is one of the biggest sources of global water pollution, mostly due to wet dyeing processes. Wastewater treatment systems are already a requirement for companies to operate in many countries, but installation of highly efficient wastewater treatment systems is a key solution to consider because these systems can greatly reduce or eliminate microplastic fibre loss from polluting the environment. Wastewater systems can also treat polluted water (i.e., dyes and chemicals) before effluent is discharged into the water body. Furthermore, innovations in wastewater technology can facilitate closed-loop water cycling at a facility.*

Signposting:

- The Microfibre Consortium have released Preliminary Manufacturing Guidelines⁶⁰ to control the release of microfibres within textile manufacturing wastewater.
- Forum for the Future's report (see appendix D, p. 86 – 89)⁶¹ details best practices and recommended upgrades for filtration and wastewater management for all wet processing facilities. These include ultrafiltration with fine membranes, membrane bioreactors (MBRs) and reverse osmosis, to capture the smallest microfibres.
 - MBRs have been found to filter out up to 99% of microfibres and are significantly more effective than traditional sludge treatments.
 - Ultrafiltration systems use a fine membrane to remove particles as small as 0.1–0.01 µm. Ultrafiltration systems are also associated with wastewater recycling systems which can enable a facility to have a more closed-loop system.
 - Reverse osmosis uses even finer membranes than ultrafiltration (0.001 µm) and can yield fresh water that can then be reused at a facility. The report recommends that other filtration systems such as ultrafiltration or MBRs are used alongside reverse osmosis to improve overall efficiency.
- Acousweep⁶², is another emergent technology created by the Hong Kong Research Institute of Textiles and Apparels (HKRITA). It is heralded as an innovative eco-alternative to wastewater separation systems, that filters and captures microplastic fibres using sweeping acoustic waves. Fibres are easily removed and the technology does not require any chemicals, solvents or additives, nor membrane filters.

⁶⁰ The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

⁶¹ Forum for the Future, Tackling microfibres at source, (Appendix D, p. 86 –89). Available [here](#).

⁶² Acousweep, Hong Kong Research Institute of Textiles and Apparels (HKRITA). Available [here](#).

- The Roadmap to Zero Programme, by ZDHC⁶³, provides the fashion industry with tools to eliminate harmful chemicals from its global supply chain. While the focus is not microplastic fibres, ZDHC does provide various guidelines, parameters, limit values and test methods, including ZDHC Wastewater Guidelines on wastewater discharge, sludge quality and disposal pathways.

3.3.5 Frequency of cleaning wastewater filters

Explanation: *Robust standard operating procedures for cleaning and maintaining wastewater equipment and filters will significantly help to prevent fibre loss to the environment. Best practice may include regular, scheduled maintenance of filters and equipment, and regular, scheduled collection of microplastic fibres.*

3.3.6 Disposal of solid or sludge material captured by filters

Explanation: *Robust standard operating procedures for handling and disposing of sludge from wastewater treatment will significantly help to prevent fibre loss to the environment.*

Signposting:

- See ZDHC's Sludge Reference Document (2022), Version 1 for disposal pathways, sludge testing and wastewater guidelines⁶⁴, which is part of a set of guidelines and solutions provided by ZDHC.

3.4 Heat setting

Explanation: *Heat setting is a process applied to synthetic fabrics, whereby fabrics are subjected to high temperatures (usually either a dry heat, super-heated steam or saturated steam environment) for a short time to give fibres, yarns or fabrics dimensional stability. Fabric first passes through a heat setting padder followed by a heating chamber. At the padder, chemicals like softeners can be applied.*

Heat setting often causes synthetic fibres to gain volume. The process is also often used to give fabrics other attributes, such as crease resistance, temperature resistance, shape retention, softness, dyeability, versatility, resilience and elasticity.

A recent study identified that heat setting is one of the processes (along with wet dyeing) that contributes the most to fibre shedding⁶⁵.

3.4.1 Location of the heat setting conveyor belt

Explanation: *The location of sizing machinery is an important consideration to reduce microplastic fibre loss. For example, locating machinery within well-managed, enclosed or sealed spaces helps contain shed fibres within the facility and reduces the risk of airborne fibre loss to the environment.*

⁶³ Roadmap to Zero Programme, ZDHC. Available [here](#).

⁶⁴ ZDHC Sludge Reference Document (2022), Version 1. Available [here](#).

⁶⁵ Forum for the Future, Tackling microfibres at source, (p. 29 & p.31). Available [here](#).

3.4.2 Capture of residual fibres from the fabric after heat setting

Explanation: *Given that heat setting is likely one of the processes that contributes the most to fibre shedding⁶⁶, capturing fibre loss at this stage can have a big impact on mitigating fibre loss at a facility.*

Robust standard operating procedures for capturing microplastic fibres collected from heat setting processes will help to prevent fibre loss to the environment. Best practice may include installing specialised vacuums on heat setting machinery, capturing fibres in a centralised vacuum system and responsibly upcycling collected fibres for use within the facility or elsewhere.

Signposting:

- In the absence of alternative methods to heat setting, facilities can experiment with lowering temperatures and duration settings to reduce fibre loss.
- We encourage facilities to conduct regular assessments to monitor fibre loss generated from each manufacturing process. Forum for the Future has developed a freely available, highly replicable and cost-effective sample collection and testing methodology that facilities can use to measure fibre loss from each processing step. See Forum for the Future's report, Tackling Microfibres at Source⁶⁷ for details on the scope and methodology and their Technical Research Report⁶⁸ for full details on how to take samples from each processing stage, what types of samples to collect and how to package and transport samples to the testing facility.

3.4.3 Disposal of residual fibres that have been removed or captured from fabric and machinery

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from heat setting processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

⁶⁶ Forum for the Future, Tackling microfibres at source, (p. 29). Available [here](#).

⁶⁷ Forum for the Future, Tackling microfibres at source (p.26). Available [here](#).

⁶⁸ Forum for the Future, Tackling Microfibres at Source - Technical Research Report. Available [here](#).

3.5 Fabric cutting

3.5.1 Capturing fibre loss during the use of fabric spreaders to lay out fabric on cutting tables

Explanation: *Fabric cutting is the process of separating (sectioning, curving, severing) a spread (fabric) into garment sections that are the exact size and shape of the pattern pieces on a marker to be ready for sewing. Fabric cutting processes can be a big contributor to microplastic fibre loss. Accurate cutting can minimise fabric wastage.*

Recommendations:

- Robust standard operating procedures for capturing microplastic fibres collected from fabric cutting processes will help to prevent fibre loss to the environment.
- Best practice may include a regular, specialised cleaning programme for high fibre loss processes, as well as implementation of specialised equipment designed to capture fibres in these areas. For example, install rubber strips and/or mats at cutting stations to capture fibres, and/or specialised vacuums, such as on cutting knives.
- Minimise personnel turnover. Personnel working on fabric cutting processes only work in this area for their shift.
- Reduce staff traffic to a minimum in these areas.
- Maintain a very regular and adapted cleaning programme for high fibre loss areas, such as fabric cutting.

3.5.2 Fabric cutting processes

Explanation: *There are two common methods of fabric cutting, mechanical and laser cutting.*

Mechanical cutting: A vertical cutting machine uses a blade that cuts through fabric, multiple layers at a time. Fragments of fibre can be released in high volumes as the fabric is cut. The longer the cutting edge, the more fibres shed. Controlled conditions with very low humidity create a perfect environment for uncontrolled fly.

Laser cutting: Usually done with a Gerber cutter, which can cut one layer at a time, and is mostly used to cut the initial panels for sampling, or the pattern itself which is made of paper. Fibres are shed from the edges where the laser has cut through the fabric. There is no mechanical action or friction, though some fibres can still be lost as the fabric is handled and at the piece edges.

Recommendations:

- The use of highly accurate cutting machinery that minimises waste, such as laser cutting, can help to reduce microplastic fibre loss at the fabric cutting stage.

- Conventional mechanical cutting techniques that use cutting knives can create higher volumes of fibre loss, but specialised, innovative technology, such as installing vacuums on cutting knives, could help reduce fibre loss.
- Alternatively, a facility can minimise fabric cutting processes by creating a precise garment shape during the knitting or weaving process (e.g., flat knit, 3D and seamless knitting).

3.5.3 Cleaning of cutting tables and cutting rooms

Explanation: *Robust standard operating procedures for cleaning cutting tables and cutting rooms will help to prevent fibre loss to the environment. Best practice may include a regular, thorough, cleaning schedule (e.g., using vacuums) of equipment and collection of microplastic fibres.*

Dry cleaning processes reduce the chance of microplastic fibres being lost to wastewater and the environment. Dry cleaning processes are improved with the use of highly efficient and specialised industrial vacuums that help reduce the risk of microplastic fibres being lost and carried in the air and water.

Recommendations:

- The facility prohibits the use of pneumatic air hoses/compressed air to blow loose fibres from cutting stations, cutting rooms and staff clothing. This reduces the risk of fibres being redistributed into the air and around the facility.
- Staff regularly and thoroughly vacuum the area to capture loose fibres.

3.5.4 Removal of frayed or loose fibres from fabric once it has been cut

Explanation: *Robust standard operating procedures for removing frayed or loose fibres from fabric will help to prevent fibre loss to the environment. Best practice may include regularly using specialised equipment (e.g., vacuums) to capture and collect microplastic fibres from cut fabric.*

3.5.5 Disposal of fibres and fly captured from fabric cutting processes

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from fabric cutting processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.6 Flocking, napping and brushing

Explanation: *Mechanical finishing, such as flocking, napping, brushing, calendaring and embossing, are mechanical processes performed on prepared and dyed fabric to either improve the dimensions of the fabric or change fabric properties such as surface appearance or feel.*

Flocking: Nylon flock <1mm long are released onto uncured adhesive (usually silicon) panels on garments within a flocking chamber. The chamber creates an electrostatic difference, whereby flock is attracted from the top of the chamber to the bottom between positive and negative charges. The garment sits in the chamber between the charges. The flock sticks to the adhesive on the garment but residual flock is also loose in the chamber. Flocking creates a soft, velvet or suede-like texture on garments and can help with grip.

Flocking fibre loss risk: The flocking process is not selective and loose microplastic fibres spread easily. Despite flocking chambers being sealed and having an exhaust system it cannot be 100% effective at preventing fibre loss. Flock escapes when the chamber door is opened and garments are removed, and loose nylon fragments distribute to the air and the floor. In terms of loose fibres on the garment, flock particles cannot be vacuumed away too strongly for risk of removing them from the garment. The flocking process is therefore considered high risk for microplastic fibre loss.

Brushing: Fabric or garments are mechanically brushed. The surface of the textile is agitated, and fibres are deliberately broken to produce a softer or fluffier texture.

Brushing fibre loss risk: Fibres are deliberately broken and mechanically stressed, so shedding is likely.

Napping: A mechanical process where fibres are raised on the surface of a fabric by rollers covered with steel wires, or via teasels. Napping can create garment characteristics such as fluffy surfaces, brushed denim, mohair, synthetic suedes and fleece.

Recommendations:

- Mechanical finishing such as flocking, napping and brushing have been found to increase fragmentation and create very high quantities of microplastic fibre loss⁶⁹. It is recommended to work with clients to explore if alternative, less abrasive methods can be used.

3.6.1 Location of flocking, napping and brushing processes

Explanation: *The location of mechanical finishing equipment is a very important consideration to reduce microplastic fibre loss. For example, locating machinery within well-managed, enclosed or sealed spaces helps contain shed fibres within the facility and reduces the risk of airborne fibre loss to the environment.*

⁶⁹ The Microfibre Consortium, 2021/2022 Report. Available [here](#).

3.6.2 Protocols to capture fibres and fly released from flocking, napping and brushing processes

Explanation: Robust standard operating procedures for capturing microplastic fibres collected from mechanical finishing processes will help to prevent fibre loss to the environment. Best practice may include a regular, specialised cleaning programme for high fibre loss processes, as well as implementation of specialised equipment designed to capture fibres in these areas. For example, reducing staff traffic in the area, minimising personnel turnover, installing ultra-fine filters, maintaining seals on airtight chambers, and/or specialised vacuums.

Recommendations:

- Finished garments could pass through an in-line vacuum system that should not affect production speed⁷⁰.
- Personnel working on mechanical finishing processes only work in this area for their shift.
- Reduce staff traffic to a minimum in these areas.
- Maintain a very regular and adapted cleaning programme for high fibre loss areas, such as mechanical finishing.

3.6.3 Cleaning programme for flocking, napping and brushing processes

Explanation: Robust standard operating procedures for mechanical finishing processes will help to prevent fibre loss to the environment. Best practice could include a regular, thorough, cleaning schedule of equipment (e.g., using vacuums), as well as passing finished garments through specialised in-line vacuums to collect loose microplastic fibres.

Recommendations:

- Staff should regularly and thoroughly vacuum the area to capture loose fibres.
- The use of dry-cleaning processes will reduce the chance of microplastic fibres being lost to wastewater and the environment. Dry cleaning processes are improved with the use of highly efficient and specialised industrial vacuums that help reduce the risk of microplastic fibres being lost and carried in the air and water.
- The facility should prohibit the use of pneumatic air hoses/compressed air to blow loose fibres from mechanical finishing equipment, finished garments and staff clothing. This would reduce the risk of fibres being redistributed into the air and around the facility.

⁷⁰ Carney Almroth, B.M., Åström, L., Roslund, S., Petersson, H., Johansson, M. and Persson, N.K., 2018. Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. *Environmental Science and pollution research*, 25, pp.1191-1199.

3.6.4 Disposal of fibres and fly from garments subjected to flocking, napping and brushing processes

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from mechanical finishing processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

Signposting:

- Some research suggests that singeing mechanical finishing can avoid the formation of microplastic fibres on a fabrics surface⁷¹.

3.7 Printing

3.7.1 Type of printing technique used at the facility

Explanation: *Textile printing is the process of applying colour to textile fabrics, via pigments and dyes. Dyes can be derived from natural sources, such as plants, but are more often synthetically produced from substances such as petrochemicals. The colour is generally bonded with the fibre to ensure that it is resistant to washing. There are several types of printing techniques that include digital printing, such as sublimation and direct digital printing, and rotary screen printing.*

Rotary screen printing: Printing paste or ink is pressed onto a fabric by cylindrical screens. Fabric is passed under multiple screens for different colours and elements of a pattern. It is then dried, for example in an infrared drying unit.

Digital printing: Inkjet printer sprays dye in discrete patterns/designs onto pre-treated textiles or garments, after which the fabric is fixed using any combination of steam, dry heat, or pressure.

Recommendations:

- Heat and abrasion from printing techniques can result in microplastic fibre loss. To reduce shedding, we recommend lowering heat and abrasive applications wherever possible.
- Depending on the desired effect, some printing techniques (e.g., sublimation and direct digital printing) can be used to replace conventional wet dyeing processes, thereby reducing water and chemical usage. However, many chemicals used in printing are still toxic and can release during heating and washing.

• ⁷¹ Mermaids (2018), cited in Belzagui, F. and Gutiérrez-Bouzán, C., 2022. Review on alternatives for the reduction of textile microfibers emission to water. *Journal of environmental management*, 317, p.115347.

Environmental considerations and recommendations for print dyes:

- Many conventional dyes used for printing are still toxic and include harmful substances, such as plasticisers including polyvinylchloride (PVC) used to soften plastics, and phthalates⁷². Phthalates are not chemically bound to the PVC used for image printing, and can leak out when worn or washed, which has led to EU legislation banning the use of certain phthalates⁷³.
- Least harmful print dyes include non-toxic, sustainable ink alternatives, such as water-based inks, free of plasticisers (e.g., polyvinylchloride (PVC)).
- We recommend that wherever possible a facility substitutes any substances of very high concern and/or substances restricted by the Stockholm Convention and EU regulations, such as the European Chemicals Agency (ECHA)⁷⁴. This is especially important because if textiles are coated with harmful chemicals and those fibres are lost to the environment, these chemicals can persist and negatively impact environmental, animal and human health.
- We recommend using dry digital printing and non-toxic, sustainable inks where possible because it reduces the risk of microplastic fibres being lost to water systems and harm to the environment.

3.7.2 Capture of fibre fragments generated from printing processes

Explanation: *Robust standard operating procedures for capturing microplastic fibres collected from printing processes will help to prevent fibre loss to the environment. Best practice may include installing specialised vacuums on printing equipment or passing printed garments through an in-line vacuum system to capture fibres in a centralised vacuum system and responsibly upcycling collected fibres for use within the facility or elsewhere.*

3.7.3 Disposal of fibre fragments generated from printing processes

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from printing processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

⁷² A new textiles economy: Redesigning fashion's future. The Ellen MacArthur Foundation & Circular Fibres Initiative. Available [here](#).

⁷³ European Union, Industrial Emissions Directive. Available [here](#).

⁷⁴ The European Chemicals Agency (ECHA). Available [here](#).

3.8 Garment assembly

3.8.1 Methods used to assemble garments, including sewing, stitching, laminating and bonding

Explanation: *Garment assembly is one of the final stages in garment manufacturing, whereby different materials are combined to form the final product. For example, different garment components will be joined together by sewing, weaving, bonding, and laminating, and accessories will be added, such as zips, decorative embellishments, buttons and linings.*

Recommendations:

- We recommend that a facility adopts garment assembly methods that reduce fibre loss and waste. These might include using laser or heat/bonding technologies or changing how garments are woven and knitted to avoid sewing and assembly of different components. For example, using 3D knitting.
- A facility might also work with its customers to reduce the use of microplastic accessories on garments, such as glitter.

3.8.2 Capture of fibres and fly generated by sewing and garment assembly

Explanation: *Robust standard operating procedures for capturing microplastic fibres collected from garment assembly processes will help to prevent fibre loss to the environment. Best practice may include installing specialised vacuums on garment assembly workstations to capture fibres in a centralised vacuum system.*

3.8.3 Disposal of fibres and fly captured from garment assembly processes

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from garment assembly processes will help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

3.9 Washing and drying

3.9.1 Pre-washing and rinsing garments processed at the facility

Explanation: *Pre-washing and rinsing garments prior to use usually refers to washing them in a washing machine at the facility before they are packaged and sold.*

It is estimated that on a global scale, the laundering of synthetic textiles contributes the greatest amount (35%) of primary microplastic pollution in the ocean⁷⁵. Once garments leave a facility there is no control over how items are domestically laundered. Plus, many regions do not have municipal wastewater treatment facilities, and in the regions where they exist, they are not 100% effective at removing microfibrils.

Research has shown that new garments release more fibres during the first few washes^{76,77}, and a significant percentage of a garment's fibre loss during the use/consumer phase could be reduced with pre-washing at the production phase⁷⁸. Therefore, pre-washing and rinsing garments at the production stage, under regulated conditions and with highly specialised wastewater treatment and filtration systems can have a very significant effect on reducing the loss of microplastic fibres to the environment.

Recommendations:

- Adhere to the highest level of national or international regulations and/or industry standards on pre-washing and rinsing garments before sale.
- Pre-washing and rinsing garments at the facility before they are sold can make a significant impact on microplastic fibre loss to the environment. If doing so, it is vital that the facility has specialised wastewater treatment processes with excellent filtration systems to capture even the smallest microfibrils.
- Any facility that has not installed a wastewater management system should do so as a first step.

Signposting:

- Facilities can improve their operations by assessing how much their processes are contributing to microfibre shedding. This can be calculated using Forum for the Future's testing methodology⁷⁹ and/or The Microfibre Consortium's test method⁸⁰ on finished products.

⁷⁵ Boucher, J. and Friot, D., 2017. *Primary microplastics in the oceans: a global evaluation of sources* (Vol. 10). Gland, Switzerland: IUCN.

⁷⁶ Pirc, U., Vidmar, M., Mozer, A. and Kržan, A., 2016. Emissions of microplastic fibers from microfiber fleece during domestic washing. *Environmental Science and Pollution Research*, 23, pp.22206-22211.

⁷⁷ Zhang, Y.Q., Lykaki, M., Alrajoula, M.T., Markiewicz, M., Kraas, C., Kolbe, S., Klinkhammer, K., Rabe, M., Klauer, R., Bendt, E. and Stolte, S., 2021. Microplastics from textile origin—emission and reduction measures. *Green Chemistry*, 23(15), pp.5247-5271.

⁷⁸ OECD, 2020, Workshop on microplastics from synthetic textiles: knowledge, mitigation, and policy - summary note, accessed 1st September 2023. Available [here](#).

⁷⁹ Forum for the Future, Tackling Microfibrils at Source (available [here](#)) and Technical Research Report. Available [here](#).

⁸⁰ The Microfibre Consortium. Available [here](#).

3.9.2 Filters on facility washing machines

Explanation: *Installation and regular maintenance of highly efficient filters on washing machines is a recommended important step to contain microplastic fibre loss within a facility. The combination of facilities prewashing garments and installing filters on washing machines can reduce microplastic fibre pollution in downstream water bodies.*

Signposting:

- Adhere to the highest level of national or international regulations and/or industry standards on washing machine filters.
- The Microfibre Consortium have released Preliminary Manufacturing Guidelines⁸¹ to control the release of microfibres within textile manufacturing wastewater.
- Forum for the Future's report (see appendix D, p. 86 – 89)⁸² details best practices and recommended upgrades for filtration and wastewater management for all wet processing facilities. These include ultrafiltration with fine membranes, membrane bioreactors (MBRs) and reverse osmosis, to capture the smallest microfibres.
 - MBRs have been found to filter out up to 99% of microfibres and are significantly more effective than traditional sludge treatments.
 - Ultrafiltration systems use a fine membrane to remove particles as small as 0.1–0.01 µm. Ultrafiltration systems are also associated with wastewater recycling systems which can enable a facility to have a more closed-loop system.
 - Reverse osmosis uses even finer membranes than ultrafiltration (0.001 µm) and can yield fresh water that can then be reused at a facility. The report recommends that other filtration systems such as ultrafiltration or MBRs are used alongside reverse osmosis to improve overall efficiency.
- Acousweep⁸³, is another emergent technology created by the Hong Kong Research Institute of Textiles and Apparels (HKRITA). It is heralded as an innovative eco-alternative to wastewater separation systems, that filters and captures microplastic fibres using sweeping acoustic waves. Fibres are easily removed and the technology does not require any chemicals, solvents or additives, nor membrane filters.

3.9.3 Filters on pipes carrying effluent from washing machines

Explanation: *Installation and regular maintenance of highly efficient filters on washing machine pipes is a recommended step to contain microplastic fibre loss within a facility. The combination of facilities prewashing garments and installing filters on washing machines and pipes can reduce microplastic fibre pollution in downstream water bodies.*

Signposting:

- See 3.9.2 signposting above.

⁸¹ The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

⁸² Forum for the Future, Tackling microfibres at source, (Appendix D, p. 86 –89). Available [here](#).

⁸³ Acousweep, Hong Kong Research Institute of Textiles and Apparels (HKRITA). Available [here](#).

3.9.4 Treatment of washing machine effluent prior to release

Explanation: *Globally, the textile industry releases a huge amount of microplastic fibres through effluent. Therefore, effluent treatment is a key area to address to prevent the loss of fibres to the environment.*

Signposting:

- Adhere to or go beyond government and/or regional regulations that require suppliers to regularly measure effluent quality (e.g., with dissolved particle testing), as well as assess microfibre concentrations in effluent.
- The Microfibre Consortium have released Preliminary Manufacturing Guidelines⁸⁴ to control the release of microfibres within textile manufacturing wastewater.
- The Roadmap to Zero Programme, by ZDHC⁸⁵, provides the fashion industry with tools to eliminate harmful chemicals from its global supply chain. While the focus is not microplastic fibres, ZDHC does provide various guidelines, parameters, limit values and test methods, including ZDHC Wastewater Guidelines on wastewater discharge, sludge quality and disposal pathways.
- If possible, install a closed-loop water cycling system at a facility.

3.9.5 Capture of fibres from washed garments or textiles during the drying process

Explanation: *Installation and regular maintenance and cleaning of highly efficient filters on drying machines is a recommended step to contain microplastic fibre loss within a facility. The combination of facilities prewashing garments and installing filters on washing and drying machines can reduce microplastic fibre pollution in the air and downstream water bodies.*

Recommendations:

- Regularly capture fibres from the filters using vacuums.
- Dry garments could pass through an in-line vacuum system before being packaged.

3.9.6 Disposal of captured fibres

Explanation: *Robust standard operating procedures for safely disposing microplastic fibres collected from wastewater filters will significantly help to prevent fibre loss to the environment. Best practice may include responsibly upcycling collected fibres and/or waste for use within the facility or elsewhere.*

Recommendations:

- Additional microplastic fibre loss can be generated from most waste management processes, including recycling¹⁴, incineration^{15, 16} and disposal in general waste. The key to best practice is to select the method that creates the least additional fibre generation and ensure that fibre capture is as safe as possible.

⁸⁴ The Microfibre Consortium, Preliminary Manufacturing Guidelines. Available [here](#).

⁸⁵ Roadmap to Zero Programme, ZDHC. Available [here](#).

Recommended resources:

- [Forum for the Future, Tackling microfibres at source](#)
- [Ocean Wise, Microfiber Partnership](#)
- [The Microfibre Consortium \(TMC\) Resources](#)
- [ZDHC Roadmap to Zero](#)

If you have any questions or would like more information, please contact:

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