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Global Framework on Chemicals – for a Planet Free of Harm from Chemicals and Waste

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**Open-ended Working Group of the
Global Framework on Chemicals – for a
Planet Free of Harm from Chemicals and Waste
First meeting**
Punta del Este, Uruguay, 24–27 June 2025
**Agenda item 4(a) of the provisional agenda[*]
Financial arrangements: Assessing the existing financial and investment flows as well as financial needs associated with the implementation of the Framework**

Financial arrangements: Chemical use in textile value chains: Cotton clothing

Note by the Secretariat

The annex to the present note contains a working paper that presents Phase 1 results of a two-phase study towards ascertaining current financial flows and future financial needs to align sector-specific value chains with the strategic objectives and targets of the Global Framework on Chemicals. It is submitted as received by the secretariat of the Framework from the UNEP Finance Initiative.

The present note, including its annex, has not been formally edited.

[*] UNEP/GFC/OEWG.1/1

ANNEX

Chemical use in textile value chains: Cotton clothing

Phase 1 of 2 towards ascertaining financial flows and financial needs in Chemicals Value Chains.

Working paper

9th May 2025

Prepared by Dr Rory Sullivan and Tanya Cox of Chronos Sustainability Ltd, for UNEP Finance Initiative (UNEP FI).

About Chronos

Chronos Sustainability Ltd is a UK-based sustainability consultancy specialising in corporate responsibility, responsible investment and multistakeholder initiatives. Nominated for Consultancy of the Year 2025 in the UK Green Business Awards, Chronos works builds strong relationships with a broad range of clients and partners to deliver transformative change in the social and environmental performance of key industry sectors.

To find out more, visit www.chronossustainability.com

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Acronyms

EHS	Environmental Health and Safety
EU	European Union
FAO	Food and Agricultural Organization
FTAs	Free Trade Agreements
GFC	Global Framework on Chemicals
HA	Hectare
HHP	Highly Hazardous Pesticide
ICAC	International Cotton Advisory Council
IPM	Integrated Pest Management
Kg	Kilogram
LMICs	Low- and Middle-income countries
MMCF	Manmade Cellulosic Fibres
MRSL	Manufactured Restricted Substances List
NGOs	Non-Governmental Organisations
PAN	Pesticide Action Network
RSL	Restricted Substances List
SMEs	Small and Medium Sized Enterprises
USA	United States of America
USD	United States Dollars
USDA	United States Department of Agriculture
WHO	World Health Organization
WTO	World Trade Organisation

Definitions

HAZARD - the inherent property of a substance, agent or situation having the potential to cause undesirable consequences (e.g. properties that can cause adverse effects or damage to health, the environment or property).

HIGHLY HAZARDOUS PESTICIDE (HHP) - pesticides that are acknowledged to present particularly high levels of acute or chronic hazards to health or environment according to internationally accepted classification systems such as WHO or GHS or their listing in relevant binding international agreements or conventions. In addition, pesticides that appear to cause severe or irreversible harm to health or the environment under conditions of use in a country may be considered to be and treated as highly hazardous[(1)]. Note: herbicides, insecticides and fungicides (as types of pesticide) can also be considered highly hazardous.

INTEGRATED PEST MANAGEMENT – a low or no chemical approach to managing pests, diseases or weeds in farming by utilising a combination of different control methods, based on good crop husbandry (cultural and agronomic practices), physical, plant breeding or biological control methods, underpinned by effective pest, weed and disease monitoring strategies[(2)].

ORGANIC COTTON - Organic cotton is cotton that is produced, and certified, according to organic agriculture standards[(3)].

PESTICIDES - Pesticides are products used in agriculture to control pests that can harm crops. They can be categorised into herbicides (targeting weeds), insecticides (targeting insects) and fungicides (targeting diseases)[(4)].

TOXICITY - a physiological or biological property which determines the capacity of a chemical to do harm or produce injury to a living organism by other than mechanical means.

SECTION 1 – EXECUTIVE SUMMARY

1.A - Project purpose

1. The Global Framework for Chemicals - For a Planet Free of Harm from Chemicals and Waste (hereafter referred to as the GFC) was formally adopted in Bonn, Germany, in 2023 at the fifth International Conference on Chemicals Management (ICCM5).

    1. The overarching aim of the GFC is "to prevent, or where prevention is not feasible, minimise harm from chemicals and waste to protect the environment and human health".

2. In order to be able to fund the transition to a safer, more sustainable chemicals future that aligns with the strategic objectives and targets of the Framework, GFC Resolution V/3 recognises that there is a need for greater clarity on the current status of financial flows and investment needs and opportunities across the value chain.

    1. To this end, Chronos Sustainability Ltd has been commissioned by UNEP FI to undertake desk-based research and produce a robust, decision-useful analysis of the current status of financial and investment flows across the global chemicals value chain and to identify future financial needs associated with the implementation of the GFC.

3. The project is being delivered in two phases:

    1. **Phase 1:** In order to effectively implement the GFC across the whole life cycle of chemicals, Chronos has identified and mapped the complexity of sector-specific values chains including key stakeholders, the types of chemicals currently being used and opportunities for innovation. Results of Phase 1 are presented in the present report and activities included:

        1. Defining the chemicals value chain;

        2. Identifying highly chemical-dependent values chains; and

        3. Performing detailed analysis of key, specific sector specific value chains (cotton textiles for clothing).

    2. **Phase 2**: Building on Phase 1 analysis, Chronos will work with key stakeholders across the cotton textile (clothing) value chain, including the finance sector, with a view to:

        1. Identifying and reviewing current financial flows to different parts of the value chain, as defined in Phase 1, including any barriers to accessing or issuing finance;

        2. Determining key indicators for a GFC-aligned cotton textile (clothing) value chain;

        3. Ascertaining future finance needs of identified stakeholders to align the cotton textile (clothing) value chain with the strategic objectives and targets of the GFC including opportunities to leverage wider finance

initiatives (e.g. circular economy projects) to drive alignment with GFC targets; and

4. Outlining key data gaps and needs to support a transition to a GFC aligned value chain.

4. Here we present the results of Phase 1 of the study: an in-depth review of the cotton textile value chain (for clothing) including:

   1. Defining the value chain and highly chemical-dependent stages;

   2. Identifying key stakeholders at distinct stages of the value chain where the largest volumes of chemicals are used;

   3. Current practices with regards to chemicals use;

   4. The emergence of more sustainable chemical alternatives; and

   5. Opportunities to align with the GFC targets.

1.B - Methodology & Audience

5. Research for this publication took the form of desk-based literature review and was supplemented with phone interviews with identified experts.

6. The results of this mapping exercise can support ongoing discussions in the sector-specific GFC Industry Implementation Programmes at the Open-Ended Working Group meeting in Punte del Este, Uruguay including:

   1. Establishing criteria for and scaling effective low-chemical outcomes across the value chain to ensure long-term environmental, social and economic benefits of GFC implementation.

   2. Identifying and consolidating lists of the most harmful chemicals in use at different stages of the value chain including prioritisation for prohibition and phase out.

   3. Establishing clear criteria for GFC-aligned chemicals and monitoring protocols which appeal to public and private investors.

1.C - Introduction

7. Today, synthetic chemicals are widely used across the life cycle of consumer products.

8. A significant proportion of these chemicals are known to have harmful or hazardous properties with severe impacts and long term, detrimental consequences for human and environmental health.

9. Chemicals value chains are long, complex, and involve many stakeholder groups spanning multiple countries and legal jurisdictions.

10. Implementing the targets and strategic objectives of the GFC presents a unique opportunity to initiate a widespread transition to a safer, more sustainable future chemicals industry with a matrix approach including voluntary, mandatory and financial measures.

1.D - Defining the Cotton Value Chain

11. In 2023, over 24 million tonnes of cotton was produced with an estimated market value of USD 41.8 billion.

12. In the same year, global total garment sales were valued at approximately USD 548 billion.

13. Cotton fibre represents approximately 20% of all fibres produced for textiles.

14. Cotton value chains involve a wide variety of stakeholders, all of whom have a role to play in the transition to a more sustainable, GFC-aligned value chain.

15. For the purpose of this study, Chronos has defined the value chain as having 9 key stages (See Figure 1).

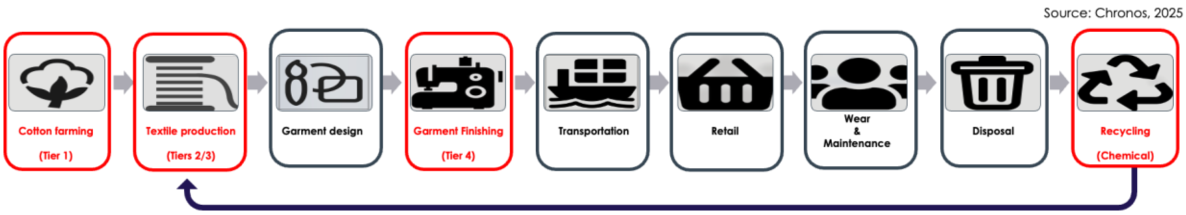


Figure 1: Cotton textile value chain for clothing, as defined for the purposes of this study.

16. The use and human and environmental exposure to harmful and hazardous chemicals and substances of concern in high volumes has been identified at four key stages of the cotton textile value chain (highlighted in red, above) which are therefore the focus of this study.

17. Throughout this report, the 4 stages are referred to as:

Stage 1: Cotton Farming

Stage 2: Cotton Textile Production

Stage 3: Cotton Garment Finishing

Stage 4: Cotton Textile Recycling

18. Most cotton stakeholders (from farmers to textile manufacturers) are small and medium sized enterprises in low- and middle-income countries.

19. Key countries have been identified at different stages of the life cycle (see Figure 2), presenting an opportunity to focus GFC implementation:

    1. Cotton fibre production: China, India, USA, Brazil.

    2. Cotton textile production: China, India, Bangladesh, Vietnam.

    3. Cotton garment finishing: China, Bangladesh, Vietnam, Italy.

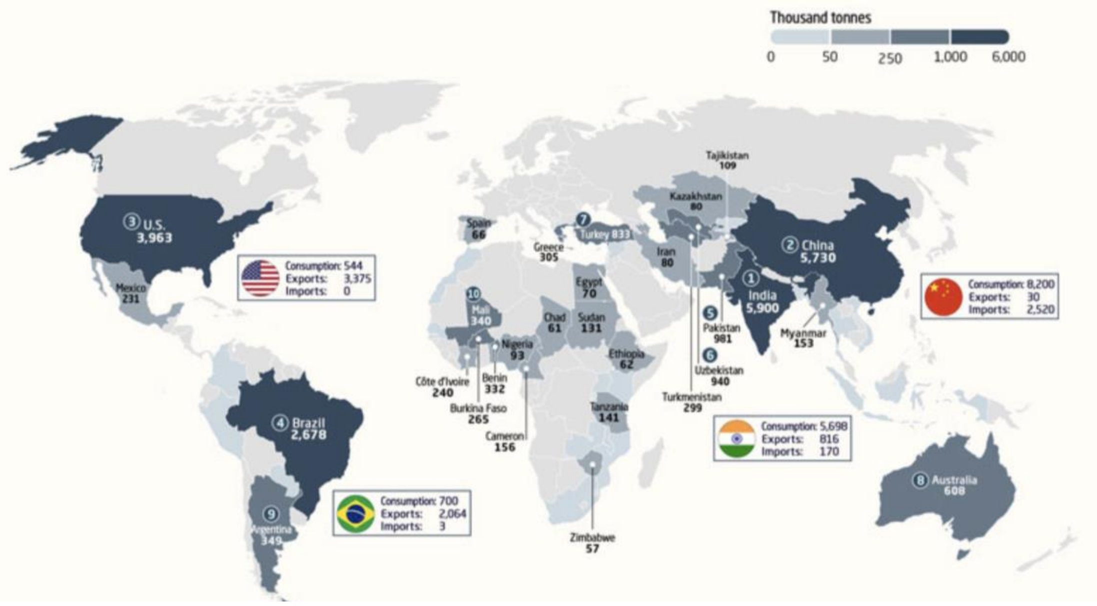


Figure 2: Global cotton import & export data 2021-2022. Image source: Econovis; Image data source: ICAC

20. In 2022, 300,000 tonnes of recycled cotton fibre was produced – equivalent to approximately 1% of the virgin fibre produced that year.

    1. Data gaps exist on the geographic spread of textile recycling facilities and on the chemicals used.

1.E - Use and impacts of harmful chemicals across cotton textile value chains

21. The textile sector is broadly considered to be one of the highest chemical-dependent industries.

    1. Estimates suggest 0.58kg chemicals are used to produce just 1 Kg of textiles[(5)].

2. Cotton fibre represents approximately 1/3 of all raw materials used to produce clothing.

22. It is estimated that over 8,000 chemicals are used in the production of textiles(6), but a definitive figure for cotton value chains is unavailable due to:

    1. Regional variations in legislation and classification of chemicals and inconsistent reporting and disclosure requirements.

    2. Absence of independent, standardised global databases or inventories; and

    3. Limited transparency in chemical use across the value chain.

23. Across cotton value chains, different types of chemicals are used for different purposes such as performance, aesthetics and functional requirements:

    1. Cotton fibre production: pesticides are used to improve crop growth and yield of cotton fibre;

    2. Cotton textile production: dyes and processing chemicals for preparation, bleaching, colour, texture, performance;

    3. Cotton garment finishing: includes antibacterial; flame-retardant; stain-proofing; and water-proofing treatments, dependant on intended use; and

    4. Cotton recycling: emerging technologies are reliant on chemicals to breakdown cotton textile waste into pulp to create secondary feedstock.

24. Many of the chemicals used are known to be harmful or hazardous to both human health and to the environment.

    1. PAN UK reports that up to 60% of cotton farmers experience negative health impacts associated with pesticide poisoning.

        1. This includes 12% of cases leading to permanent effects such as paralysis, nervous system impacts and loss of eyesight.

    2. Illness (short- and long-term) associated with chemical exposure has economic impacts due to reduced working time.

        1. 33% of cotton farmers surveyed by PAN UK had to take time off work due to acute pesticide-poisoning.

25. Cotton textile manufacturers (Tiers 2-4, see Figure 1) are also exposed to a wide variety of health-harming chemicals and particulate matter, but data paucity prevents a clear overview of the true scale of impact. Known health impacts include:

    1. The use of formaldehyde to achieve a crease-free finish on cotton clothing. Formaldehyde is a known carcinogen and linked to allergic contact dermatitis.

    2. Silica used in cotton denim distressing causes lung disease (silicosis) in exposed workers.

3. Long term exposure to PFAS's disrupts endocrine systems, weakens immunity and increases the risk of cancer.

26. Environmental impacts associated with cotton production are widespread and accumulative over time:

    1. Cotton farming is associated with significant water use (>8,000 litres per Kg of cotton)[(7)] and global greenhouse gas emissions (63 million tonnes CO2 equivalent globally in 2020)[(8)].

    2. HHP use contaminates groundwater, soil and nearby food crops.

    3. Dyes and process chemicals used in manufacturing and recycling are washed into waterways contaminating local ecosystems.

    4. Energy-intensive manufacturing and recycling processes release particulate matter into air and water.

1.F - Opportunities to align the cotton value chain with the GFC

27. A transition away from the status quo will impact upstream stakeholders most severely (e.g. small-scale farmers, small and medium sized enterprises in LIMCs) where profit margins are smallest but would likely have greatest positive impacts in terms of:

    1. Capacity building for sustainable chemicals management;

    2. Global alignment on:

        1. Priority lists of harmful or hazardous substances for immediate elimination;

        2. Implementation plans for phase-out and reduction of substances of concern; and

        3. Alignment with and transition to circular economy principles.

        4. Developing clear, sector-specific criteria for GFC-aligned alternative chemical use across the value chain to support innovation and prevent regrettable substitutions;

        5. Identifying and building opportunities for GFC-aligned financial investments;

        6. Protecting human health by eliminating and significantly reducing exposure to harmful chemical substances; and

        7. Preventing further degradation of environmental health and restoring biodiversity.

28. A range of voluntary, mandatory and financial measures spanning public and private finance will be required to facilitate this transition and must protect the livelihoods of upstream stakeholders to ensure a just transition to a more sustainable future value chain.

    1. All measures should be developed with clear timelines and structured, multistakeholder implementation plans.

1.G - Key challenges for aligning cotton value chains with GFC targets

29. Key challenges to consider in aligning the cotton value chain with the strategic objectives and targets of the Global Framework on Chemicals (GFC) are:

    1. **Fragmented chemical policy frameworks** on a global scale result in inconsistent elimination and phase out of the most harmful substances.
    2. **Weak regulatory and licencing frameworks** mean harmful substances are readily available for use, at low costs.
    3. **High numbers of diverse stakeholders** whose livelihoods rely on cotton production, sale and manufacturing.
    4. **Limited awareness of the risks** associated with use and exposure to harmful chemicals.
    5. **Low transparency and traceability** of chemical use across fragmented value chain.
    6. **Market dominance of major chemical manufacturers and suppliers** – notably relating to crop protection.
    7. Limited capacity for **innovation** and transition to safer chemical use.
    8. **Significant data gaps** relating to the **quantities and combinations of chemical substances** used – particularly in post-fibre production stages of the life-cycle – and the **monetary costs associated with social and environmental chemical impacts.**
    9. Low capacity, limited infrastructure and technology gaps for **end-of life management of textile waste.**
    10. **Investment risks** associated with high numbers of diverse stakeholders operating at low profit margins.
    11. **The absence of clear criteria or indicators established for 'GFC-aligned' safter chemical alternatives** and lack of globally agreed assessment methodology or measurement of impact.

1.H - Summary: Key barriers to overcome to align the Cotton value chain with the GFC

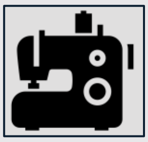
Stage 1: **Cotton farming** 	• Fragmented regulatory frameworks; • High numbers of individual stakeholders, including small-scale farmers heavily reliant on access to international cotton market; • Cheap, hazardous pesticides are readily available, particularly in LMICs where cotton production is high; • Limited access to training and capacity building programmes to scale up transition to more sustainable farming practices; • Low profit margins and prize squeeze from garment manufacturers; • Concerns of reduced yield and limited market access associated organic cotton farming; and • Two-to-three-year transition period required to achieve organic cotton certification impacting livelihoods.
Stage 2: **Cotton textile production**  **Stage 3:** **Cotton garment finishing** 	• High numbers of SMEs operating with low profit margins; poor safety records and weak governance all considered 'high risk' factors for investment in the absence of protective measures; • Hazard criteria apply to specific substances yet dyes and chemicals used in textile production/finishing are complex formulations; • Regional differences in chemical restrictions and prohibitions; • Low transparency and traceability of chemical use in textile value chains; • No internationally defined criteria for GFC-compliant chemicals used to produce textiles/finish garments; and • Short termism of procurement contracts limits ability to scale up more sustainable practices across the sector.
Stage 4: **Cotton Textile Recycling** 	• Technological limitations – chemical recycling reliant on high-cost, energy intensive emerging technologies that are not yet proven at scale; • Production costs - Competition from lower cost, virgin materials; • Raw material supply – low collection and sorting infrastructure on a global scale requires significant investment to capture end-of-life fabrics and materials to support recycling; • Capital needs – long term investments needed to bring new recycling capacity online and expand/improve technologies on a global scale; and • Transition risks - meeting consumer demand for clothing as value chains transition from linear to circular models.

Table 1: Key barriers to overcome to align the Cotton value chain with the GFC

1.I - Key levers to align specific stages of the cotton value chain with the GFC

30. Several existing initiatives aim to consolidate information on chemical use across the value chain which presents a timely opportunity to link to specific targets of the GFC – notably:

    1. A2 – consolidated guidelines for sound chemicals and waste management;

    2. B1, B2 and B3 – relating to transparency and traceability of chemical use; and

    3. A7 – relating to HHP elimination and D4 which supports R&D and a transition to a safer, future chemicals industry.

31. Supporting a transition to a more circular economy for cotton textiles would:

    1. Help drive down harmful and hazardous chemical use across the cotton textile value chain; and

    2. Align the sector with the GFC strategic objectives and targets.

32. Transitioning to a more circular economy for textiles presents an opportunity to reduce the reliance on and use of harmful and hazardous substances across the value chain, creating investment opportunities to align the sector with the GFC targets.

    1. In line with waste hierarchy principles, the transition must first prioritise an avoidance and reduction in the use of chemicals.

    2. Scaling investment in R&D and technological improvements into safer alternatives at each stage of the value chain would facilitate this transition.

    3. Standardised circular design principles are necessary to reduce the overall environmental footprint of cotton garments and to improve the quality of end-of-life materials.

    4. Reduced complexity and composition of final garments and lower chemical application facilitates reuse and recyclability of textiles.

33. Recycling – both mechanical and chemical – will play a key role in the transition towards a circular economy but long-term viability on a commercial scale is only possible when coupled with:

    1. Safer, more sustainable chemical use at each stage of the value chain;

    2. Circular product design that takes whole environmental footprint into account across product life cycle;

    3. Significant up-scaling of infrastructure to efficiently recapture, sort and process end-of-life garments; and

    4. Technological improvements to recycling processes that:

1. Improve the quality of secondary materials and reduce ongoing reliance on virgin materials; and

2. Reduce broader environmental impacts of recycling methods (such as energy use, chemical use, harmful emissions).

34. Chemical recycling trials reportedly generate higher-grade fibres for use as secondary feedstock in the clothing industry compared to mechanical recycling.

    1. However, several environmental and social issues have been associated with chemical recycling including:

    2. the addition of chemicals in unknown quantities;

    3. significant energy use; and

    4. higher levels of harmful emissions (of nano- and microparticles) to the environment.

1.J - Summary: Barriers and levers for change for specific stages of the cotton value chain

Identified barriers	Levers for change (Opportunities)	Value Chain stage:			
		1	2	3	4
Low transparency and traceability of chemical use across the value chain	• Adopting and enforcing mandatory transparency measures such as 'no data no market' and building standardised digital product passports for cotton textiles.	✓	✓	✓	✓
Limited awareness about the risks and impacts of exposure to chemicals	• Capacity building through on-site training and access to appropriate personal protective equipment. Market adjustments to incentivise use of safer chemical alternatives.	✓	✓	✓	✓
Lack of standardised assessment methodology and measure of impact for chemicals in use in cotton yarn/textile value chain	• Using the expert multistakeholder GFC Implementation Programme for textiles to develop a standardised assessment methodology and measure of (environmental and human health) impacts and facilitate value chain monitoring.	✓	✓	✓	✓
Prohibited use / risk of prohibited use of specific chemicals can lead to regrettable substitutions	• Stronger regulation taking a hazard-based approach, following the mitigation hierarchy, and eliminating groups of chemicals with similar properties as opposed to individual chemicals, based on a life cycle assessment can avoid the introduction of regrettable substitutions.	✓	✓	✓	✓

Identified barriers	Levers for change (Opportunities)	Value Chain stage:			
		1	2	3	4
High numbers of small and medium sized stakeholders require mandatory change in practice to achieve consistency – voluntary efforts are unlikely to drive sector wide change	• Consistent regulations and government incentives or subsidies to enable a transition to low-chemical fibre, yarn and textile production. Prohibited use of the most harmful chemicals.	✓	✓	✓	✓
Concerns about interruption to livelihood during transition to organic/low pesticide farming - either as a result of increased labour costs, reduced yield or during organic certification process	• Provide support and livelihood protection through subsidies and incentives during the transition to low/no chemical farming. • Subsidise cotton market to establish reliable market price for low-chemical cotton fibre. • Improve access to crop protection insurance.	✓			
Low profit margins make ready availability of low-cost chemical treatments appealing	• Greener procurement and price adjustment to put premium on non-safe chemical use as opposed to a premium on greener production methods. • Market adjustments to factor in price of externalities associated with harmful chemical use. • Introduce regulated licencing conditions and import restrictions for safe chemical use, supplemented with market interventions and finance mechanisms to scale safer production methods.	✓	✓	✓	
The absence of strong market signals/access to organic cotton markets	• Public and private incentives for brands and retailers to source organic cotton.	✓	✓	✓	

Identified barriers	Levers for change (Opportunities)	Value Chain stage:			
		1	2	3	4
Inconsistencies between RSLs/MRSLs can undermine compliance/create gaps in the value chain where harmful chemicals are used	• Creating an international, GFC-aligned RSL/MRSL for cotton yarn and textile production within the GFC Textile Sector Implementation Programme. • Establishing clear criteria for what constitutes GFC-aligned chemicals.		✔	✔	
Limited design for circularity rendering garments 'unrecyclable' at end of life in a cost-effective way	• Incentivise circular, sustainable design techniques to increase quality and value of end-of-life materials • Embed circular design principles, in line with waste hierarchy. • Aligning emerging technology with aims and objectives of the GFC from the outset to limit use of harmful chemicals. • Investment in- and demand for novel chemical treatments based on green and safe chemical design principles.		✔	✔	✔
Fragmented supply chains make it difficult to match suppliers of recycled content with requirements from garment manufacturers/brands	• Build and expand on existing coalitions of stakeholders to map and match specific supply and demand requirements across the whole value chain.		✔	✔	✔
Limited commercial-scale recycling of textiles due to limited infrastructure, poor design for end-of-life, technology limitations and wider environmental impacts (e.g. high energy inputs, water use, chemical use, harmful emissions)	• Up-scaling infrastructure for recapturing, sorting and recycling end-of-life textiles. • Increase investment in R&D and innovation to reduce overall environmental footprint and improve efficiencies of recycling processes.				✔

Identified barriers	Levers for change (Opportunities)	Value Chain stage:			
		1	2	3	4
Manual sorting high volumes of post-consumer textile waste is time-consuming and offers limited accuracy	• Investing in Near Infrared (NIR) sorting technology increases quality of raw material for recycling purposes, in turn increasing volume of secondary raw materials.				✔
Limited textile recycling capacity results in volumes of post-consumer waste outpacing processing capability	• Extended Producer Responsibility supporting reuse, repair and return of end-of-life garments. • Technological improvements and investments to build recycling capacity, improving quality and availability of secondary materials.				✔

Table 2: Common barriers and levers for change for specific stages of the cotton value chain

1.K - Recommended next steps

35. Identifying sector-specific financial needs for implementing and aligning with GFC targets for specific products used in key value chains can be done by:

    1. Mapping key value chains in terms of stakeholders represented, chemical use, and barriers and levers for change;
    2. Understanding current financial needs of value chain stakeholders;
    3. Determining appropriate sources of finance;
    4. Ascertaining indicative costs associated with GFC-alignment;
    5. Establishing time-bound targets to achieve the transition; and
    6. Adopting a matrix approach including voluntary, mandatory and financial measures (see Table 3).

36. To fully support the implementation of the GFC, and to align stakeholder expectations, it is crucial that indicative criteria need to be developed to help investors determine if investment decisions are GFC-compliant.

    1. Such criteria could form the basis of future financial disclosures.
    2. Adopting EU ‘No data, no market’ rules which stipulate that manufacturers and importers of chemicals must identify and manage risks linked to substances produced or placed on the market would greatly increase transparency in chemical use and reduce risks across product life cycles.

37. Carefully designed, time-bound, multi-stakeholder Implementation Programmes for highly chemical-dependent sectors, like textiles, are vital to drive change in practices and fully support the implementation of the GFC targets and objectives.

38. In order to avoid regrettable substitutions, future chemicals policies must be science-led, precautionary and follow a hazard-based approach in line with the mitigation hierarchy.

    1. Green and sustainable design and chemistry principles should be applied to promote system change in combination with the introduction of greener chemicals; and
    2. All solutions and technologies must be supported by full life cycle assessments that take into account wider social and environmental impacts.

39. Policymakers and regulators need to create an enabling environment that facilitates a just transition for all stakeholders and broad value-chain alignment with the GFC.

    1. Strong policy commitments and buy in from vested stakeholders at all stages of the value chain and across the life cycle will likely build support and create opportunities for financial investments.

Voluntary measures:	• Scaling implementation of sustainable chemical **best practice measures** including third party certification; • **Improved transparency** about chemical usage, particularly during garmenting; • **Capacity building programmes** covering GFC-aligned chemical use, handling, use and disposal of chemicals across the value chain; • Provision of effective, climate-appropriate **personal protective equipment** to reduce exposure risks; • Investment to support transition to **safer,** more **circular technologies and practices** (e.g. closed loop fibre sourcing, dry-dye techniques, reusable yarn treatments); and • Scale up adoption and implementation of **consolidated, international HPP, MRSL and RSL lists.**
Mandatory measures:	• **Import restrictions** to control and reduce access to internationally identified harmful substances; • Implementation of **adequate filtration and effluent treatment systems** to prevent harmful emissions to air and water; • International **prioritisation and prohibition of the most hazardous substances** in use; • **Phased out use of substances of concern** and harmful chemicals via mandatory MRSL and RSL compliance; • **Traceability and disclosure schemes** for chemical use such as digital product passports; and • Effective, **climate-appropriate ventilation and protective equipment requirements** to protect workers health.
Financial measures:	• Financial incentives to support **safer chemical use and production methodology** across the value chain; • Requirement for third party certification to increase **compliance with MRSL/RSLs**; • **Longer-term procurement contracts** to support transition to more sustainable production; and • **De-risking and investments** to facilitate transition to GFC-aligned, circulate textile industry.

Table 3: Adopting a matrix approach of voluntary, regulatory and financial measures, to align the cotton value chain with the objectives and targets of the GFC.

SECTION 2 – Introduction

2.A - Introduction

40. International Conference on Chemicals Management (ICCM5). The overarching aim of the GFC is "to prevent, or where prevention is not feasible, minimise harm from chemicals and waste to protect the environment and human health".

41. In order to fund the transition to a safer, more sustainable chemicals future that aligns with the strategic objectives and targets of the Framework, GFC Resolution V/3 recognised that there is a need for greater clarity on the current status of financial flows and investment need/opportunities across the value chain.

42. To this end, Chronos Sustainability Ltd has been commissioned by UNEP FI to undertake desk-based research and produce a robust, decision-useful analysis of the current status of financial and investment flows across the global chemicals value chain and to identify future financial needs associated with the implementation of the GFC.

43. Initial analysis of the global chemicals value chain revealed a complex landscape of large, vertically integrated companies that produce, manufacture and distribute different types of chemicals for a variety of end-use markets (see Figure 1).

44. Basic chemicals are produced from either organic (e.g. fossil fuel- or biomass-based raw materials) or inorganic (e.g. derived from minerals, salts and gases) feedstocks and are further refined to create:

    1. Commodity chemicals (e.g. polymers),

    2. Intermediate chemicals (e.g. pigments, dyes and surfactants) and

    3. Higher-value, speciality chemicals (e.g. adhesives, paints and personal care preparations)

45. 90% of all manufactured products are thought to contain synthetic chemicals derived from fossil fuels[9].

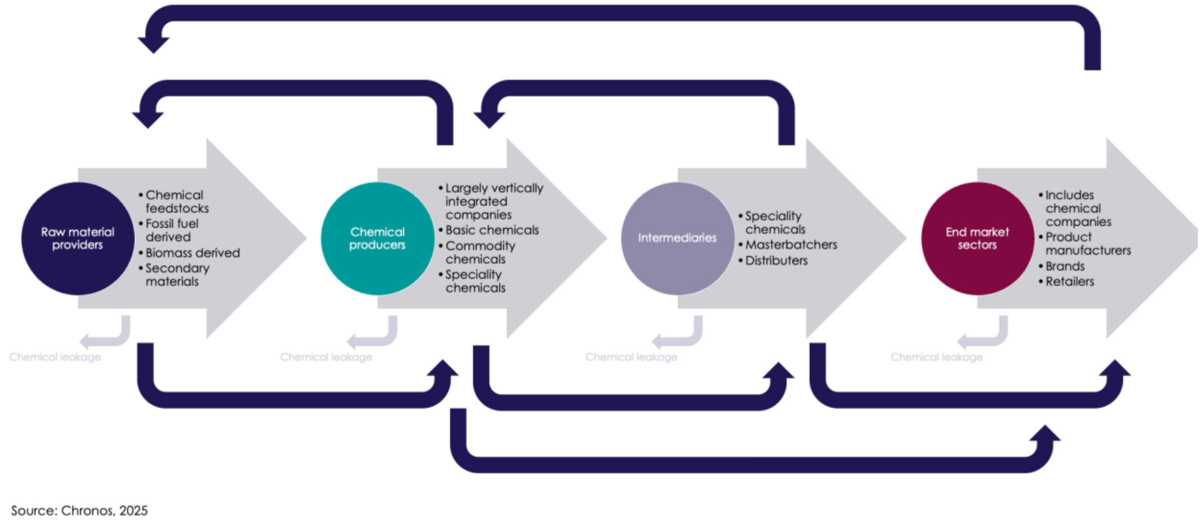


Figure 3: Illustrative outline of chemicals value chain.

46. In 2023, the total value of the global chemicals industry was estimated to be EUR 5.2 trillion[10] with sector activity concentrated in:

    1. China & the wider Asian region (43.08% and 14.13% of total value respectively)
    2. EU27 (12.61%)
    3. USA (11.26%)

47. Sectors with the highest dependencies on chemicals are identified as: Mining, Textiles, Pharmaceuticals, Agrichemicals, Electronics and Construction[11].

    1. Estimates suggest over 8,000 chemicals are for textile manufacturing[12] .
    2. For cotton specifically, it is estimated that 0.35-1.5Kg of chemicals are used to make 1Kg of cotton textile[13].

48. There is very limited transparency on the quantities and types of chemicals used to manufacture different chemicals or groups of chemicals and extremely limited data regarding the presence, quantities, fate and impact of different chemicals in final products across all sectors.

    1. This is driven by a range of factors: inconsistent definitions, a lack of systematic data collection and disclosure and differing regulatory priorities around the world.

49. Data gaps severely hinder chemical traceability across the life cycle, stymying the transition to a safer, more circular resource economy.

50. To support the ongoing engagement of both policymakers and the finance sector, and to supplement further discussions on sector-specific financial needs of key value chains transitioning to align with the targets and objectives of the GFC, Chronos has been mapping specific value chains.

51. The results presented herein focus on cotton fibre for clothing value chains and the use of chemicals including highly hazardous pesticides across the life cycle.

SECTION 3 – Defining the cotton textile (clothing) value chain

3.A – Overview of the cotton industry

52. Cotton is one of the world's oldest commercial crops. It is estimated that 24.4million tonnes of cotton fibre was produced in 2022/2023 on just 2% of global arable land[14].

53. The global cotton market was valued at USD 41.8billion in 2023[15] and represents approximately 20% of global fibre production for apparel (see Figure 4).

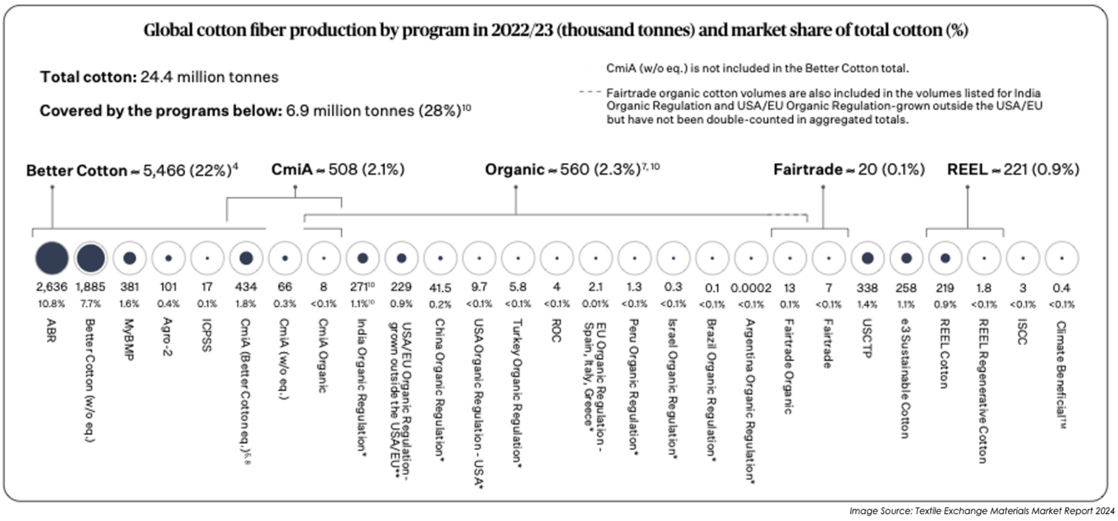


Figure 4: Global cotton fibre production by programme in 2022-2023 and market share of total cotton (%).

54. Cotton is grown in 85 countries (31% of which are classed as Least Developed Countries) with major contributions from: China (36% of global cotton seed production in 2020), India (22%), the United States of America (12%) and Brazil (8%)[16].

55. Over 350million people are involved in the growing, farming and processing of cotton fibre around the world.

56. The majority of cotton (~60%) is cultivated by hand by small-scale farmers (nearly 50% of whom are women)[17] .

57. Farming practices in high-income countries such as the USA and Australia are highly mechanised, supported by cutting edge technology and agroecological research and carried out on an industrial scale.

58. 80% of the cotton fibre produced annually is destined for cotton apparel[18]. This represents approximately 1/3 of the raw material used in the textile industry (see Figure 5).

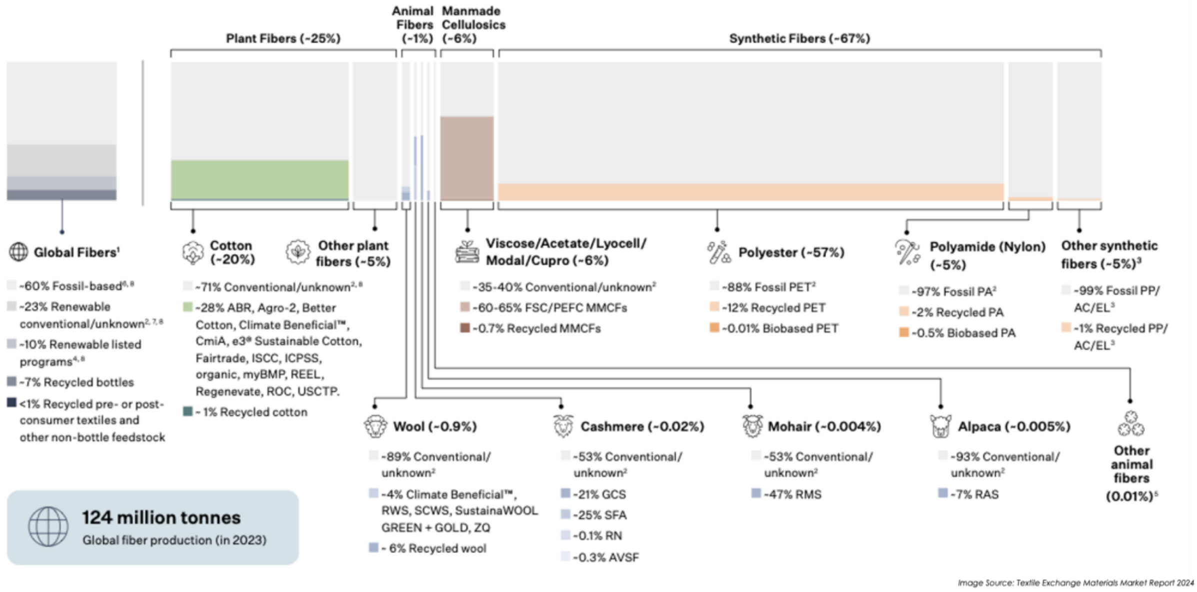


Figure 5:Overview of the textile industry, and relative share of cotton fibre (%).

59. For the purposes of this study, we have defined a cradle-to-cradle, cotton value chain as one that includes 9 key stages (See Figure 6).

60. Chemicals are used directly and indirectly at every stage of the life cycle – from field to 'frock', with highest direct dependencies during the cotton growth stage, during textile production and garment finishing and at the end of life (highlighted in red in Figure 6).

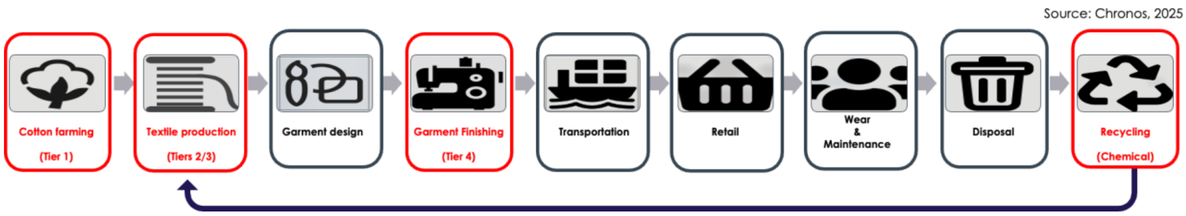


Figure 6: The cotton value chain for clothing is organised into 9 distinct stages with heavy use of and reliance on chemical inputs at four key stages, highlighted in red. Namely, these stages are: Cotton farming; garment production & finishing; and recycling

61. In order to begin to understand existing and future financial flows across different chemical value chains such as cotton textiles, it is important to first develop a clear understanding of:

    1. Who the key stakeholders are at highly chemical-dependent stages of the value chain?

    2. What chemicals are currently used and what impact are they having?

3. Are more sustainable chemical alternatives emerging and how do they align with the targets of the GFC?

SECTION 4 – Value Chain Analysis & Initial findings

Stage 1: Cotton fibre production – Farming phase

4.1.A - Cotton fibre production

62. Key stakeholders involved in the production of cotton fibre are:

1. Farmers; Farming cooperatives, associations and unions;
2. National cotton board;
3. Standards/certification bodies for low chemical or organic cotton production;
4. Pesticide & fertiliser manufacturers and suppliers;
5. Non-Government Organisations (NGOs);
6. Agroecologists; and
7. Government agencies (e.g. Ministry of Agriculture).

63. All parts of the cotton plant are harvested (manually or mechanically) for a variety of uses in addition to cotton fibre – including use as fertiliser, insecticides and fungicides – making cotton a valuable, multi-use crop, linked to multiple value chains (see Figure 8).

64. Chemical use across each of these associated value chains also needs to be examined if all cotton value chains are to fully align with GFC targets.

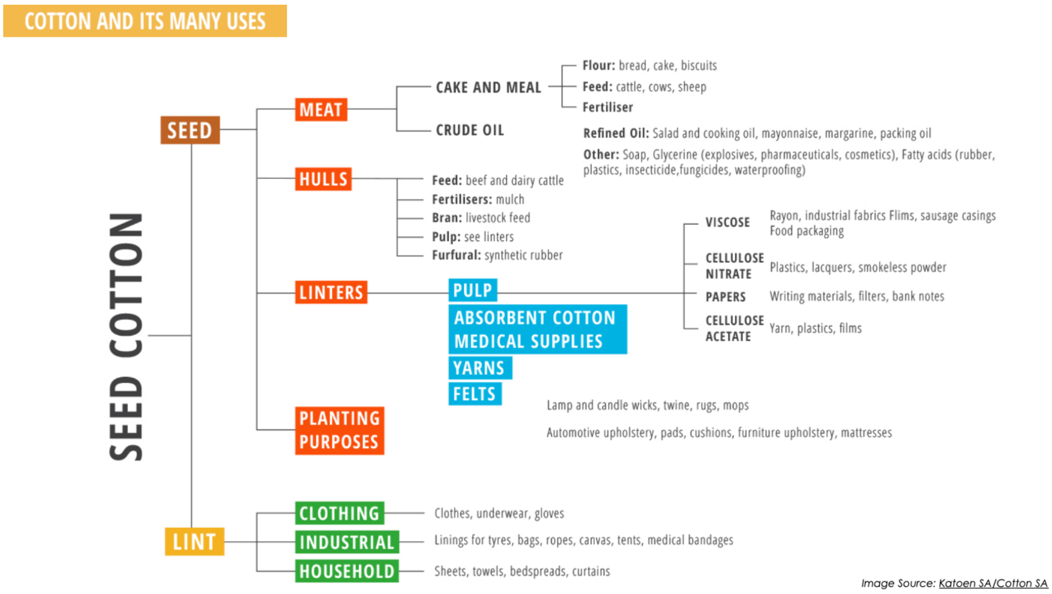


Figure 7: Cotton crops support many value chains, as illustrated here, beyond cotton textiles.

65. Once harvested, cotton fibre is transported to a ginnery where the lint is separated from the seed; baled and subsequently sent for onward processing at mills.

66. Global cotton fibre consumption is expected to continue growing by 1.7% annually, in line with population growth and an expansion of emerging markets across Asia (e.g. Bangladesh and Vietnam)[(19)].

67. The top four fibre producing countries in 2022 were China (19% of global total), India (17%), the United States of America (10%) and Brazil (8%) (See Appendix 1: FAOSTAT Data).

68. Cotton export revenue is a significant contributor to Gross Domestic Product (GDP) and an important source of foreign exchange for a number of nations, notably the C-4 nations (Benin, Burkina Faso, Chad and Mali)[(20)] despite these countries producing significantly less cotton fibre than other nations (See Appendix 1: FAO Stat Data).

69. Cotton farmers face multiple challenges linked to climate change and water availability affecting yield; supply-side factors driven by inequitable trade policies and market access[(21)]; and fluctuating market value (in turn driven by competition from substitutes such as synthetic fibres and 'price squeezes' throughout manufacturing supply chains)[(22)].

    1. The International Cotton Advisory Committee (ICAC) reports that the global average cultivation cost for cotton lint production was USD1.56 /Kg in 2023, ranging from USD 3.42 /Kg in Mali to USD 0.26 / Kg in Uganda[(23)].

70. To protect revenue and livelihoods, different countries around the world reportedly utilise a range of measures including[(24)]:

    1. Direct (financial) support to farmers;

    2. Border protection;

3. Crop insurance subsidies; and

4. Price support mechanisms.

71. Finance measures create a significant opportunity to redirect support towards safer, more sustainable cotton farming more aligned with the GFC targets.

    1. For example, GFC-aligned production and processing techniques could be incorporated into Sustainable Finance Taxonomies to stimulate Green Finance Instruments and products/services.

72. In order to try to maximise crop yield and profit, and in the absence of subsidised capacity building programmes promoting more sustainable farming practices, cotton farmers often rely on the application of readily available, low-cost and often poorly regulated, synthetic pesticides and fertilisers.

4.1.B - Cotton fibre production – Chemicals use

73. In conventional cotton farming, a combination of synthetic insecticides, herbicides and fungicides – all types of pesticides (see definitions) – are used by cotton farmers at various stages of the crop cycle (dependent on local and climatic conditions) to support crop growth (see Figure 8).

    1. In India, 50% of all pesticides are reportedly diverted to cotton production[25].

74. Pesticides are, by their nature, inherently hazardous substances and a proportion of the pesticides produced are Highly Hazardous Pesticides (HHPs) which cause "disproportionate harm to the environment and human health including severe environmental hazards, high acute and chronic toxicity"[26].

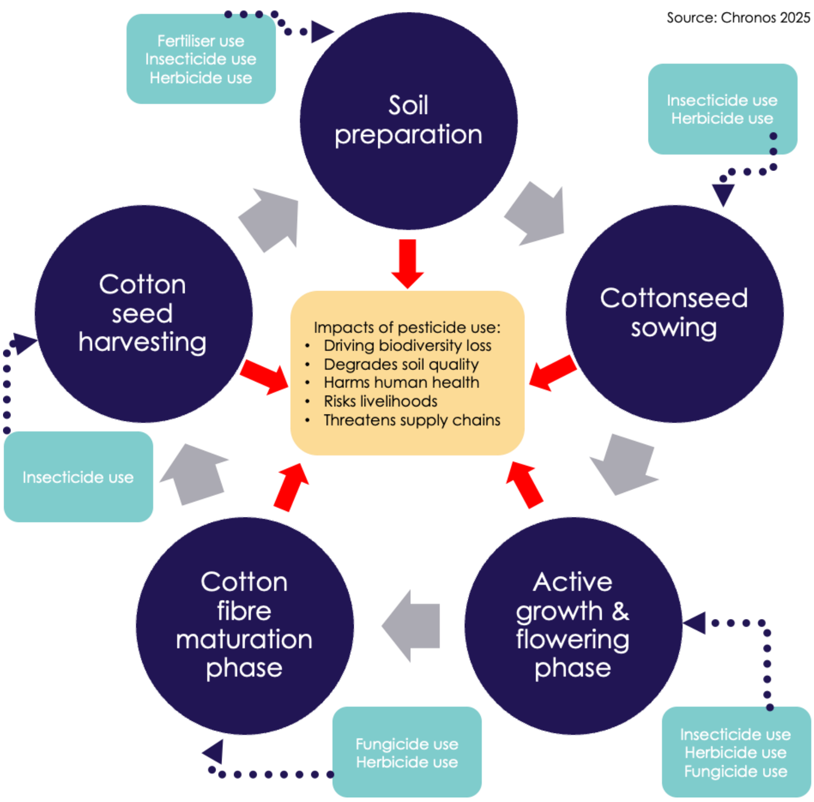


Figure 8: Different chemical pesticides are used by cotton farmers at various stages of the crop cycle in conventional cotton farming, as conceptualised here. The quantity, timing – and the type of pesticide applied – varies with climate and geography.

75. Evidence suggests that cotton farming is the fourth largest user of agrichemicals, including HHPs[27].

    1. An FAO study cites that between 6-10% of registered pesticides in use in African, Caribbean and Pacific countries were considered HHPs[28].

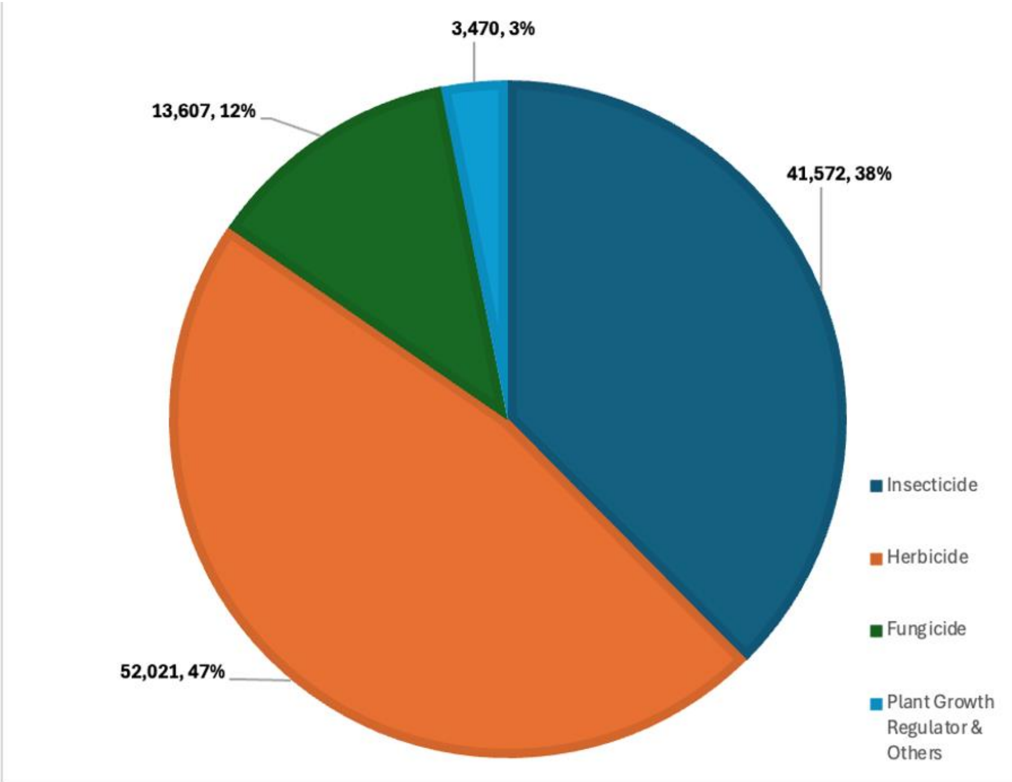
    2. PAN UK reports[29] 51% of cotton producers experience acute pesticide poisoning in Benin in 2018 (see Appendix 6: Impacts of Pesticide use).

        1. 33% of these incidents result in farmers missing work.

        2. 12% of incidents caused permanent health impacts including paralysis, loss of eyesight and tremors (nervous system damage).

76. ICAC reported that 110,675 tonnes of pesticides were used in Cotton production over the 2022-2023 growing season.

77. Major pesticide users are: Brazil (31.2% of total), USA (23.6%), India (11.8%) and China (10.3%) [30] (See Figures 9 & 10 and Appendix 4: Pesticide use).



Data source: ICAC 2025

Figure 9: Total pesticide use in 34 countries in 2021 by type (tonnage per active ingredient).

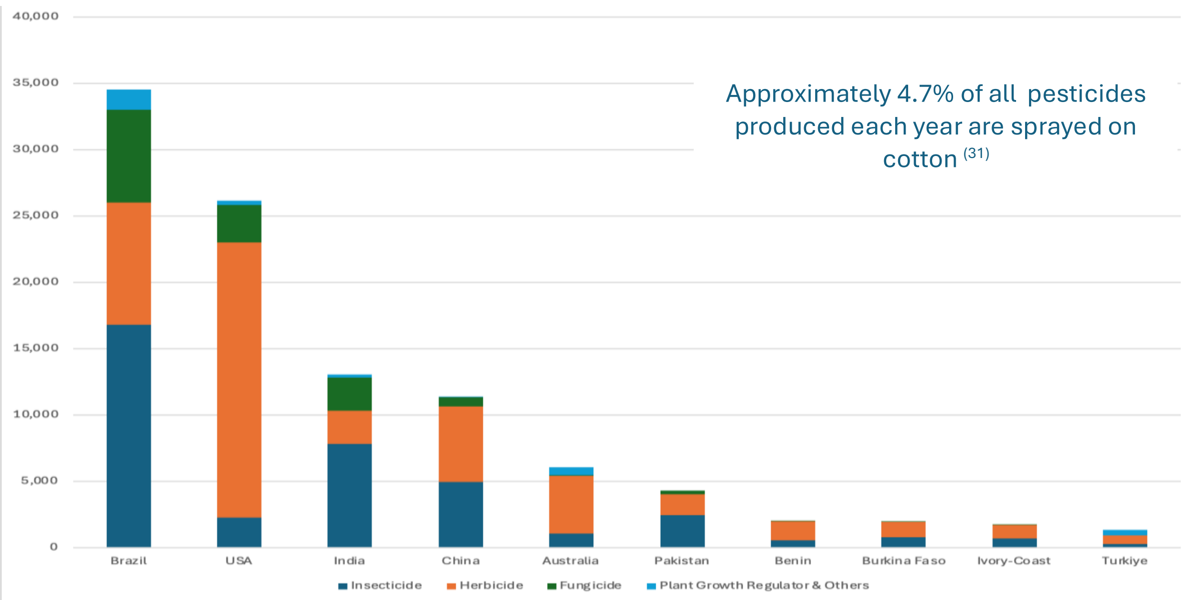


Figure 10: Total pesticide use in 34 countries in 2021 by country (tonnage per active ingredient).

78. When comparing pesticide use against volumes of cotton lint (ginned) produced, the heaviest users of pesticides are Brazil, followed by Malawi, Benin, USA and Burkina Faso (See Appendix 5: Production rates vs Pesticide use).

79. 47% of all pesticides used on cotton in 2022/2023 were herbicides

80. The WHO estimates that over 350,000 people lose their lives annually as a direct result of acute pesticide poisoning[32].

    1. Appendix 6 provides an overview of the known impacts associated with HHPs.

81. UK based Pesticide Action Network (PAN) maintains an international list of HHPs[33] that builds upon and expands the 8 criteria listed by FAO/WHO (See Appendix 3: PAN International list of HHPs).

82. Updated in 2021, the PAN list of HPPs includes 338 chemical substances, that meet one or more of the 8 FAO/WHO criteria for HHPs (See Appendix 2: Defining HPPs) and advocates that these substances should be prioritised for elimination.

    1. Classification is primarily based on active ingredient present in pesticides and not by the combined hazard of different substances in a formulation.

    2. Limited geographic data is available on the prevalence and use of different chemical substances included in the PAN list as a result of a lack of systematic registration, licencing and monitoring.

    3. PAN highlights a lack of systematic or globally recognised assessment or classification in place to determine acute toxicity thresholds for either human health or environmental impacts.

83. The number of HHPs in existence varies significantly depending on the criteria used to assess a substance. For example, ICAC pesticide classification does not include FAO/WHO Criterion 8.

    1. ICAC considers that 13% of the cotton pesticides in use meet HHP criteria.

    2. If comparing the same list of chemicals with criteria included on the PAN list plus Philips McDougal sales data, this number of HHPs on the ICAC list would increase to 70%[34].

4.1.C - Agrochemical manufacturers & suppliers

84. It was reported that cotton farmers handled USD 2billion worth of agrichemicals in 2004[35].

85. By 2023, this figure had risen to USD 73.847 billion in sales by the top 20 manufacturing companies[36].

1. Approximately 40% of these chemicals handled in 2004 were deemed toxic enough to meet World Health Organization (WHO)-determined classification for hazardous chemicals[37].

86. Global supply of agrochemicals is dominated by major multinational companies (See Appendix 7 for details).

1. Nearly 60% of global sales were secured by just four companies: Syngenta, Bayer CropScience, BASF and Corteva (See Appendix 5: Global crop protection manufacturers and suppliers).

2. 20% of the top 20 companies are headquartered in China.

3. Overall, pesticide sales fell by almost 14% compared to the previous year, possibly as a result of the Ukrainian-invasion, supply chain disruptions and fluctuating exchange rates.

87. Subsidiaries of these crop protection companies (BASF, Bayer, Syngenta, Dow and DuPont) also significantly contribute to the research and development of new chemical pesticide products [38].

4.1.D - Sustainable alternatives to synthetic pesticide use

88. A growing number of initiatives seek to improve cotton production by reducing or omitting (in the case of organic cotton) reliance on HHPs and chemical fertilisers and pesticides, however organically produced cotton only represents 2.3% of the total cotton fibre produced each year[39].

89. Agroecology and Integrated Pest Management principles, when properly implemented in cotton farming have been proven to successfully reduce reliance on synthetic fertilisers, genetically modified crops and synthetic pesticides [40].

1. Turkey banned the use of genetically modified cotton crops and is strictly implementing IPM across its cotton-growing region[41].

2. Turkish cotton yield has reportedly doubled to over 1700kg/Ha as a consequence – twice the global average.

90. In Benin, PAN UK and the Beninese Organisation for the Promotion of Organic Agriculture (OBEPAB) have worked with cotton farmers to support more sustainable farming practice based on IPM principles that has resulted in[42]:

1. Reduced reliance on hazardous pesticides and a national ban on Endosulphan – a widely used HHP linked to the high numbers of acute pesticide poisonings in Benin;

2. Training of over 6000 farmers through bottom-up, capacity building Farmer Field School programmes;

3. Development of a sustainable biocide using local, low-cost ingredients as an alternative to synthetic pesticides;

4. Improved yields and yield quality plus organic cotton certification for 4000 farms; and

5. Increased revenue for cotton farmers (3.2x increased profit for organic cotton; GBP 9.40 return for GBP 1 investments in 2021)[(43)].

91. A number of sustainability standards exist that promote low, or no pesticide use in cotton production (where percentages indicate market share of total cotton fibre produced)[(44)]:

1. Fairtrade Cotton (0.1%);

2. Fairtrade Organic Cotton (<0.1%);

3. Better Cotton Initiative (22%);

4. Cotton Made in Africa (CMiA and organic CMiA; 2.1%); and

5. Organic Cotton – certified according to 11 different schemes (2.3%).

92. PAN UK reports that over 1.7million farmers and 3.7 million hectares of arable land are covered by these sustainability schemes[(45)].

93. Organic cotton farming brings holistic benefits to biodiversity, soil health and water by putting emphasis on place-based solutions and more sustainable farming practices[(46)].

1. Organic cotton farmers avoid the input of inorganic fertilisers (and pesticides) using proven techniques such as crop rotation and organic (green) manures in addition to biocide use.

2. Achieving organic crop status requires a farm to demonstrate that no synthetic treatments were used in the preceding 3 years. Certification is provided by third party issuers for a fixed fee.

4.1.E - Cotton fibre production – Fertiliser use

94. Inorganic fertilisers are applied to agricultural land to support crop growth.

1. They are not considered a pesticide but do represent an additional chemical input (N, P_2O_2 and K_2O) to cotton value chains.

95. Synthetic fertiliser production and use for cotton accounts for 47% and 12% of the crop's greenhouse gas emissions respectively[47].

96. Reliable data quantifying synthetic fertiliser use per crop is reportedly limited[48] however, some studies reference an over-reliance on inorganic fertiliser in certain areas.

    1. For example: nitrogen fertiliser use has reportedly quadrupled in China's Xinjiang cotton growing region over the past forty years.

97. Although synthetic fertiliser use has increased in line with cotton yield, it has wider negative impacts on environmental quality due to run off and leaching effects[49].

98. Organic and low-chemical cotton farming either prohibits or discourages the use of synthetic fertilisers and focuses on restoring soil health via more sustainable fertiliser use (e.g. organic green manures, crop rotation etc).

4.1.F - Identified levers to scale the transition to low-chemical fibre production

Barriers to low chemical farming practices:	Levers for change (opportunities):
Perception and fear of lower crop yield affecting income.	Improved access to crop protection insurance.
Ready availability of low-cost synthetic pesticides.	Introduce licencing conditions and import restrictions for safe chemical use.
Limited awareness of alternative farming practices.	Build capacity of farmers through locally appropriate education and agroecological training.
Concerns about additional labour input time/costs with low-chemical farming.	Subsidise cotton market to establish reliable market price for low-chemical cotton fibre.
Interruption to livelihood during transition to organic/low pesticide farming.	Provide support and livelihood protection through subsidies and incentives during the transition to low/no chemical farming.
The absence of strong market signals/access to organic cotton markets.	Public and private incentives for brands and retailers to source organic cotton.

Table 4: Identified levers to scale the transition to low-chemical fibre production.

Stage 2: Cotton textile production – Chemical use

4.2.A - Cotton textile production (spinning & weaving)

99. Key stakeholders identified in the production of cotton textiles include:

1. Spinning mills
2. Weaving mills
3. Dye houses
4. Cotton brokers
5. Textile dye and treatment manufacturers and suppliers

6. Garmenting factories (procurement)

7. Labour unions

8. NGOs

9. Investors

100. Spinning mills extrude cotton fibre into long, continuous yarn which are subsequently woven or knitted into cotton textiles.

101. Spinning mills are often located near cotton ginneries (where the lint is stripped from the seed head and baled) to reduce transport costs.

102. Textile production is characterised by small and medium sized enterprises with a small proportion of vertically integrated companies (composite mills).

4.2.B - Regional differences in cotton textile production

103. Top cotton lint importing countries in 2023 were: China, Vietnam, Bangladesh, Türkiye and Pakistan.

    1. Collectively, these countries imported 5.4 million tonnes of ginned lint with a combined value of USD 12 billion (See Appendix 8: Cotton lint export and import).

104. Cotton fibre spinning capacity is growing in emerging economies such as Bangladesh and Vietnam but declining in high income countries such as the USA.

    1. China & India (owing to high, national cotton production) reportedly represent over 54% of global cotton spinning capacity in 2024 [(49)].

105. A number of factors reportedly control spinning output across textile producing nations:

    1. Cotton market price;

    2. Reliance on imported cotton verses domestic production;

    3. Spinning mill location (proximity to fibre production sites); and

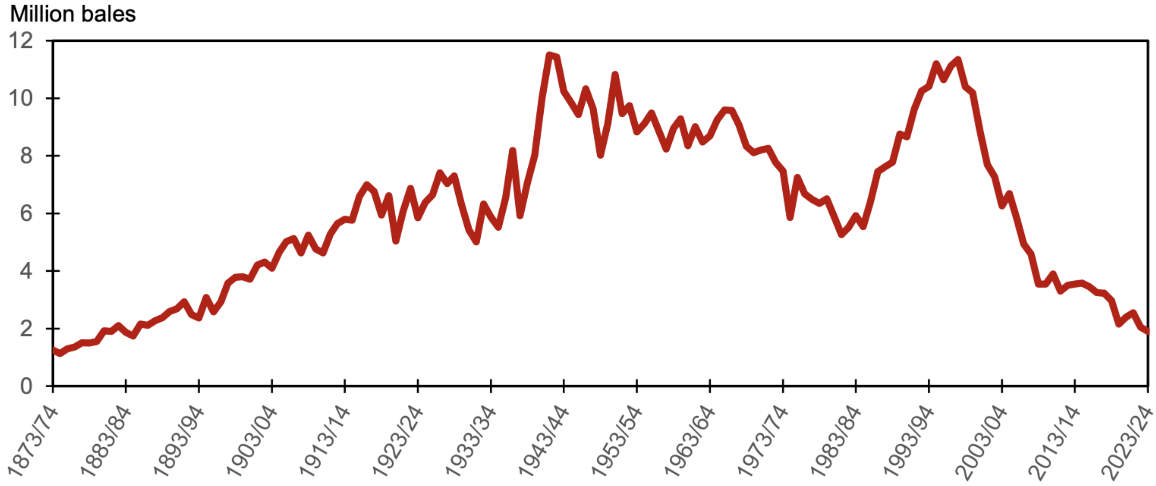
    4. Investment in spinning capacity (number of spindles and mills relative to fibre volume) and technology modernisation.

106. In the USA, the United States Department of Agriculture (USDA) reports a 30-year decline in spinning mill utilisation (see Figure 11).

107. Causes for the decline are attributed to[(51)]:

    1. Soaring demand for synthetic fibres over natural fibres across the textile industry (since the 1950s), and

2. Termination of quotas on trade in textile and clothing products under the World Trade Organization (WTO) Agreement on Textiles and Clothing in 2005[52].



Note: 1 bale = 480 pounds. Original running bale data for 1873/74-1959/60 converted to statistical bales using a 1.03 factor.
Source: USDA, Economic Research Service using data from USDA *Statistics on Cotton* and USDA, *World Agricultural Supply and Demand Estimates* reports.

Figure 11: USA cotton mill estimates, 1873/74-2023/24, projected.

108. Appendix 9 provides case study examples of how the spinning industry is organised in four key cotton spinning countries: China, India, Bangladesh and Vietnam.

4.2.C - Chemical use in cotton textile production - spinning

109. Post-ginning, cotton textile production generally takes place over three stages which require different processes and direct application of chemicals (see Appendix 10 for examples of chemicals used).

1. Chemicals may be organic (derived from plants or minerals) or inorganic chemicals (synthetically produced);

2. Chemical processes can be wet (requiring water input) or dry;

3. Additional auxiliary chemicals are required to facilitate each process (indirect chemical use).

110. A higher proportion of chemical treatments are applied to cotton fabric post-weaving or knitting in 'wet processing' facilities[53].

1. Over 8,000 chemicals are reportedly used by the textile industry during manufacturing processes(54) but limited data is available to indicate what chemicals at what volumes are used for specific textiles.

111. Hazards are known only for specific substances used in textile dying and processing.

    1. The hazards of chemical combinations in the formulations – or the cumulative effects of chemicals – that are used by companies is poorly understood due to limited monitoring and voluntary disclosure.

112. In order to improve the environmental health and safety (EHS) performance across the textile sector, including cotton value chains, Manufacturing Restricted Substance Lists (MRSLs) have been developed to restrict the use of certain chemicals.

4.2.D - Manufacturing Restricted Substances Lists (MRSLs)

113. MRSLs focus on restricting the use of harmful chemicals in textile processing and specify acceptable limits for other chemical uses.

    1. Restricted Substance Lists (RSLs) by comparison, focus on the application of chemicals to final products and are therefore relevant in garment finishing processes (see Section 4.3.D).

114. MRSLs help regulate the individual substances that go into chemical formulations – thus improving safety – but do not control the final chemical formulation.

115. Brands and retailers impose MRSLs on suppliers (top-down influence) and the emphasis is on suppliers to carry out due diligence with stakeholders at each tier of the supply chain.

    1. However, MRSLs are developed by brands and companies for compliance with legislation in specific target markets.

116. MRSLs help brands and companies to manage risks associated with manufacturing value chains and MRSL compliance improves transparency in practices.

    1. Brands often publish MRSLs as part of their Environmental and Chemical policies.

117. MRSLs are voluntary in nature and not globally applicable/comprehensive.

    1. EU REACH is an example of regional legislation that restricts certain chemical substances, which may in turn be included in brands' MRSLs (See Appendix 11 for details).

118. Table 5 offers an overview of MRSLs.

Benefits:	Drawbacks:
MRSLs reduce the use of – and worker exposure to - harmful substances in manufacturing supply chains, reducing risk for companies and investors.	There is no agreed, international or consolidated MRSL for cotton value chains resulting in regional and geographic variations.
Helps companies ensure compliance with regional/national legislation in target market.	MRSL implementation is not mandatory (but restricting use of prohibited substances is mandatory).
Cotton suppliers often supply to several brands and retailers therefore scaling the number of MRSL-compliant value chains.	Brands and companies develop their own MRSLs resulting in a complex and fractured landscape for suppliers to comply with.
MRSL compliance can be independently assessed and verified, increasing transparency in value chains.	It is not always clear what criteria have been used to develop MRSLs.
Supports transition to safer, more sustainable chemical use in textile manufacturing value chains, in line with GFC targets with benefits for human and environmental health.	Transition is associated with short-term cost implications and investment needs that can be challenging for SMEs.

Table 5: Overview of benefits and limitation of MRSLs.

4.2.E - ZDHC Roadmap to Zero

119. In order to improve coherence and compatibility between MRSLs, non-profit organisation Zero Discharge of Hazardous Chemicals (ZDHC) issued a holistic, comprehensive approach to chemicals management via the ZDHC MRSL and Roadmap to Zero initiative[55].

120. The ZDHC MRSL was compiled with multistakeholder input via a Technical Advisory Committee and the MRSL Council and includes:

    1. Substances banned from intentional use in the processing of textiles (including cotton);

    2. Concentration limits on substances used in commercially available substitutions; and

    3. Provisions for substances used in adhesives, inks, detergents, dyes, colourants, auxiliaries, coatings and finishing agents used during raw material production, wet processing, process machinery maintenance and wastewater treatment.

121. The MRSL also includes a Candidate List for substances proposed for inclusion because they lack safer alternatives but are suspected to be harmful or hazardous.

    1. The Candidate list encourages innovation and presents an opportunity for investors to help align the sector with the GFC targets.

122. ZDHC reports that over 300 international brands and companies are signatories to the ZDHC Roadmap to Zero[56].

4.2.F - Identified levers to scale the transition to low-chemical textile production

Barriers to low chemical textile production:	Levers for change (opportunities):
High numbers of small and medium sized stakeholders require mandatory change in practice to achieve consistency – voluntary efforts are unlikely to drive sector wide change.	Consistent regulations and government incentives or subsidies to enable a transition to low-chemical yarn and textile production. Prohibited use of the most harmful chemicals.
Limited awareness about the risks and impacts of chemical exposure during fibre/textile production.	Capacity building through on-site training, access to appropriate personal protective equipment.
Low profit margins make low-cost chemical treatments appealing to companies.	Market interventions and finance mechanisms to scale safer production methods.
Inconsistencies between MRSLs can undermine compliance/create gaps in the value chain where harmful chemicals are used.	Creating an international, GFC-aligned MRSL for cotton yarn and textile production within the GFC Textile Sector Implementation Programme. This should include clear criteria for what constitutes GFC-aligned chemicals.
Lack of standardised assessment methodology and measure of impact for chemicals in use in cotton yarn/textile production.	Using the expert multistakeholder GFC Implementation Programme for textiles to develop a standardised assessment methodology and measure of (environmental and human health) impacts and facilitate value chain monitoring.
Low transparency and traceability of chemical use across the value chain.	Adopting and enforcing mandatory transparency measures such as ‘no data no market’ rules and building standardised digital product passports for cotton textiles.

Table 6: Identified levers to scale the transition to low-chemical textile production.

Stage 3: Cotton garment finishing – Chemical treatments

4.3.A - Cotton garment finishing processes

123. Key stakeholders identified in the production of cotton textiles include:

    1. Dye houses
    2. Cotton brokers
    3. Textile manufacturing companies
    4. Garment manufacturing companies
    5. Manufacturers and suppliers of chemical treatments
    6. Cotton traders
    7. Brands & retailers
    8. Investors

124. The garment manufacturing industry is highly diverse and with a wide geographic spread across developing and emerging economies[(57)].

125. The top 5 garment exporting countries in 2023 were: China (30.06% of total global apparel exports), Bangladesh (8.65%), Vietnam (5.66%) and Italy (5.52%) (See Appendix 12 for details).

126. Most garment manufacturers are still SMEs and are typically geographically concentrated in Asia.

    1. The EU reports over 700 known garment manufacturers operate in Cambodia alone[(57)].
    2. As the industry becomes more profitable in line with growing global consumerism, there is a growing number of larger, vertically integrated garment manufacturers that produce clothing from a wider range of textiles (including synthetics).

127. Garment manufacturing is a major source of foreign exchange for exporting nations but is reliant on stable, free trade agreements (FTAs) that offer strong export options, lower sourcing costs and increase investment opportunities[(58)].

    1. Apparel exports reportedly account for over 80% of Bangladesh's total exports[(59)].

128. However, garmenting is a labour-intensive industry and as a result, factories are typically located in countries with lower labour costs in order to maximise profits[(61)].

    1. Garment manufacturers are typically tier 1 suppliers and therefore most impacted by 'price-squeeze' from fast-fashion companies.

2. This typically increases the risk of unsafe working conditions, including exposure to chemical treatments[62].

129. Significant data gaps exist for this section of the value chain, but it is estimated that spinning and garment manufacturing processes combined obtain between 15-40% of the total value of the final clothing item[63].

130. Most chemical applications to cotton reportedly occur during the manufacturing of cotton yarn and textiles (as discussed in the previous section) but there are a number of examples of chemically dependent finishing processes in the literature (see Appendix 10 for more details) including:

1. Antimicrobial treatments;
2. Flame Retardants;
3. Stain-proofing and easy-care features;
4. Waterproofing; and
5. Wrinkle-proofing.

131. Little information has been published on the range of chemicals involved in these processes however stain-proofing, water-proofing and flame-retardant applications have arguably received greatest attention in recent years due to the known use of Per- and Polyfluoroalkyl substances (PFASs) to achieve these effects[64].

132. PFASs are known for their environmental persistence and are increasingly being associated with human health impacts such as decreased fertility, developmental delays, increased cancer risk, endocrine-system disruption[65].

1. PFAS was identified as a priority topic, alongside HHP use at ICCM5 when the GFC was adopted.

4.3.C - Chemical use in cotton garment processing

133. As with other stages of the value chain, regional policy variations, poor enforcement and weak import controls results in the continued use of harmful and prohibited substances in a number of garment manufacturing nations.

1. Substances that are either obtained illegally or that have been prohibited in other nations are often perceived to be more affordable than more sustainable alternatives.

134. However, exposure to harmful and hazardous chemicals poses long term health implications for factory workers – externalities that are not always factored into the cost of chemicals;

1. Sandblasting[66], for example, is a finishing treatment using silica on denim cotton to produce a distressed effect.

2. Exposed workers were found to develop a high risk of lung disease (silicosis).

3. Many brands and retailers committed to avoid sandblasting in their value chains, but the practice was replaced with chemical spraying instead (using potassium permanganate sprays).

135. Multiple examples exist of either regrettable substitutions or illegal/ongoing use of restricted substances in garment manufacturing[67], for example:

   1. Aromatic amines (from azo dyes, used to provide vibrant colours to textiles);

   2. Formaldehyde (used to increase colourfastness and anti-wrinkle of the textiles);

   3. Phthalates (increases the flexibility of clothing or textiles); and

   4. Pentachloroethane (used to clean fabrics).

4.3.D - Restricted Substances Lists (RSLs)

136. A Restricted Substance List (RSL) is a list of chemical substances that manufacturers are either prohibited to use or restricted to use in finished textile products like apparel[68].

   1. RSLs do not focus on the use – or exposure to – chemicals during the manufacturing stages.

   2. Accordingly, RSLs are consumer-focused as opposed to MRSLs.

137. Like MRSLs, RSLs allow companies to[69]:

   1. Comply with laws and regulations;

   2. Manage their supply chains; and

   3. Reduce risk associated with harmful chemical use.

138. RSLs are also developed by brands and retailers (leading to similar compliance fragmentation noted with respect to MRSL implementation – see Appendix 14 for comparison.

4.3.E - AFIRM Group RSL – an overview

139. The AFIRM (Apparel and Footwear International RSL Management) Working Group (hereafter referred to as AFIRM Group) was convened in 2004 to establish a centralised RSL applicable to apparel, footwear and accessories, in addition to non-textile products.

1. The aim of the RSL is to 'assist supply chain participants seeking to increase product quality and safety or to reduce environmental impact by limiting the use of certain substances in apparel and footwear'[(70)].

140. AFIRM member brands have access to and can provide chemical information sheets (in a range of languages) to suppliers in order to promote chemicals management best practices[(71)].

1. Similarly, member brands can request chemical Safety Data Sheets to check compliance with the AFIRM RSL.

141. AFFIRM Membership exceeds 80 global brands and consumer groups.

4.3.F - Identified levers to scale the transition to low-chemical garment finishing

142. All barriers and levers identified for a transition to low-chemical cotton yarn/textile production exist for garment finishing (see Table 6 for details).

143. Specific, additional elements are observed for the garment finishing stage of the value chain (see Table 7).

Barriers to low chemical garment finishing:	Levers for change (opportunities):
Limited innovation in low-chemical / no-chemical finishing treatments.	Investment in- and demand for novel chemical treatments based on green and safe chemical design principles would stimulate innovation in the sector and support a transition to safer, more recyclable products.
Prohibited use / risk of prohibited use of certain chemical treatments (e.g. PFAS) can lead to regrettable substitutions.	Stronger regulation taking a hazard-based approach, following the mitigation hierarchy, and eliminating groups of chemicals with similar properties as opposed to individual chemicals can avoid the introduction of regrettable substitutions.
Inconsistencies between RSLs can undermine compliance/create gaps in the value chain where harmful chemicals are used.	Creating an international, GFC-aligned RSL for cotton yarn and textile production within the GFC Textile Sector Implementation Programme. This should include clear criteria for what constitutes GFC-aligned chemicals.
Tier 1 suppliers are affected by 'price squeeze' from buyers and therefore adopt low-cost but often unsafe production methods.	Greener procurement and price adjustment to put premium on non-safe chemical use as opposed to a premium on greener production methods would help scale transition across the sector.

Table 7: Identified levers to scale the transition to low-chemical textile production.

Stage 4: Cotton textile waste management - chemical recycling

4.4.A - Cotton fabric recycling - end-of-life treatment

144. 87% of the material used to make clothing is either land-filled or incinerated at end of life[(72)].

145. Less than 1% of the material in circulation today is recycled[(73)].

    1. The Global Fashion Agenda "Scaling Circularity Report" equates this to a USD 100 billion annual loss in resources[(74)].

146. Various initiatives are emerging to promote and increase the recyclability of materials, including cotton to support the transition to a more circular textile industry.

147. There are currently two main ways in which fabric can be recycled (see comparison in Table 8):

    1. Mechanical recycling; and

    2. Chemical recycling.

148. In 2022, 300,000 tonnes of cotton was recycled which was equivalent to ~ 1% of total global cotton production that year[(75)].

	Mechanical Recycling	Chemical Recycling
Description	Involves physically processing and shredding textiles to recapture fibres. The fibres are shortened in the process which reduces quality[76].	Uses chemical solvents to break down textiles to a molecular level. For cottons, the fabrics are reduced to pulp and cellulosic fibres known as 'Man-Made Cellulosic Fibres' (MMCFs). These fibres are subsequently used to produce MMCF yarn and textiles such as viscose or Lenzing[77].
Benefits	• Well-established technology, • Less energy intensive • No chemical inputs • Does not require water input	• Resultant fibres are considered to be of a higher quality that can be used for cotton-derived MMCF textiles (but not pure 'cotton').
Limitations	• Lower quality fibres that typically require blending with virgin fibres for strength and functionality. • Final products are often downcycled and not intended for textile-textile recycling	• High-cost operations reliant on emerging technologies. • Highly energy intensive operations • Requires water use • Requires the use of chemicals • Results in higher emissions of pollutants to air, soil and water.

Table 8: Comparison, benefits and limitations of the two commercially viable recycling techniques for cotton textiles.

149. In order to effectively recycle cotton, the process requires high quality, post-consumer textile waste (i.e. at least 95% cotton content).

    1. This requires careful sorting (post-consumer stage) and sourcing (trade and supply logistics) to guarantee a reliable source of raw materials for recycling.

    2. In addition to the quality (in terms of cotton content), cotton fibre length is an important factor in determining the quality of the final MMCF.

150. Recycling of cotton fabric is further hampered by:

    1. Yarn blends such as polycotton (polyester and cotton blend): separating such blends requires additional processing and chemical use and not all recycling technologies have this capability; and

    2. Dyes and chemicals previously applied to garments during manufacturing: the absence of traceability technology such as digital product passports means that identification of these chemicals is impossible in the absence of costly laboratory tests.

151. Commercial-scale, textile recycling is still in its infancy – particularly in the case of chemical recycling. Notable examples of trials that have evolved into pilot schemes or commercial chemical recycling operations include (see Appendix 15 for further details):

    1. NuCycl by Evrnu;

    2. Circulose by Renewcell;

3. Ioncell by Aalto; and
4. Refibra by Lenzing.

152. Details of the chemicals used in each of these examples are limited. Only Aalto discloses that the chemicals used are non-ionic liquid solvents.

153. Information about investors and indicative funds raised to support the ventures is provided for each of the examples. Finance has been provided largely by institutional investors, corporate partners and investment banks. Some public finance has been secured in the form of grants.

154. Despite early success with pilot schemes and securing textile supplies and financial backing from investors, Renewcell filed for bankruptcy in 2024 due to insufficient funds, highlighting the risks and uncertainties involved with emerging technologies.

4.4.B - Cotton fabric recycling: Barriers and opportunities

Barriers	Levers for change (opportunities):
Chemical recycling relies on high energy inputs, water and unknown volumes/types of chemical substances.	Aligning this emerging sector with aims and objectives of the GFC from the outset to limit use of harmful chemicals.
Manual sorting high volumes of post-consumer textile waste is time-consuming and offers limited accuracy.	Investing in Near Infrared (NIR) sorting technology increases quality of raw material for recycling purposes, in turn increasing volume of secondary raw materials.
Limited design for circularity rendering garments ‘unrecyclable’ at end of life in a cost-effective way.	Incentivise circular, sustainable design techniques to increase value of end-of-life materials.
Fragmented supply chains make it difficult to match suppliers of recycled content with requirements from garment manufacturers/brands.	Build and expand on existing coalitions of stakeholders to map and match specific supply and demand requirements across the whole value chain.
Limited textile recycling capacity results in volumes of post-consumer waste outpacing processing capability.	Incentivising and supporting transition to circular economy for textiles – starting at the design phase – coupled with technological improvements and investments to build recycling capacity will improve quality and availability of reliable recyclable materials.

Table 9: Cotton fabric recycling: Barriers and opportunities.

SECTION 5 – Conclusions

5.A - Key challenges and opportunities across the value chain

155. The textiles sector, including cotton value chains, is dominated by high numbers of small and medium sized enterprises (SMEs).

156. Value chains are global, with limited transparency on chemical application and use across the life cycle of textiles and garments.

157. Low and unstable incomes for farmers make low-cost pesticides an attractive option, despite growing evidence of improved yield and higher income associated with more sustainable farming practices.

158. Small scale and subsistence farmers in low- and middle-income countries (LIMCs) represent the majority of cotton producers (~60%).

159. Regional differences exist in the scale and access to subsidies for cotton farmers which results in inequitable access to global cotton markets.

160. Cotton exports (from fibre to finished garments) are an important source of foreign exchange revenues for LIMCs[(78)].

161. The largest cotton lint producing and exporting states are Brazil, China, India and the USA – collectively exporting approximately 4.8 million tonnes of ginned lint in 2023 at a combined value of USD 9.8 billion (FAO Stat data)

162. Fluctuating global market prices and price-squeeze instigated by fashion brands and retailers results in low wages and often poor working conditions for workers throughout the cotton value chain, increasing the risk of exposure to harmful chemicals and HHPs.

163. Procurement contracts with brands and retailers are often offered on a short-term basis for fibre processors and garment manufacturers, limiting the ability to support or influence a transition to a more sustainable industry.

164. The drive for more sustainable, circular textile economies is largely driven by the climate agenda but presents a timely opportunity to support the implementation of the GFC targets across the life cycle of cotton and other textiles.

165. Textile recycling technology – both mechanical and chemical – is improving but requires rapid and extensive expansion and investment in innovation to overcome today's limitations and to support a transition to a more circular economy for textiles that is also aligned with GFC targets.

166. There is a pressing need to ensure a fair and just transition towards a chemically-safe and circular economy for cotton that protects the livelihoods of upstream stakeholders (including farmers, spinners, weavers and cotton garmenting factories) who are face the highest risk of impact. This could be achieved by a range of voluntary and mandatory financial measures including subsidies, crop insurance and a price premium for organic/low-chemical cotton fibre.

5.B - Summary: Key barriers to overcome to align the Cotton value chain with the GFC (Table 10)

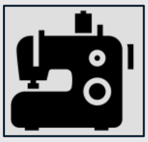
Stage 1: **Cotton farming** 	• Fragmented regulatory frameworks; • High numbers of individual stakeholders, including small-scale farmers heavily reliant on access to international cotton market; • Cheap, hazardous pesticides are readily available, particularly in LMICs where cotton production is high; • Limited access to training and capacity building programmes to scale up transition to more sustainable farming practices; • Low profit margins and prize squeeze from garment manufacturers; • Concerns of reduced yield and limited market access associated organic cotton farming; and • Two-to-three-year transition period required to achieve organic cotton certification impacting livelihoods.
Stage 2: **Cotton textile production**  **Stage 3:** **Cotton garment finishing** 	• High numbers of SMEs operating with low profit margins; poor safety records and weak governance all considered 'high risk' factors for investment in the absence of protective measures; • Hazard criteria apply to specific substances yet dyes and chemicals used in textile production/finishing are complex formulations; • Regional differences in chemical restrictions and prohibitions; • Low transparency and traceability of chemical use in textile value chains; • No internationally defined criteria for GFC-compliant chemicals used to produce textiles/finish garments; and • Short termism of procurement contracts limits ability to scale up more sustainable practices across the sector.
Stage 4: **Cotton Textile Recycling** 	• Technological limitations – chemical recycling reliant on high-cost, energy intensive emerging technologies that are not yet proven at scale; • Production costs - Competition from lower cost, virgin materials; • Raw material supply – low collection and sorting infrastructure on a global scale requires significant investment to capture end-of-life fabrics and materials to support recycling; • Capital needs – long term investments needed to bring new recycling capacity online and expand/improve technologies on a global scale; and • Transition risks - meeting consumer demand for clothing as value chains transition from linear to circular models.

Table 10:Key barriers to overcome to align the Cotton value chain with the GFC.

SECTION 6 – Opportunities to align the cotton value chain with GFC targets

6.A - Governments:

167. Build and implement awareness raising programmes in partnership with communities and civil society organisations. Awareness programmes should include:

    1. Work with national and international stakeholders and academic institutions to develop national strategies and sectoral programmes of work that eliminate most harmful chemicals across the life cycle including implementation timelines (GFC Target: C1).

    2. Raise awareness and educate cotton value chain stakeholders on the hazards of use and exposure to harmful pesticides, chemicals and chemical treatments in terms of health risks (for workers directly and families indirectly), environmental degradation, commercial impact (e.g. water contamination, degrading soil quality reducing crop viability and long-term profit) (GFC Targets: B4, B5, E2, D7).

    3. Increased understanding on benefits of low/no pesticide farming including farmer training programmes based on agroecological farming practices and integrated pest management principles (GFC Targets: A3, B4, B5, D7).

    4. Training for healthcare workers to recognise and respond to pesticide poisoning including access to national poison centres (GFC Targets: A6, B5, B7, D7).

168. Incentivise sustainable chemical management across the value chain:

    1. Subsidise organic and regenerative farming practices (GFC Targets: D1, D2, D4, D5, E5).

    2. Support access to international cotton markets (GFC Target A1).

169. Introduce stricter chemicals legislation on production, trade and use, prioritising the most hazardous chemicals for elimination and phasing out substances of concern:

    1. Prohibit use of HHPs and suspected HHPs in line with international policy frameworks (GFC Targets: A1, A4, A7).

    2. Obligate the sharing of data on the types/quantities/properties of all chemicals placed on domestic market for cotton growth/processing/finishing/recycling (GFC Targets: B1, B2, B3, B6, B7).

    3. Notify, regulate or prohibit the export of chemicals used in cotton value chains that have been prohibited nationally (GFC Targets: A5).

4. Incentivise innovation in the development of safer, alternative chemicals for use at each stage of the value chain (GFC Target D4).

6.B - Intergovernmental agencies and development banks:

170. Develop multistakeholder guidelines and internationally agreed minimum standards for the safe production, use and disposal of chemicals for each stage of the cotton value chain (GFC Target: A2).

171. Foster knowledge exchange to develop regionally appropriate and sector-specific, sustainable chemical and waste management strategies across the cotton life-cycle, sharing best practices, technological developments and lessons learnt (GFC Target: D6, E1, E2, E4).

172. Identify funding needs and gaps to support implementation of sector-specific chemical and waste management strategies (GFC Targets: E3, E4).

6.C - Investors:

173. Develop strategies and programmes to incorporate sound management of chemicals and waste across cotton value chains in finance approaches and business models, strengthening linkages and synergies with wider policies and approaches linked to climate change solutions, biodiversity conservation, human rights and health protection (GFC Target: D3, E3, E6).

174. Support transition to low/no chemical cotton production and use by supporting transparency and traceability schemes and supply chain initiatives such as Better Cotton Initiative and Fairtrade Organic cotton farming (GFC Targets: D3, D4, D7).

175. Support the development and adoption of international reporting and disclosure standards (GFC Target: D3).

SECTION 7 – Recommended next steps

176. Addressing the widespread use of hazardous chemicals across consumer product value chains is vital to protect the health of both people and planet and reverse biodiversity loss; in line with agreed sustainable development goals and economic growth.

    1. The adoption of the GFC marked a pivotal moment towards sustainable chemicals management. The high-level strategic objectives and targets provide a roadmap to a safer future chemicals industry.

177. Achieving the goals and targets of the framework, will however, require a coordinated, consorted effort from a great variety of stakeholders to break from the status quo.

    1. Private sector should continue to innovate while applying the principles of green and sustainable chemistry in a systemic change towards transparent and traceable processes and safer chemicals alternatives.

178. Adopting a precautionary, hazard-based approach in future chemicals policies - following the mitigation hierarchy will help avoid regrettable substitutions.

    1. 'No data, no market' rules would greatly increase transparency in chemical use and reduce risks across product life cycles.

179. Carefully designed, time-bound, multistakeholder Implementation Programmes for highly chemical-dependent sectors, like textiles, are vital to drive change in practices.

180. Policymakers and regulators need to create an enabling environment that facilitates a fair and just transition towards value-chain alignment with the GFC.

    1. Strong policy commitments and buy in from vested stakeholders at all stages of the value chain and across the life cycle will likely build support and create opportunities for financial investments.

181. Identifying sector-specific financial needs for implementing and aligning with GFC targets for specific products used in key value chains can be done by:

    1. Mapping key value chains in terms of stakeholders represented, chemical use, and barriers and levers for change;

    2. Interviewing key stakeholders at each stage of the value chain to understand current financial needs and costs of externalities (socio-economic and environmental) associated with conventional chemical uses; indicative costs associated with GFC-alignment; timelines to achieve the transition and potential barriers to change.

182. Indicative criteria need to be developed to help investors determine if investment decisions are GFC-compliant.

    1. Such criteria could form the basis of future financial disclosures.

183. Better integration of the finance sector in an informal thematic workstream or GFC Industry Sector Programme within the GFC Industry Implementation Programme

1. This would build capacity and better align investor expectations to fully support the implementation of the GFC targets and objectives.

SECTION 8 – Appendices

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Appendix 1 – Cotton lint production

Area	Item	Year	Unit	Value	% of Global Total
China	Cotton lint, ginned	2022	t	5,980,200	9.7
India	Cotton lint, ginned	2022	t	5,290,060	8.6
United States of America	Cotton lint, ginned	2022	t	3,150,040	5.1
Brazil	Cotton lint, ginned	2022	t	2,470,414	4
Australia	Cotton lint, ginned	2022	t	1,273,521	2.1
Türkiye	Cotton lint, ginned	2022	t	1,017,500	1.6
Pakistan	Cotton lint, ginned	2022	t	835,101	1.4
Uzbekistan	Cotton lint, ginned	2022	t	828,395	1.3
Greece	Cotton lint, ginned	2022	t	536,291	0.9
Argentina	Cotton lint, ginned	2022	t	391,065	0.6
Kazakhstan	Cotton lint, ginned	2022	t	361,819	0.6
Burkina Faso	Cotton lint, ginned	2022	t	255,780	0.4
Côte d'Ivoire	Cotton lint, ginned	2022	t	240,000	0.4
Mexico	Cotton lint, ginned	2022	t	233,820	0.4
Benin	Cotton lint, ginned	2022	t	219,130	0.4
Turkmenistan	Cotton lint, ginned	2022	t	180,556	0.3
Mali	Cotton lint, ginned	2022	t	163,646	0.3
Cameroon	Cotton lint, ginned	2022	t	141,700	0.2
Sudan	Cotton lint, ginned	2022	t	131,000	0.2
Nigeria	Cotton lint, ginned	2022	t	104,000	0.2
Tajikistan	Cotton lint, ginned	2022	t	99,546	0.2
Azerbaijan	Cotton lint, ginned	2022	t	90,958	0.1
Egypt	Cotton lint, ginned	2022	t	90,000	0.1
Myanmar	Cotton lint, ginned	2022	t	85,000	0.1
Ethiopia	Cotton lint, ginned	2022	t	62,630	0.1
Zimbabwe	Cotton lint, ginned	2022	t	52,517	0.1
Uganda	Cotton lint, ginned	2022	t	47,000	0.1
United Republic of Tanzania	Cotton lint, ginned	2022	t	45,000	0.1
Chad	Cotton lint, ginned	2022	t	43,544	0.1
Spain	Cotton lint, ginned	2022	t	40,549	0.1
Iran (Islamic Republic of)	Cotton lint, ginned	2022	t	32,604	0.1
Syrian Arab Republic	Cotton lint, ginned	2022	t	26,690	0
Kyrgyzstan	Cotton lint, ginned	2022	t	25,249	0
Afghanistan	Cotton lint, ginned	2022	t	23,950	0
Bangladesh	Cotton lint, ginned	2022	t	22,350	0
Mozambique	Cotton lint, ginned	2022	t	20,450	0
Togo	Cotton lint, ginned	2022	t	19,539	0
Peru	Cotton lint, ginned	2022	t	19,000	0
Israel	Cotton lint, ginned	2022	t	17,515	0
Central African Republic	Cotton lint, ginned	2022	t	16,800	0
Guinea	Cotton lint, ginned	2022	t	15,843	0

Table A1.1 - Cotton lint (ginned) producing countries in 2022. Data source: FAO STAT

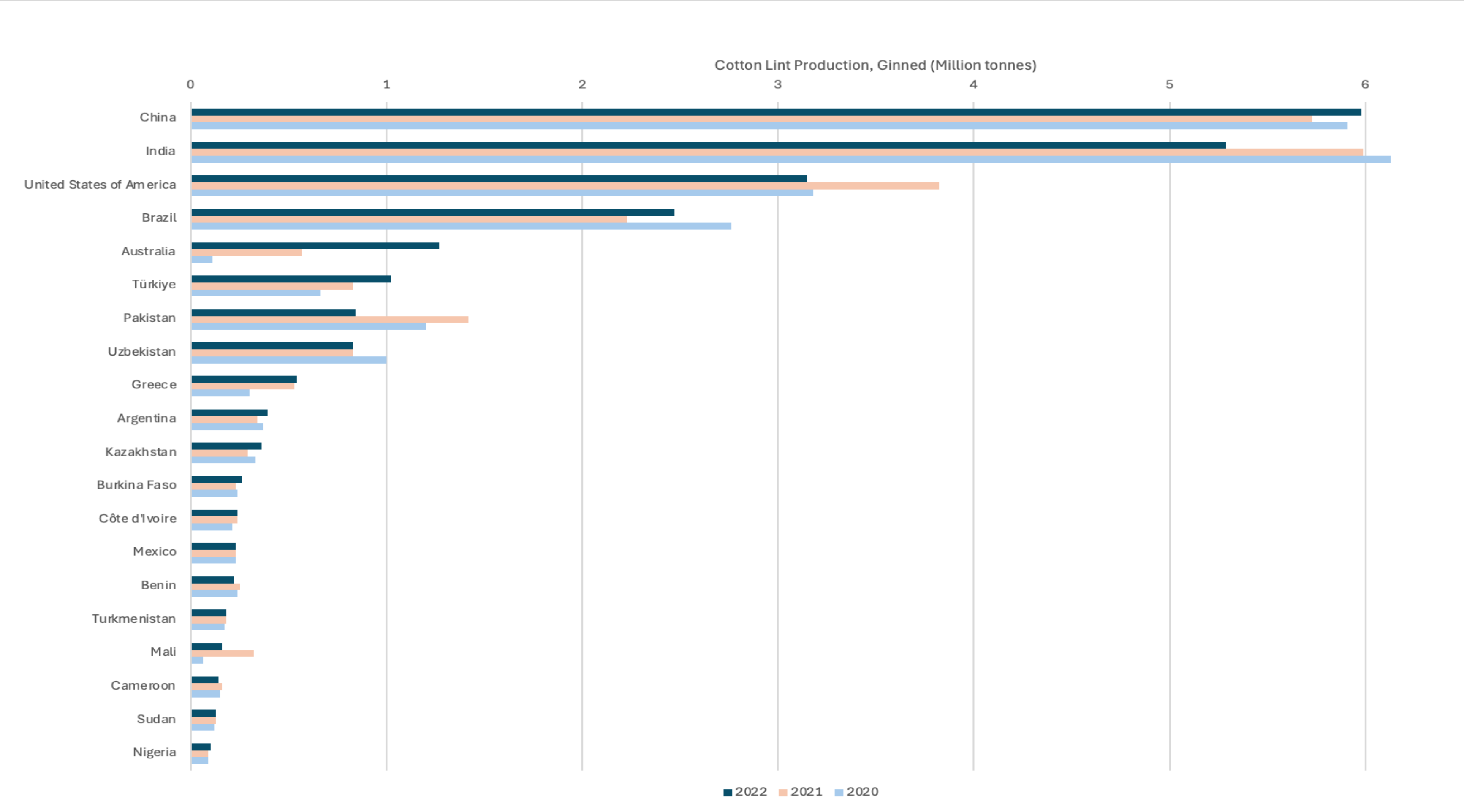


Figure A1.1: Top 20 cotton lint (ginned) producing countries, ranked by 2022 data in Table A1.1. Note: 2021 and 2020 data show annual variation in production volumes, but overall top 20 representation remains constant over three years. Data source: FAO STAT

Appendix 2 – Defining Highly Hazardous Pesticides (HHPs)

- The United Nations World Health Organization and the Food and Agriculture Organization (FAO) issued the updated fourth edition of the International Code of Conduct on Pesticide Management in 2014[(79)] which includes additional criteria for both public health and environmental aspects of pesticide use to support safer chemicals management.
    - The Code of Conduct is a voluntary framework, complementing both voluntary mechanism such as the Strategic Approach to International Chemicals Management (SAICM), now superseded by the Inter-Organization Programme for the Sound Management of Chemicals (IOMC) and existing international, legally-binding instruments:
        - The Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade
        - The Stockholm Convention on Persistent Organic Pollutants
        - The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal
    - The objective of the Code is to establish voluntary standards for the sound management of pesticides across the life cycle, thus addressing international and inter-regional differences in national legislation regulating pesticide use.
    - The Code is supplemented by separate WHO-issued guidance on the registration and classification of pesticides by hazard[(80)].
- The WHO/FAO issued 8 Criterion for the identification of HHPs in 2008[(81)]. Any pesticide that meets <u>one or more</u> of the following criteria is considered an HHP:
    1. Pesticide formulations that meet the criteria of classes Ia or Ib of the WHO Recommended Classification of Pesticides by Hazard
    2. Pesticide active ingredients and their formulations that meet the criteria of carcinogenicity categories 1A or 1B of Globally Harmonised System (GHS):
    3. Pesticide active ingredients and their formulations that meet the criteria of mutagenicity Categories 1A and 1B of GHS
    4. Pesticide active ingredients and their formulations that meet the criteria of reproductive toxicity Categories 1A and 1B of GHS.
    5. Pesticide active ingredients listed by the <u>Stockholm Convention on Persistent Organic Pollutants</u> in its <u>Annexes A and B</u> and those meeting all the criteria in paragraph 1 of Annex D of the Convention.
    6. Pesticide active ingredients and formulations listed by the <u>Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade</u> in its <u>Annex III</u>.
    7. Pesticides listed under the <u>Montreal Protocol on Substances that Deplete the Ozone Layer</u>.
    8. Pesticide active ingredients and formulations that have shown a high incidence of severe or irreversible adverse effects on human health or the environment.

Appendix 3 – PAN International List of Highly Hazardous Pesticides

- PAN List of HHPs is available here: www.pan-uk.org/site/wp-content/uploads/PAN-HHP-List-2021.pdf
    - This working list contains 338 substances, identifiable by hazard criterion indicators
- The PAN list is the only international list of substances in use and is intended to serve as a basis for developing action plans and progressive, global bans on HHPs and the introduction of safer alternatives which could, in turn, align with the strategic objectives and targets of the GFC.
- The classifications used compile information from recognised authorities:
    - FAO/WHO Criteria 1-8 included for identification of HHPs ,
    - European Union (EU Commission),
    - National agencies (USA Environmental Protection Agency; Japan's Globally Harmonised System for Classification)
    - Pesticide Property Database.
- The list is organised into four 'hazard groups' ranging from acute toxicity, long term (chronic) health effects, environmental hazard criteria and international regulations (global conventions related to pesticides)
- It is presented as a working list and not a comprehensive list – updated periodically in line with new and emerging evidence, data and listings in regulatory frameworks.
- In order to prioritise elimination of HHPs, the PAN list does not incorporate WHO Class II chemicals, Dioxin-contaminated pesticides or pesticides considered obsolete by FAO/WHO.
- All 338 chemical substances on the list are identifiable by CAS number (a unique, chemical identification number issued for specific substances link), that meet the criteria to be classified as HHPs and should be prioritised for elimination.
- The list is organised into four 'hazard groups' ranging from acute toxicity, long term (chronic) health effects, environmental hazard criteria and international regulations (See Appendix 16 for international conventions related to pesticides)
    - See Figure A3.1 for details
    - It is presented as a working list and not a comprehensive list – updated periodically in line with new and emerging evidence, data and listings in regulatory frameworks.
- In order to prioritise elimination of HHPs, the PAN list does not incorporate WHO Class II chemicals, Dioxin-contaminated pesticides or pesticides considered obsolete by FAO/WHO

High acute toxicity
'Extremely hazardous' (Class Ia) according to WHO Recommended Classification of Pesticides by Hazard or
'Highly hazardous' (Class Ib) according to WHO Recommended Classification of Pesticides by Hazard or
'Fatal if inhaled' (H330) according to the EU or the Japan Globally Harmonized System (GHS) or
Long term toxic effects
Carcinogenic to humans according to IARC or US EPA or
'Known or presumed human carcinogens' (Category I) according to the EU or the Japan Globally Harmonized System (GHS) or
Probable/likely carcinogenic to humans according to IARC, US EPA or
Likely to be Carcinogenic to Humans: At High Doses according to EPA or
'Substances known to induce heritable mutations or to be regarded as if they induce heritable mutations in the germ cells of humans', 'Substances known to induce heritable mutations in the germ cells of humans' (Category I) according to the EU or the Japan Globally Harmonized System (GHS) or
'Known or Presumed human reproductive toxicant' (Category I) according to the EU or the Japan Globally Harmonized System (GHS) or
Endocrine disruptor
EU interim criteria as laid down in Reg. (EC) No 1107/2009 'Suspected human reproductive toxicant' (Category 2) *AND* 'Suspected human carcinogen' (Category 2) according to the EU or the Japan Globally Harmonized System (GHS) or
Pesticides identified as endocrine disrupters in the EU according to Reg. (EU) 2018/605
High environmental concern
Pesticides listed in Annex A & B of the Stockholm Convention or meeting the Conventions' criteria or Ozone depleting pesticides according to the Montreal Protocol or
High environmental concern – where <u>two</u> of the three following criteria are met:
P = 'Very persistent' half-life > 60 days in marine- or freshwater or half-life > 180 days in soil ('typical' half-life), marine or freshwater sediment) (Indicators and thresholds according to the Stockholm Convention) *AND/OR*
B = 'Very bioaccumulative' (BCF >5000) or Kow logP > 5 (existing BCF data supersede Kow log P data) (Indicators and thresholds according to the Stockholm Convention) *AND/OR*
T = Very toxic to aquatic organisms (LC/EC 50 [48h] for Daphnia spp. < 0,1 mg/l)
Hazard to ecosystem services
'Highly toxic for bees' according to U.S. EPA (LD50, µg/bee < 2) or
Known to cause a high incidence of severe or irreversible adverse effects
Pesticides listed in Annex III of the Rotterdam Convention or meeting the Conventions' criteria

Figure A3.1: PAN International Indicators for identifying HHPs

Appendix 4 – Pesticide use on Cotton

Country	Pesticides (tonnes)	% of total
Brazil	34,527	31.2
USA	26,162	23.64
India	13,068	11.81
China	11,381	10.28
Australia	6,047	5.46
Pakistan	4,323	3.91
Benin	2,023	1.83
Burkina Faso	1,969	1.78
Ivory-Coast	1,754	1.58
Turkiye	1,325	1.2
Uzbekistan	1,320	1.19
Greece	1,172	1.06
Cameroon	949	0.86
Turkmenistan	865	0.78
Argentina	845	0.76
Mexico	696	0.63
Mali	520	0.47
Zimbabwe	283	0.26
Egypt	262	0.24
Azerbaijan	175	0.16
Tajikistan	154	0.14
Mozambique	140	0.13
Malawi	139	0.13
Spain	96	0.09
Togo	93	0.08
Peru	89	0.08
Kazakhstan	74	0.07
Colombia	64	0.06
Israel	48	0.04
Zambia	41	0.04
South Africa	40	0.04
Myanmar	14	0.01
Kyrgyzstan	9	0.01
Ghana	8	0.01
Total	110,675	100

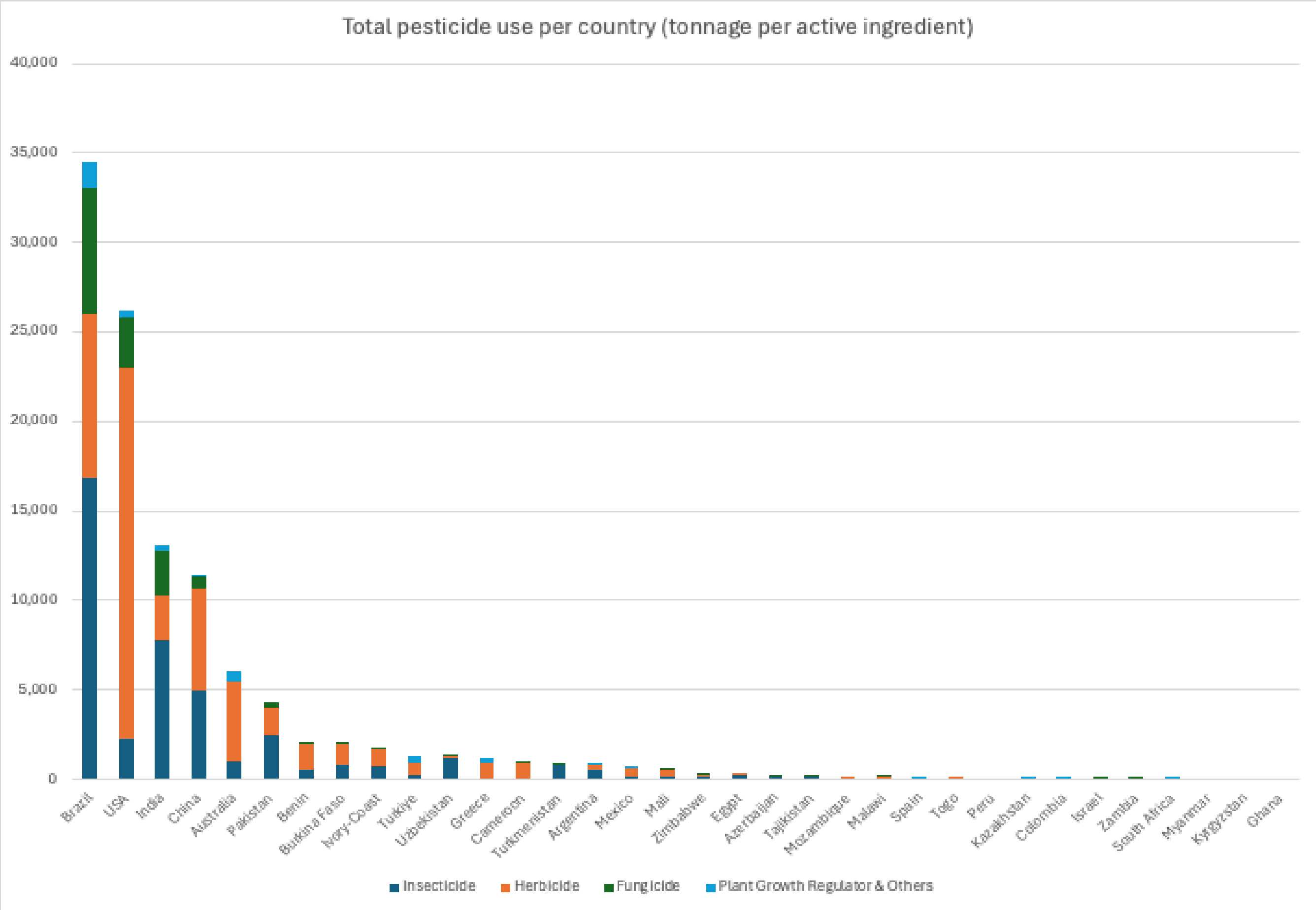
Country	Insecticides (tonnes)	% of total
Brazil	16,829	40.48
India	7,814	18.8
China	4,963	11.94
Pakistan	2,446	5.88
USA	2,261	5.44
Uzbekistan	1,200	2.89
Australia	1,057	2.54
Burkina Faso	803	1.93
Turkmenistan	791	1.9
Ivory-Coast	702	1.69
Argentina	570	1.37
Benin	546	1.31
Turkiye	266	0.64
Egypt	259	0.62
Mali	185	0.45
Zimbabwe	175	0.42
Azerbaijan	152	0.37
Tajikistan	127	0.31
Mexico	122	0.29
Cameroon	60	0.14
Mozambique	49	0.12
Malawi	38	0.09
Greece	30	0.07
Togo	22	0.05
Israel	21	0.05
Zambia	18	0.04
Colombia	14	0.03
Myanmar	14	0.03
Kazakhstan	12	0.03
Spain	10	0.02
Kyrgyzstan	5	0.01
Peru	5	0.01
South Africa	5	0.01
Ghana	1	0
Total	41,572	100

Country	Herbicides (tonnes)	% of total
USA	20,748	39.88
Brazil	9,212	17.71
China	5,704	10.96
Australia	4,372	8.4
India	2,519	4.84
Pakistan	1,579	3.04
Benin	1,464	2.81
Burkina Faso	1,155	2.22
Ivory-Coast	1,014	1.95
Greece	937	1.8
Cameroon	888	1.71
Turkiye	639	1.23
Mexico	470	0.9
Mali	329	0.63
Argentina	219	0.42
Malawi	101	0.19
Mozambique	91	0.17
Spain	81	0.16
Zimbabwe	76	0.15
Togo	71	0.14
Uzbekistan	70	0.13
Turkmenistan	62	0.12
Kazakhstan	59	0.11
Colombia	41	0.08
South Africa	31	0.06
Israel	25	0.05
Azerbaijan	19	0.04
Zambia	19	0.04
Tajikistan	14	0.03
Ghana	7	0.01
Kyrgyzstan	3	0.01
Egypt	2	0
Myanmar	0	0
Peru	0	0
Total	52,021	100

Country	Fungicides (tonnes)	% of total
Brazil	6,995	51.41
USA	2,835	20.83
India	2,474	18.18
China	659	4.84
Pakistan	298	2.19
Peru	83	0.61
Uzbekistan	50	0.37
Ivory-Coast	39	0.29
Australia	34	0.25
Zimbabwe	32	0.24
Mexico	19	0.14
Benin	13	0.1
Tajikistan	12	0.09
Turkmenistan	12	0.09
Burkina Faso	10	0.07
Colombia	8	0.06
Greece	8	0.06
Azerbaijan	5	0.04
Mali	5	0.04
Zambia	4	0.03
Argentina	3	0.02
South Africa	3	0.02
Spain	2	0.01
Cameroon	1	0.01
Israel	1	0.01
Kyrgyzstan	1	0.01
Turkiye	1	0.01
Egypt	0	0
Ghana	0	0
Kazakhstan	0	0
Malawi	0	0
Mozambique	0	0
Myanmar	0	0
Togo	0	0
Total	13,607	100

Country	PGR & Others	% of total
Brazil	1,490	42.94
Australia	584	16.83
Turkiye	420	12.1
USA	318	9.16
India	261	7.52
Greece	197	5.68
Mexico	85	2.45
China	54	1.56
Argentina	52	1.5
Spain	4	0.12
Kazakhstan	3	0.09
Colombia	1	0.03
South Africa	1	0.03
Azerbaijan	0	0
Benin	0	0
Burkina Faso	0	0
Cameroon	0	0
Egypt	0	0
Ghana	0	0
Israel	0	0
Ivory-Coast	0	0
Kyrgyzstan	0	0
Malawi	0	0
Mali	0	0
Mozambique	0	0
Myanmar	0	0
Pakistan	0	0
Peru	0	0
Tajikistan	0	0
Togo	0	0
Turkmenistan	0	0
Uzbekistan	0	0
Zambia	0	0
Zimbabwe	0	0
Total	3,470	100

Table A4.1: Total pesticide use on Cotton – 2022 data. Note: Tonnage data given for active ingredient only. Data source: ICAC, 2025



Country	Pesticides (tonnes)	% of total
Brazil	34,527	31.2
USA	26,162	23.64
India	13,068	11.81
China	11,381	10.28
Australia	6,047	5.46
Pakistan	4,323	3.91
Benin	2,023	1.83
Burkina Faso	1,969	1.78
Ivory-Coast	1,754	1.58
Türkiye	1,325	1.2
Uzbekistan	1,320	1.19
Greece	1,172	1.06
Cameroon	949	0.86
Turkmenistan	865	0.78
Argentina	845	0.76
Mexico	696	0.63
Mali	520	0.47
Zimbabwe	283	0.26
Egypt	262	0.24
Azerbaijan	175	0.16
Tajikistan	154	0.14
Mozambique	140	0.13
Malawi	139	0.13
Spain	96	0.09
Togo	93	0.08
Peru	89	0.08
Kazakhstan	74	0.07
Colombia	64	0.06
Israel	48	0.04
Zambia	41	0.04
South Africa	40	0.04
Myanmar	14	0.01
Kyrgyzstan	9	0.01
Ghana	8	0.01
Total	110,675	100.03

Figure A4.1: Pesticide use by type – 2021 data. Note: Tonnage data given for active ingredient only. Data source: ICAC, 2025

Appendix 5 – Cotton production vs pesticide use

Country	Pesticides (tonnes) ICAC Data	% of total pesticide use	Cotton Lint Produced (ginned) Tonnes FAO Stat Data	% of total Cotton lint produced (ginned)	Tonnes Pesticide used per Tonne cotton lint (ginned) produced (Kg)
Brazil	34,527	**31.2**	2,470,414	9.95	13.98
USA	26,162	**23.64**	3,150,040	12.69	8.31
India	13,068	**11.81**	5,290,060	21.31	2.47
China	11,381	**10.28**	5,980,200	24.09	1.90
Australia	6,047	**5.46**	1,273,521	5.13	4.75
Pakistan	4,323	**3.91**	835,101	3.36	5.18
Benin	2,023	1.83	219,130	0.88	9.23
Burkina Faso	1,969	1.78	255,780	1.03	7.70
Ivory-Coast	1,754	1.58	240,000	0.97	7.31
Turkiye	1,325	1.2	1,017,500	4.10	1.30
Uzbekistan	1,320	1.19	828,395	3.34	1.59
Greece	1,172	1.06	536,291	2.16	2.19
Cameroon	949	0.86	141,700	0.57	6.70
Turkmenistan	865	0.78	180,556	0.73	4.79
Argentina	845	0.76	391,065	1.58	2.16
Mexico	696	0.63	233,820	0.94	2.98
Mali	520	0.47	163,646	0.66	3.18
Zimbabwe	283	0.26	52,517	0.21	5.39
Egypt	262	0.24	90,000	0.36	2.91
Azerbaijan	175	0.16	90,958	0.37	1.92
Tajikistan	154	0.14	99,546	0.40	1.55
Mozambique	140	0.13	20,450	0.08	6.85
Malawi	139	0.13	12,352	0.05	11.25
Spain	96	0.09	40,549	0.16	2.37
Togo	93	0.08	19,539	0.08	4.76
Peru	89	0.08	19,000	0.08	4.68
Kazakhstan	74	0.07	361,819	1.46	0.20
Colombia	64	0.06	12,892	0.05	4.96
Israel	48	0.04	17,515	0.07	2.74
Zambia	41	0.04	7,500	0.03	5.47
South Africa	40	0.04	13,987	0.06	2.86
Myanmar	14	0.01	85,000	0.34	0.16
Kyrgyzstan	9	0.01	25,249	0.10	0.36
Ghana	8	0.01	6,100	0.02	1.31
Total	**110,675**	**100**	**24,182,192**	**97.40**	-

Total Cotton lint produced in 2022 = 24,826,443.53 tonnes
Pesticide use data is not available for all countries providing data to FAO

Country	Pesticides (tonnes) ICAC Data	% of total pesticide use	Cotton Lint Produced (ginned) Tonnes FAO Stat Data	% of total Cotton lint produced (ginned)	Tonnes pesticide used per tonne cotton lint (ginned) produced (Kg)
Brazil	34,527	31.2	2,470,414	9.95	**13.98**
Malawi	139	0.13	12,352	0.05	**11.25**
Benin	2,023	1.83	219,130	0.88	**9.23**
USA	26,162	23.64	3,150,040	12.69	**8.31**
Burkina Faso	1,969	1.78	255,780	1.03	**7.70**
Ivory-Coast	1,754	1.58	240,000	0.97	**7.31**
Mozambique	140	0.13	20,450	0.08	6.85
Cameroon	949	0.86	141,700	0.57	6.70
Zambia	41	0.04	7,500	0.03	5.47
Zimbabwe	283	0.26	52,517	0.21	5.39
Pakistan	4,323	3.91	835,101	3.36	5.18
Colombia	64	0.06	12,892	0.05	4.96
Turkmenistan	865	0.78	180,556	0.73	4.79
Togo	93	0.08	19,539	0.08	4.76
Australia	6,047	5.46	1,273,521	5.13	4.75
Peru	89	0.08	19,000	0.08	4.68
Mali	520	0.47	163,646	0.66	3.18
Mexico	696	0.63	233,820	0.94	2.98
Egypt	262	0.24	90,000	0.36	2.91
South Africa	40	0.04	13,987	0.06	2.86
Israel	48	0.04	17,515	0.07	2.74
India	13,068	11.81	5,290,060	21.31	2.47
Spain	96	0.09	40,549	0.16	2.37
Greece	1,172	1.06	536,291	2.16	2.19
Argentina	845	0.76	391,065	1.58	2.16
Azerbaijan	175	0.16	90,958	0.37	1.92
China	11,381	10.28	5,980,200	24.09	1.90
Uzbekistan	1,320	1.19	828,395	3.34	1.59
Tajikistan	154	0.14	99,546	0.40	1.55
Ghana	8	0.01	6,100	0.02	1.31
Turkiye	1,325	1.2	1,017,500	4.10	1.30
Kyrgyzstan	9	0.01	25,249	0.10	0.36
Kazakhstan	74	0.07	361,819	1.46	0.20
Myanmar	14	0.01	85,000	0.34	0.16
Total	**110,675**	**100**	**24,182,192**	**97.40**	-

Figure A5.1: A comparison exercise between top cotton lint producing countries and countries recording the highest amount of pesticide use. Note: data gaps exist between the ICAC published data and FAO Stat data and therefore pesticide use data per country should be considered as estimates only.

Appendix 6 – Impacts of Pesticides

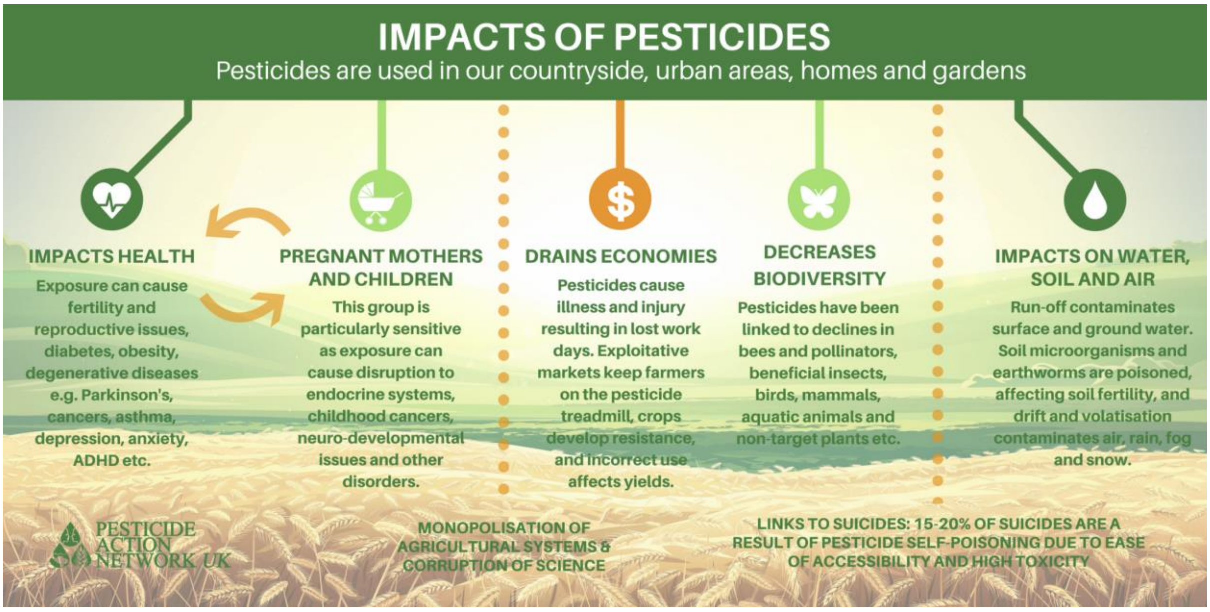


Figure A6.1: Socio-environmental impacts associated with pesticide use. Image Source: PAN, UK

- Despite known hazards of HHPs, there are significant differences in government policies and prohibitions, particularly in developing countries[82], which results in ongoing exposure to, and impacts of HHPs including poisoning and pesticide-related ill health.
- Accurate figures for annual deaths from unintentional, acute pesticide poisonings vary significantly due to lack of systematic monitoring.
- A WHO-led study in the 1990s estimated that over 350,000 people in Kenya alone were hospitalised as a direct result of acute pesticide poisoning[83]. A more recent but contested estimate from 2021 estimated annual, global acute pesticide poisonings reached 385 million cases and led to 11,000 deaths[83].
- PAN UK estimates that 750,000 people in developing countries are estimated to suffer ill health as a result of long-term exposure to pesticides[85].
- Additionally, deaths from intentional pesticide poisoning reportedly range between 110,000 and 168,000 deaths per year[86].
- The use of pesticides and synthetic fertiliser during the production of cotton not only directly impacts the health of farm workers and soil and water quality on cotton plantations but also affects nearby food crops through contaminated soil and water.
- Discarded pesticides and pesticide containers results in a high number of pesticide poisonings each year through spillage and accidental consumption[87].

- It is estimated that 10% of the 3 million hospitalised acute poisonings each year results in death, although data gaps and accessibility of medical treatment may limit the accuracy of this figure[88] .
- Crop sprayers, which often includes children, are most at risk for direct exposure to harmful pesticides.
- Farmers reportedly lack training in safe pesticide use and have limited access to climate-appropriate and affordable Personal Protective Equipment (PPE).

Appendix 7 – Global pesticide manufacturers and suppliers

Global Ranking	Company Name	Country of HQ	Parent company	Crop protection business sales in 2023 (USD Billion)	Crop protection business sales in 2022 (USD Billion)
1	Syngenta Crop Protection	Switzerland	Sinochem	15.433	16.136
2	Bayer Crop Science	USA	Bayer	11.919	13.875
3	BASF	Germany	BASF	8.863	8.851
4	Corteva	USA	DowDuPont	7.754	8.476
5	UPL	India	UPL Corp	4.417	5.881
6	Adama	Israel	Sinochem	4.243	5.020
7	FMC	USA	FMC Corp	4.235	5.382
8	Sumitomo Chemical	Japan	Sumitomo Group	3.142	3.666
9	Nufarm	Australia	Nufarm Australia Ltd	2.059	2.280
10	Rainbow Agro	China	Rainbow Agro	1.622	2.149

Table A7.1: Annual estimated income (by sales) for top ten agrochemicals companies. Data source: Agropages FY 2023

Appendix 7 – Global pesticide manufacturers and suppliers

- A series of recent of mergers and acquisitions of major agrichemical companies reportedly raised concerns of reduced competition, market dominance and stymied innovation, prompting the EU to introduce a number of divestiture conditions prior to completion:
  - **2018 Bayer acquisition of Monsanto for USD 63 billion[89]**
    - As part of the acquisition, BASF acquired the non-selective herbicide products (Glyphosate and Glufosinate) for EUR 7.6 billion[90].
  - **2017 Dow Chemicals & DuPont merger worth USD 130 billion[91]**
    - An EU condition of the merger was the divestiture of parts of DuPont's pesticide business which was purchased by FMC in an asset swap deal[92].
  - **2016 ChemChina acquisition of Syngenta for USD 43 billion[93]**
    - EU divestiture conditions included large parts of ChemChina's European pesticide and plant growth regulators business areas:
      - These business areas due to be sold were owned by Adama Agricultural Solutions Ltd (Israeli-based ChemChina subsidiary) that produces generic chemicals. These were reportedly purchased by American Vanguard Corp.
      - In addition, Adama reportedly sold 29 generic pesticide formulations that were in development at the time and granted interested third-parties access to the field trial results for the products[94].
- Syngenta sold off part of its fungicide and herbicide businesses to NuFarm in a deal worth USD 49 million[95].

Appendix 8 – Global cotton lint import and export data

Top ten importing nations by volume (ginned cotton lint):

Country	Year	Value (tonnes)
China	2023	1,998,914.36
Viet Nam	2023	1,206,255.32
Bangladesh	2023	1,052,243.25
Türkiye	2023	749,708.23
Pakistan	2023	417,056.21
Indonesia	2023	366,718.08
Egypt	2023	220,175.39
India	2023	211,000.51
Malaysia	2023	151,444.08
Thailand	2023	102,637.68

Top ten exporting nations by volume (ginned cotton lint):

Country:	Year	Value (tonnes)
United States of America	2023	2,797,340.78
Brazil	2023	1,618,187.73
Australia	2023	1,316,111.62
India	2023	344,866.25
Türkiye	2023	288,337.99
Benin	2023	239,071.22
Greece	2023	212,075.20
Sudan	2023	161,703.22
Burkina Faso	2023	124,345.72
Tajikistan	2023	109,258.00

Data source: FAO Stat

Table A8.1: Import and export data for cotton lint (ginned) in 2023. Data source: FAO Stat

Appendix 9 - Cotton spinning operations: national case studies

China	India	Bangladesh	Vietnam
90% of spinning mills are located in Xinjiang Uyghur Autonomous Region (XUAR), consuming 90% of cotton produced[96].	55% of India's spinning capacity is concentrated in Tamil Nadu[98].	Bangladesh Textile Mills Association (BTMA) is the national trade association representing both yarn manufacturers (spinners), textile producers (weavers and knitters) and garment finishers[99]	The spinning industry is represented by the Vietnam Cotton and Spinning Association.
The China National Cotton Exchange (CNCE) is a member-based platform that is managed by Chinatex Corporation Ltd. The platform supports the procurement and sale of national cotton reserves. Chinatex manages China's cotton enterprises (including ownership of 335,000 of the country's spindles)	Government of Tamil Nadu launched 'Tamil Nadu New Integrated Textile Policy' in 2024 which includes 6% interest reduction for spinning mills to support modernisation	Over 500 spinning mills are spread across several large industrial regions in Bangladesh and jointly processing ~3 million tonnes of cotton fibre annually[100]. Industrial areas include: Ashulia, Shreepur, Dhaka, Gazipur.	There are approximately 121 cotton yarn spinning mills in Vietnam. The mills are widely spread throughout the country and spinning capacity has reportedly remained constant[104] despite an overall year-on-year increase in cotton fibre imports (FAO Stat data)
There are approximately 110 million spindles in China but the nation is reportedly experiencing an overcapacity issue resulting in	Tamil Nadu Co-operative Spinning Mills Federation Ltd (TANSPIN), Chennai regulates purchase of	Rapid capacity expansion funded by local entrepreneurs has added an additional 745,400 new spindles since 2021 but national gas supply	USDA reports that 46 (38%) of the mills are owned by foreign investors while 75 (62%) are locally-owned mills[105].

only 77% of this capacity being met[97]	cotton fibre for the cooperative spinning mills 6 cooperative spinning mills currently operate in Tamil Nadu	shortages reportedly limit output capacity[101].	There are approximately 8.9 million spindles in operation in Vietnam
The China Cotton Index (CCI) serves as both a price indicator for cotton (yuan per tonne) and a measure of the value of cotton destined to be sold on the CNCE that banks can use.	Regional government-owned Tamil Nadu Textile Corporation Ltd (TNTC) establishes textile and spinning mills throughout the region including large 'power loom' complexes for cotton spinning, weaving and textile manufacture; TNTC also has power to take over struggling smaller enterprises (under powers of Development and Regulations Act 1951)	Bangladesh relies almost entirely on imported cotton lint which increases production costs and reduces competitiveness due to fluctuating global fibre prices[101] Sectors sees a need to modernise equipment, increase proportion of locally produced cotton fibre and impose duty fees on imported yarn to improve competitiveness and growth in the sector[103].	Cotton yarn dominates Vietnam's overall yarn export (50% by volume) China is Vietnam's largest export market (82%), followed by South Korea (8%) and Cambodia (2%).

Table A9.1: High-level overview of cotton spinning operations located in China, India, Bangladesh and Vietnam

Appendix 10 – Chemical use in cotton textile production

Wet processes				
Stage:		**Type of wet process:**	**Chemical Inputs (non-exhaustive list):**	**Notes:**
Fibre (yarn)	Fibre Preparation	Scouring	Detergent Hot water Soda ash Caustic Soda Sequestering agents Acetic acid	Scouring and bleaching can be combined for efficiencies Scouring removes impurities from ginning process Scouring with either detergent (for light imperfections) or solvents (for oil/grease marks) is repeated following knitting/weaving to remove marks caused by the machinery used
Fibre (yarn)	Fibre Preparation	Bleaching	Example of bleach solution: Detergent (1%), Sodium Hydoxide (Caustic soda) (4%), Sodium Silicate 42° Be (2%), Hydrogen Peroxide 7% (35% of solution) Hot water (90-100°C) Acetic acid Alternative bleaching agent: Sodium Hypochlorite (0.5-3g/l Cl)	(Percentages) represent typical composition of bleach solution Acetic acid used to neutralise Alkali bleach at the end of the process Bleaching, like scouring, removes leftover impurities and prepares the fibre for dye application Bleaching can be repeated on the knit/woven cotton fabric to remove further impurities
Fibre (yarn)	Fibre Preparation	Mercerising	Sodium Hydroxide (Caustic soda)	An alkali solution used to make cotton fibre swell and straighten, improving the effectiveness of dye application/retention. Creates silky sheen on fabric, can contribute to 'wrinkle-free' garment finishing effects.
Fibre (yarn)	Fibre Preparation	Chemical finishing	Softeners (e.g. cationic substancs, non-ionic substances of silicone-based polymers) Lubricants (e.g. paraffin waxes, synthetic oils) Starch (for sheen and lustre)	Silicone-based softeners are usually based on organic polysiloxane polymers. Two examples in the literature are: Dow Corning 36 and Dow Corning 37

Wet processes				
Stage:		**Type of wet process:**	**Chemical Inputs (non-exhaustive list):**	**Notes:**
Fabric (woven)	Fibre Preparation	Desizing	Enzymes (e.g. Amylase) Detergent Water	This process removes any starch (sizing) used during weaving
Fabric (woven)	Dying	Reactive dyes	Exhaust method: Dye, salt, alkali added to dye bath, heated, rinsed (x2 times) Semi-continuous method: Dye and alkali added to a pad which is rolled over fabric to transfer dye. Fabric rinsed, hot washed and rinsed to fix the dye Continuous method: pad fabric with dye, alkali agent, apply steam, rinse, hot wash and rinse	Good colour-fastness, used in higher quality fabrics
Fabric (woven)	Dying	Direct dyes	Exhaust method: Dye added to dye bath and fabric soaked, heated, Sodium Chloride (Salt) added to fix the dye, rinsed	Used for cheaper fabrics where colour-fastness is of lower priority
Fabric (woven)	Dying	Vat dyes	Exhaust method: vat dye made using sodium hydroxide (caustic soda) , sodium dithionite or sodium hydrosulfite (reducing agents). Vat dye is added to dye bath and heated then rinsed, oxidised using acetic acid and hydrogen peroxide. Detergent and soda ash used to finish the process ALternatively, vat dye can be added to a pad and used in a 'continuous method' of dying (see Direct Dyes)	Dye used is in pigment form
Fabric (woven)	Dying	Sulphur dyes	Soda Ash to solubise pigment dyes Sodium sulfide reducing agent Exhaust or continuous method can be used	Fixed using Chlorine-washing; dye used is in pigment form
Fabric (woven)	Chemical finishing	Starch removal	Enzymes (Amylase)	Used to break down remaining starch and impurities in fabrics.

Stage	Finishing effect	Chemical inputs (non-exhaustive list):	Notes
Garment finishing	Wrinkle-resistance	fluoro chemicals (PFASs) Sequia soft 69 Mykon 39 Catalyst 531	Scotchguard, by 3M is the most commonly used example Silicone emulsion Magnesium chloride solution
Garment finishing	Softening	fluoro chemicals (PFASs) Sequa Soft 69	Scotchguard, by 3M is the most commonly used example Silicone emulsion
Garment finishing	Stain proofing	fluoro chemicals (PFASs) Prym 119	Scotchguard, by 3M is the most commonly used example
Garment finishing	Flame retardants	Most common Phosphorus-based examples: Proban Pyrovatex CP Other agents widley used: Halogenated compounds Formaldehyde	Organic polymeric, nonpolymeric and polymeric/nonpolymeric hybrid materials composed of one or more of the following substances can be used: N, S, P, Si, B, Cl Fabric can be treated or coated with flame retardant formulations
Garment finishing	Water repellence	Silicones Fluorocarbons (PFASs)	
Garment finishing	Antimicrobials (permanent or temporary)	Triclosan Betaine Inorganic ions	
Garment finishing	Printing	Print paste usually consists of: dyes or pigments, thickeners, sequestering agents (e.g. Calgon), surfactants (dispersing agents), humectants (water retaining agents), defoamers (sodium alginate), catalysts, resin systems (to fix pigments), adhesion promotors	Textile preparation (scouring, bleaching, washing, deszing, finishing) significantly affects the amount of dye needed for printing processes
Garment finishing	Durability	Permafresh Silver (Dimethylurea/Glyoxal)	Provides durable press finish for textiles (non-formaldehyde based) Another example contains DMDHEU and is formaldehyde based

Table A10.1: Examples of chemical inputs used to achieve different fihinishing effects during cotton garmenting (non-exhaustive list). Data source: csitc.org

Appendix 11 – Examples of legislation on restricted substances that frame MRSLs

Name	Geography	Details

European Union Regulation on Registration, Evaluation, Authorisation and Restrictions of Chemicals
 	
(EU REACH)[(106)]
	European Union manufacturing and manufactured products destined for sale in the EU	• Aims to improve protection of human health and environment from the risks posed by chemicals
		• Restricted chemicals are either hazardous or harmful
		• Provides methodology for hazard assessment that avoids testing on animals
		• Applies to all chemical substances
		• Places burden of proof on companies to demonstrate chemical safety and risk management measures
		• Authorities can ban hazardous substances where risks are unmanaged
		    • There are currently 74 unique substances restricted on the EU market[(107)]
		• The Candidate list includes substances of very high concern (SVHC) that are not yet restricted
		    • There are currently 247 unique substances on the EU REACH Candidate list[(110)]
		• Substances are identifiable by CAS number

Table A11.1: Overview of EU Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Regulation

Appendix 12 – Top 10 apparel exporting countries in 2023

2023	Clothing export value	
	USD (millions)	% of total export value
China	164,743	30.06
Bangladesh	47,386	8.65
Vietnam	31,039	5.66
Italy	30,268	5.52
Germany	29,704	5.42
Türkiye	18,729	3.42
Netherlands	17,569	3.21
France	16,853	3.08
Spain	15,434	2.82
India	15,366	2.80
Total global value clothing exports	**548,046**	**70.63**
Data Source: https://stats.wto.org/dashboard/merchandise_en.html		

Table A12.1: Garment export data in 2023

Note: WTO data does not break apparel export down by fabric type and therefore this data represents exports of all manufactured apparel. Cotton fibre represents approximately 20% of all fibres used for apparel (by volume). While this data does not reliably confirm where the largest cotton garment manufacturing takes place, the ranking does largely align with the top cotton lint importing nations shown in Appendix 8.

Appendix 13 – MRSLs vs RSLs: a comparison

	MRSL	RSL
Objective:	Restricting or prohibiting the use of hazardous chemicals in all manufacturing stages across the value chain	Restricting or prohibiting the use of hazardous chemicals that will remain in the final product
Developed by?	Brands & Retailers	Joint textile initiatives Trade associations
Consolidated example?	ZDHC	AFIRM Group
Voluntary?	✓	✓
Leverages responsible chemical management across multiple value chains?	✓	✓
Independently verifiable?	✓	✓
Form part of supplier requirements?	✓	✓
Allow conformity with legislation?	✓	✓
Example of restricted chemical for cotton	Flame retardants (penta-, hexa-, octa- and deca-brominated biphenyl ethers, PCB's and PCT's) used on cotton[109]	Chlorophenol– used to prevent mould when storing/transporting cotton[110]

Table A13.1: An overview and comparison of MRSL and RSLs for textiles

Appendix 14 – Examples of legislation-linked frameworks supporting RSLs

Name	Geography	Details

The EU Ecolabel for textile products
 	
(EU Ecolabel)
	European Union manufacturing and manufactured products destined for sale in the EU	• The aim of the EU Ecolabel is to promote goods and services with a guaranteed reduced environmental impact across the entire life cycle[111].
		• Compliance with the regulation reduces the risk of greenwash, empowering consumers and businesses to make safer choices.
		• Annex 3 to the Regulation includes a Restricted Substance List (RSL), which sets criteria for the prohibition or restricted use of certain chemicals[112].
		• The Ecolabel aims to guarantee compliance with a number of European laws relating to:
		  ◦ Ecodesign rules
		  ◦ Sustainability labelling
		  ◦ Green claims (EU Taxonomy)
		  ◦ Since its launch in the early 1990s:
		    ▪ Ecolabels have been awarded to over 100,000 consumer products; 11% of which were clothing and textile products
		    ▪ 57% of the Ecolabel licence holders are SMEs (a licence refers to an EU Ecolabel contract encompassing one or more products within a specified group).

Table A14.1: Overview of EU Ecolabel for Textile Products

Appendix 15 – Chemical recycling case studies

	NuCycl (by Evrnu)	Circulose by Renewcell (Now known as Circulose)	Ioncell (Aalto)	Refibra (Lenzing)
HQ location	Seattle, USA	Kristinehamn, Sweden	Espoo, Finland	Austria
Location of recyling operations	South Carolina (under construction) Anticipated to be operational in 2026	Sundsvall, Sweden	Finland	Global; Multiple sites
Status of technology (trial/closed loop/commercial)	Trial	Closed loop / commercial Following initial trials and commercial-scale pilot schemes, Renewcell had to file for bankruptcy due to insufficient operational funds	Trial / pilot	Commercial
Investor companies	FullCycle Climate Partners, Hansae, Bestseller, and PDS Venture, PDS Multinational Fashions', Radicle Impact, Twynam Investments Pty Ltd, Plum Alley Investments, The Mills Fabrica Fund and Giant Leap Fund, Closed Loop Partners, CYCLEffect Regenerative Ventures, Future Tech Lab, and Magic Hour.	Renewcell has been renamed Circulose. Assets were acquired by Altor investment firm based in Sweden. Renewcell Investors: H&M Group, Tangshan Sanyo, European Investment Bank l(EUR 30.75 million loan to build its first commercial-scale factory in Sundsvall, Sweden, which will be able to produce 60,000 tonnes of Circulose per	Ownership: Partially owned by Aalto university (founding shareholder) Investors: Jane and Aatos Erkko Foundation granted Aalto University EUR 10.5 million to establish a bioinnovation centre	Owner: Lenzing
Recycling Process	1.Collect, sort, shred textile waste 2.Liquify/purify into liquid pulp 3.Extrude pulp into fibre 4.Weave/knit fibre into fabric	1. Textile waste is shredded, de-buttoned, de-zipped, de-colored and turned into a slurry. 2. Contaminants and other non-cellulosic content are separated from the slurry. 3. The slurry is dried to produce CIRCULOSE®, a branded 'dissolving pulp' made from 100% recycled textiles. 4. The sheets of CIRCULOSE® are finally packaged into bales and fed back into the textile production value chain as a biobased equal-quality replacement for virgin materials like cotton, oil and wood.	1. The Ioncell® process utilizes a ionic liquid solvent to dissolve cellulose. 2. In the dissolved state, cellulose can be transformed into strong fibers using the dry-jet wet spinning technology. 3. The only chemicals applied are the non-toxic ionic liquid and water. They are both re-circulated in the process in a closed loop.	1. Input materials - cotton scraps and wood - are turned into pulp. The wood is extracted from certified and controlled forests and turned into wood chips. 2. The wood chips and cotton waste are dissolved with an organic solvent. 3. This solvent turns the chips and the cotton into a paste. This paste is pushed through tiny holes to create threads or fibres. 4. Fibres are then spun into yarn and later woven into soft, low-impact fabric.

	NuCycl (by Evrnu)	Circulose by Renewcell (Now known as Circulose)	Ioncell (Aalto)	Refibra (Lenzing)
Chemicals used	Not disclosed	Not disclosed	Non-toxic ionic liquid and water that are re-circulated in a closed loop process	Not disclosed
Stakeholders involved	Not disclosed	The CIRCULOSE® Supplier Network is comprised of yarn and textile producers streamlining CIRCULOSE® production across the supply chain.	Supply chain/production stakeholders not specified. Aalto University and University of Helsinki (partner in company)	Levis, Kings of Indigo, Closed and Boyish. Sodra (collaboration partner): The OnceMore® pulp from Södra, (jointly developed further by Lenzing and Södra), is used as raw material to produce Lenzing
Volume of cotton successfully recycled	None yet produced commercially. Once built, the company estimate that 18,000 tonnes of Nucycl® fiber will be produced each year. It is unclear what volume of textile waste is required to achieve this output however the company states that "1Kg of fibre produced will divert 1Kg of fibre from landfill"	With an initial annual capacity of 60,000 metric tons, Renewcell 1 will be scaled up to produce 120,000 metric tons of pulp, equivalent to 600 million t-shirts.	Not disclosed	Not disclosed
Cost to produce MMCF	Not disclosed	Not disclosed Approx twice the price of alternative materials	Not disclosed	Not disclosed

	NuCycl (by Evrnu)	Circulose by Renewcell (Now known as Circulose)	Ioncell (Aalto)	Refibra (Lenzing)
Pros	•Lower water usage than conventional cotton production - manufacturing 18,000 tons of Nucycl® fiber will reportedly consume less than half a million tonned of water compared to 36million tonnes of water for the same volume of conventional cotton •Reduction in textile waste •Reduced CO2 emissionsby reducing cotton waste and avoiding landfill gas emissions •The MMCF produced is versatile and stronger than virgin cotton •It can be recycled up to 5x.	Compared to producing fibres from virgin cotton or forestry products, Renewcell states that its fibre production process saves large amounts of water, manages chemicals in a closed-loop, zero-leakage environment, requires zero land for fibre cultivation, and stores rather than emits CO2.	Ioncell® fibers feel soft and are strong even when wet. Because of their high tenacity, Ioncell® fibers are optimal also in technical applications such as composites.Ioncell® fiber properties: Moisture absorbing, Biodegradable, Bright lustre, Can be dyed like cotton and viscose The Ioncell® process uses a novel solvent called ionic liquid. It's an environmentally friendly solvent that can be recycled and isn't flammable	The fibers contain a minimum of 20% recycled material, which is sourced from pre- and post-consumer textile waste. LENZING™ ECOVERO™ fibers with REFIBRA™ technology also support fabric softness and drape, which are preferred fiber qualities of fashion and textile brands.
Cons	•Chemical recycling process is costly and energy-intensive •Involves the use of a proprietary blend of chemicals, which may not be sustainable or environmentally friendly. •The fate of chemicals used in the process is not disclosed •Extra costs included in pre-processing which comprises of washing, opening, separation process, removal of contaminations, decolour, etc.	Cost: Twice the price of competing wood pulp Versatility: Renewcell's technology, whilst being appropriate for a very narrow slice of the available textile feedstock (i.e. mostly pure cotton of known composition), was not necessarily the most innovative, out of all the approaches in this space, and in general was rather limited in its capabilities, especially for dealing with non-cellulosic contaminants. Which in		Limited by availability of recycled pulp: April 2024: Lenzing Halts Production of Tencel Refibra Fibres Amid Recycled Pulp Shortage

Table A15.1: High level overview of four chemical recycling operations (case study review)[113,114,115,116]

Appendix 16 – Relevant global chemical policies and frameworks

Type	Entered into force:	Name
Binding	1992	Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal (Basel Convention)
	2004	Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (Rotterdam Convention)
	2004	Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention)
	2005	The Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)
	2003	International Labor Organisation (ILO) Convention C184 Safety and Health in Agriculture Convention (Agriculture Convention)
Non-binding	2022	The UN Kunming-Montreal Global Biodiversity Framework, Target 7
	2023	Global Framework on Chemicals, Target A7
	2013	UN FAO/WHO Code of Conduct on Pesticide Management
	1992	Globally Harmonized System of Classification and Labelling of Chemicals (GHS)
	1991	OECD Pesticides Programme – Guidelines for the Testing of Chemicals

Table A16.1: Examples of binding and non-binding global chemical policies and frameworks

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